International Finance Corporation
WORLD BANK GROUP
Creating Markets, Creating Opportunities

Climate-Smart Mining

NET ZERO ROADMAP FOR COPPER AND NICKEL

Technical Report

January 2023

Sponsored by

Government of the Netherlands

AngloAmerican

RioTinto

FOREWORD

As a development finance institution, IFC is committed to climate action and the sustainable development of critical minerals in emerging markets. We support our clients in their decarbonization journeys by catalyzing investment in low-carbon technologies, using green and sustainability-linked financing, mobilizing private capital in emerging markets, and co-sponsoring research, as well as by working in partnership with the public and private sector.

To meet the Paris Agreement's goal of limiting global warming to 1.5°C, the world needs to rapidly transition towards a low-carbon economy. This transition is reliant on mining minerals and metals such as copper and nickel, which are critical inputs to clean energy technologies, from electric vehicles to renewable energy sources like wind and solar for energy transmission and storage.

Our baseline models indicate that by 2050, annual nickel supply will need to increase by 208 percent and annual copper supply will need to grow 156 percent relative to 2020 production levels, to satisfy the needs of clean technology deployments. Nickel and copper are among at least 17 minerals and metals requiring significantly expanded production to meet net zero emissions goals by 2050. And herein lies the challenge: There are significant greenhouse gas (GHG) emissions associated with mining these critical minerals today. To achieve net zero on a global basis by 2050 or sooner, the mining sector must find ways to meet the exponentially growing demand for these critical minerals while operating on a net zero basis itself.

To this end, the industry's net zero commitments must: include credible, science-based plans, with interim targets on scope 1, 2, and material scope 3 GHG emissions; lay out technological deployment pathways and associated resourcing; lead in social and environmental outcomes; build community and supply chain resilience; ensure a just transition; and be intentional about collaboration. Scaling the existing and emerging technology solutions at the necessary rate will require extensive collaboration across the mineral value chain. Positive examples of such collaboration with upstream and downstream suppliers and customers are described in this roadmap.

On behalf of the World Bank Group's Climate Smart Mining (CSM) initiative, I am pleased to bring you IFC's net zero roadmap for copper and nickel value chains. This document was developed in partnership with the Carbon Trust, Rocky Mountain Institute (RMI), the Colorado School of Mines, and the Colombia Center on Sustainable Investment at Colombia University. We hope that this resource will support mining companies in building their decarbonization action plans and encourage continued collaboration among industry players, policymakers, communities and sustainable finance investors to ensure the metals and minerals for green technologies are supplied in a resilient, equitable, and sustainable manner.

Namrata Thapar

IFC Global Mining

Manager

Veronica Nyhan Jones

IFC Sustainable Infrastructure Advisory

Manager

Disclaimer

IFC does not guarantee the accuracy, reliability or completeness of the content included in this work, or for the conclusions or judgments described herein, and accepts no responsibility or liability for any omissions or errors (including, without limitation, typographical errors and technical errors) in the content whatsoever or for reliance thereon. The boundaries, colors, denominations, and other information shown on any map in this work do not imply any judgment on the part of The World Bank concerning the legal status of any territory or the endorsement or acceptance of such boundaries. The findings, interpretations, and conclusions expressed in this volume do not necessarily reflect the views of the Executive Directors of The World Bank or the governments they represent.

The contents of this work are intended for general informational purposes only and are not intended to constitute legal, securities, or investment advice, an opinion regarding the appropriateness of any investment, or a solicitation of any type. IFC or its affiliates may have an investment in, provide other advice or services to, or otherwise have a financial interest in, certain of the companies and parties named herein.

ACKNOWLEDGEMENTS

The **Net Zero Roadmap for Copper and Nickel Mining** was prepared by the International Finance Corporation (IFC) as part of the World Bank Group's Climate Smart Mining Initiative and sponsored by the International Council on Mining and Metals (ICMM).

We thank the project's Steering Committee and Technical Working Group members for their diligent reviews, input and support during the development of the Roadmap. Thanks, as well, to the many subject experts that were interviewed and assisted with peer reviews of various elements of the Roadmap.

The Roadmap was coordinated by the IFC, with analysis and development by specialists from the Carbon Trust, RMI, The Payne Institute for Public Policy at the Colorado School of Mines, and Columbia Center on Sustainable Investment.

Expert contributors

Steering Committee		
Jonathan Dunn, Anglo American	**Veronica Nyhan Jones**, IFC	**Balada Amor**, World Bank
Stan Pillay, Anglo American	**David Poulter**, IFC	**John Drexhage**, World Bank
Daniele La Porta (previously World Bank)	**Jonathan Grant**, Rio Tinto	
Veronica Martinez (previously ICMM)	**Todd Malan**, Talon Metals	

Technical Working Group		
Fernando Lucchini, Alta Ley	**Bernard Respaut**, International Copper Association	**Gerardo Alvear Flores**, Rio Tinto
Ben Davies, Anglo American	**Louise Assem**, International Copper Association	**Rachael Davis**, Rio Tinto
Kathryn Horlin, BHP	**Veronica Martinez**, ICMM	**Oxana Meggle** (previously Société Générale)
Sophie Lu, BHP	**Steven Potter**, IFC	**Steven Brown**, Steven Brown Consulting
Marielle Canter Weikel, Center for Environmental Leadership in Business	**Aaron Cosbey**, International Institute for Sustainable Development (IISD)	**Antonina Scheer**, Transition Pathway Initiative
Michele Brulhart, Copper Mark	**Michael Lewis**, Komatsu	**Ferdinand Maubrey**, Tesla
Koen Langie, Engie	**Brendan Marshall**, Mining Association of Canada	**Saleem Ali**, University of Delaware
Fleming Voetmann, FLSmidth	**Daniel Hill**, Natural Resources Canada	**Vivian MacKnight**, Vale
Andrea Vaccari, Freeport-McMoRan	**Mark Mistry**, Nickel Institute	**Jörgen Sandström**, World Economic Forum
Diego Arrigorriaga, Haldeman Mining Company	**Nicola Steen**, Redshaw Advisors	

Subject matter expert assistance		
Charles Akefu, African Legal Support facility	**Meredith Sumpter,** Council on Inclusive Capitalism	**Howard Mann**, International Institute for Sustainable Development (IISD)
Ben Davies, Anglo American	**Amy Sexton**, Freeport-McMoRan	**Yunshu Li**, International Renewable Energy Agency (IRENA)
Kathryn Horlin, BHP	**Tracy Bame**, Freeport-McMoRan	**Nadim Kara**, Natural Resources Canada
Alex Powel-Davies, Carbon Trust	**Stephanie Bouackert**, International Energy Agency (IEA)	**Nicola Woodroffe**, Natural Resource Governance Institute (NRGI)
Benjamin Curnier (previously Carbon Trust)	**Ignacio Del Calonje**, IFC	**Patrick Heller**, Natural Resource Governance Institute (NRGI)
Gina Hall, Carbon Trust	**Neil Pereira**, IFC	**Cecilia Perla**, Rio Tinto
Helen Tipper, Carbon Trust	**Yanilka Fernandez,** IFC	**Paul Kluge**, Rio Tinto
Khodani Mulaudzi (previously Carbon Trust)	**Ekaterine Autet**, IFC	**Justine Morven Sylvester**, World Bank
Pietro Rocco, Carbon Trust	**Isabel Ramdoo**, Intergovernmental Forum (IGF)	**John Drexhage**, World Bank
Deniz Yaylaci, Colorado School of Mines	**Aaron Cosbey**, International Institute for Sustainable Development (IISD)	**Wolfhart Pohl**, World Bank

Project Team

IFC		
Arjun Bhalla, Climate Advisory Lead, IFC	**Ross Hamilton**, Decarbonization Advisor, IFC	**Krishna Matturi**, Climate Advisory Operations, IFC
Carbon Trust		
Christelle van Vuuren, Director	**Paul Huggins**, Associate Director	**Renata Lawton-Misra**, Manager
Reinhardt Arp, Senior Analyst	**Juliana Meng**, Consultant	**Tim Mew**, Senior Analyst
RMI		
Lachlan Wright, Manager	**Paolo Natali**, Principal	**Sravan Chalasani**, Associate
Valentina Guido, Associate	**Alastaire Dick**, former Operations Leader	
The Payne Institute for Public Policy at the Colorado School of Mines		
Jordy Lee, Program Manager	**Sebnem Duzgun**, Full Professor and Fred Banfield Distinguished Endowed Chair in Mining Engineering	**Deniz Yaylaci**, Net Zero Transition Research Associate
Columbia Centre on Sustainable Investment		
Perrine Toledano, Head of Mining and Energy	**Martin Brauch**, Senior Legal and Economics Researcher	**Jack Arnold**, Program Associate
Bryan Sherrill, Research Intern	**Sarah Ahmad**, Research Intern	

The Carbon Trust is a global climate consultancy driven by the mission to accelerate the move to a decarbonized future. We have been pioneering decarbonization for more than 20 years for businesses, governments, and organizations. Drawing on a network of over 300 experts internationally, the Carbon Trust guides organizations through their journey to Net zero. From strategic planning and target setting to delivery, activation, and communication - we provide smarter ways to turn intent into impact.

RMI is an independent non-profit founded in 1982 that transforms global energy systems through market-driven solutions to align with a 1.5°C future and secure a clean, prosperous, zero-carbon future for all. We work in the world's most critical geographies and engage businesses, policymakers, communities, and NGOs to identify and scale energy system interventions that will cut greenhouse gas emissions at least 50 percent by 2030. RMI has offices in Basalt and Boulder, Colorado; New York City; Oakland, California; Washington, D.C., and Beijing.

The Payne Institute for Public Policy at Colorado School of Mines, founded in 1874, serves as a nexus for high-quality, data-driven, solutions-oriented research that is needed to inform energy and environmental policy. As part of the world's foremost mining university, the Payne Institute can harness the faculty and student body of an institution with deep roots in material extraction, but also with programs spanning renewable energy, water purification, civil and environmental engineering, materials science, and others.

The Columbia Center on Sustainable Investment, founded in 2008, is a joint centre of Columbia Law School and the Earth Institute at Columbia University, and is the only university-based applied research centre and forum dedicated to the study, practice, and discussion of sustainable international investment. CCSI integrates legal, economic and policy expertise, and approaches sustainable investment holistically, bridging investment law, natural resource management, human rights, economics, political economy, and environmental management. One of CCSI's areas of expertise is energy systems and their impact on climate change. CCSI has developed a body of research and guidance on the role of the extractive industries in the energy transition and how it should be regulated to accelerate decarbonization.

TABLE OF CONTENTS

1. INTRODUCTION

1.1. Objectives and scope of the net zero roadmap technical report

This report, the **Net Zero Roadmap for Copper and Nickel Mining** (herein referred to as the 'Roadmap'), builds on current industry knowledge and sets out a science-based net zero transition strategy for copper and nickel mining value chains.[1] The Roadmap can be used by copper and nickel mining value chain actors[2] to guide their net zero transition. It sets out clear actions to facilitate a successful net zero transition, with proposed achievement waypoints in the lead up to 2050. It also considers broader ecosystem actions, such as management of ESG impacts, enabling a just transition to net zero mining, overcoming policy challenges, and securing access to sustainable finance, all of which are essential to support the transition to net zero greenhouse gas (GHG) emissions.

Copper and nickel mining value chains were used as test cases to explore the challenges and opportunities that will occur between now and 2050 as the global energy transition (GET) accelerates. The Roadmap learnings are adaptable to other energy transition metals[3] (ETM) required to ensure a successful GET.

1.2. The case for a just transition to net zero copper and nickel mining

"The net zero equation means reducing GHG emissions as much as possible and offsetting all that cannot be reduced — while simultaneously pursuing sustainable economic development and inclusive growth".[i]

According to the Intergovernmental Panel on Climate Change (IPCC), to avoid the worst impacts from climate change the global economy needs to prevent average global temperatures from increasing by more than 1.5°C above pre-industrial levels.[ii] The Paris Agreement – a legally binding international Government treaty on climate change – recognizes this imperative and aims to limit global warming to well below 2°C, and preferably to 1.5°C.[iii]

Staying within the 1.5°C temperature limit requires global GHG emissions to reach net zero by 2050. This means reducing GHG emissions by between 85% and 90% from 2020 levels by 2050.[iv] Net zero will be achieved when the remaining 10% to 15% of residual or hard-to-abate emissions[4] are "neutralized" or "balanced" using credible carbon removal offsets[5].

Achieving net zero global emissions requires deep decarbonization of the global energy sector, referred to as the GET. The GET will be achieved by moving away from fossil fuels to renewable energy sources, such as solar, wind and batteries, and the adoption of low-carbon technologies, such as battery electric vehicles.

The scale of the technological transformation required is unparalleled. The copper and nickel mining and metals sectors have critical roles to play in the GET. Renewable and low-carbon technologies are

---

[1] The scope of the Roadmap is confined to copper and nickel mining value chains, which are defined as extraction and processing of each metal into an intermediary product. For example, extracting copper and processing into a copper cathode.
[2] Mining value chain actors are defined as companies with extraction and/or processing activities within the scope of the defined mining value chain.
[3] Energy transition metals (ETMs) are those required for renewable energy and low-carbon technologies, such as solar PV, wind, batteries and electric vehicles. ETMs include copper, nickel, cobalt, and aluminium, amongst others.
[4] Residual or hard-to-abate emissions are those that cannot be mitigated due to technology or economic limitations. For example, GHG emission from chemical reactions in a production process that cannot be avoided.
[5] Carbon removal offsets are those that sequestrate or remove GHG emissions from the atmosphere.

metals-intensive and reliant on ETMs, such as copper and nickel. Copper is a key input for solar, wind and transmission technologies, and nickel is used extensively in electric vehicles and batteries. The GET will substantially increase demand for all ETMs, not just copper and nickel.

Securing long-term and consistent supply of copper and nickel is a significant risk to the GET. Future demand for these metals requires the unprecedented scale-up in primary and secondary production. Any delay to this scale-up threatens the GET and, therein, the global community's capacity to achieve net zero emissions.

Business-as-usual copper and nickel production processes are carbon-intensive. If these are used to support the GET, they will rapidly increase GHG emissions from primary metal production, prevent net zero from being achieved, and exacerbate the climate crisis. This cannot be allowed to happen. Copper and nickel mining value chain actors need to ensure that metals supply is aligned to the Paris Agreement.

1.3. The structure of the Roadmap

This report consists of seven chapters, each focused on one building block needed to achieve net zero mining in a just and inclusive manner by 2050.

Table 1: Structure of the Roadmap

Chapter	Precis
1. Introduction to the Roadmap	How copper and nickel mining value chains support the GET and the global community's action on climate change.
2. The decarbonization challenge for copper and nickel	**There is a very large decarbonization challenge to be solved across copper and nickel mining value chains as they scale up to meet substantial growth in demand.** To reach net zero emissions by 2050, copper and nickel mining value chains will need to reduce absolute emissions by ~90% from 2020 levels, and "neutralize" the remaining ~10% with credible carbon removal offsets: • Copper from 85 $MtCO_2e/y$ to 8.5 $MtCO_2e/y$ and remove remaining emissions • Nickel from 88 $MtCO_2e/y$ to 8.8 $MtCO_2e/y$ and remove remaining emissions However, these emissions reductions will need to occur while simultaneously increasing supply to meet growing demand from the GET. By 2050, demand for these metals will increase significantly from 2020 levels: • Copper by 156% to 59 Mt/y • Nickel by 208% to 11.5 Mt/y Under a business-as-usual (BAU) scenario, GHG emissions from primary production will also increase substantially: • Copper by 125% to 192 $MtCO_2e/y$ • Nickel by 90% to 167 $MtCO_2e/y$ It is, therefore, critical that copper and nickel mining value chains decouple GHG emissions from supply growth and reach net zero by 2050. Failure to do so will have

Chapter	Precis
	perverse outcomes for the GET, which could contribute to the climate crisis rather than mitigate it.
3. A Net Zero Roadmap for copper and nickel mining	**Very deep decarbonization can be achieved through use of low-carbon technologies. These are cost-effective and can help achieve net zero emissions by 2050.** To achieve net zero, copper and nickel mining value chains need to take immediate and coordinated action to deeply decouple supply growth from GHG emissions. This decoupling, as presented in this report, is achievable for copper and nickel mining value chains. Central to decoupling is wide-scale investment and adoption of cost-effective renewable energy technologies, deployment of energy efficient processes and/or new processes and technologies with lower emissions footprint (such as mine site electric trucks). **ESG co-benefits can be captured, enhancing wider sustainability impacts.** Increased copper and nickel production is likely to exacerbate environmental and socio-economic risks associated with mining and metals production. Increased production, if not done in a sustainable and inclusive manner, is likely to place additional pressure on biodiversity, water resources, and local communities in mining regions. This could perpetuate and intensify existing negative environmental and socio-economic impacts of mining. A wholistic ESG approach to climate action is encouraged and mining value chain actors should consider how implementing these decarbonization solutions can be used to capture environmental, social and governance (ESG) co-benefits (e.g., biodiversity, water security, gender inequality).
4. Delivering a just transition	**Decarbonization can be used to deliver a just transition to net zero mining and can support regional resilience building.** Supplying the GET, whilst decarbonizing copper and nickel mining value chains, will require substantial capital investment that can be used to achieve multiple outcomes. Value chain actors are encouraged to adopt the principle of "governance for additionality"[6] and work together with all mining stakeholders to co-deliver a just transition. A just transition should ensure that stakeholders' "lives and livelihoods are uplifted" because of net zero mining and the GET. In doing so, it can positively and strongly contribute to the Sustainable Development Goals (SDGs).
5. Sustainable finance for a just transition to net zero mining	**Embracing sustainable finance opportunities can help fund the transition to net zero mining in an inclusive and just manner, with additional financial and non-financial co-benefits to mining value chain actors.**

[6] The governance for additionality principle is a requirement in emerging sustainable social taxonomies and carbon offsets. It requires net-positive outcomes that would not have occurred in the absence of an intervention or project that goes beyond business-as-usual. Please refer to the European Union Platform on Sustainable Finance, Social Taxonomy for more information.

Chapter	Precis
	The sustainable finance ecosystem is rapidly evolving, and mining value chain actors are encouraged to act quickly to secure access to sustainable finance opportunities, or risk being left behind. Sustainable finance can not only support a just transition to net zero mining but provide value chain actors with addition co-benefits. These include diversifying a company's investment pool, pricing advantages and cheaper cost of capital, communicating sustainability strategies internally and externally, adherence to sustainability leadership and stewardship governance frameworks that guide capital investment and enhance reputation due to independent financier oversight of the sustainability outcomes of different projects.
6. Policy, legal and regulation	**Mining value chain actors are encouraged to engage with governments to help overcome policy, legal and regulatory barriers obstructing the transition to net zero mining.** National governments have an enabling role for a just transition to net zero mining. The apparatus of government is evolving to create the legal landscape, policy incentives and financial instruments, to support sustainable net zero mining that co-delivers positive ESG and just transition outcomes. Regulatory factors will be needed to support transition while providing the framework for a stable and functioning market and economic environment. Understanding mining value chain actors' needs, and collaboratively engaging with governments will be required to decarbonize mining activities and achieve net zero emissions efficiently at scale.
7. Collaborative initiatives to support the net zero transition	**Collaboration will aid Roadmap implementation and amplify decarbonization, sustainability and just transition impacts across the mining sector and beyond.** The enormity of transforming copper and nickel mining value chains in less than 30 years is beyond the capability of any one company. Sustained multi-stakeholder collaboration, such as with industry associations, governments, technology developers, labor and local communities, will be key to achieving a just transition to net zero mining across both value chains.

2. THE DECARBONIZATION CHALLENGE FOR COPPER AND NICKEL MINING

This chapter of the Roadmap discusses the global scale of both the opportunity and challenge posed by the energy transition upon copper and nickel mining value chains. It also provides insights relevant to the broader mining and metals industry.

2.1. Copper and nickel demand growth forecasts

The metals and mining sector has a critical role to play in the GET and fight against climate change. Renewable energy and low-carbon technologies that enable the GET are metals-intensive and reliant on ETMs, such as copper and nickel. Copper is a key input for solar, wind and transmission technologies, and nickel is used extensively in electric vehicles and batteries. The GET will increase demand for all ETMs not just copper and nickel. The following section provides a deep dive into demand growth forecasts for copper and nickel.

Box 1: Demand and GHG emissions forecast methodology

The demand and emissions forecasts were developed by:

- Analyzing internationally recognized models (listed in Figure 1) of the global technology mix required for a 1.5°C energy transition, including the fraction of global energy needs that can be electrified and the pace of deployment required for key technologies, such as solar PV, wind, and batteries.
- Estimating copper and nickel demand growth based using data on the material intensity of these key technologies. Sensitivity analysis is used to consider impacts to demand from technology changes (e.g., shifting Li-ion batteries towards more nickel-rich chemistries).
- Determining the share of copper and nickel production from recycled (secondary) sources that would be available given the new demand. This share is determined by the stock and recycling rate of copper and nickel in the global economy. The remainder of demand will be met by increasing primary (i.e., from ore) production.
- Estimating the emissions associated with this increasing primary demand, given forecasts of declining ore grades and the impact of reducing the emissions intensity of the electricity grid.

The estimates cover all emissions (direct emissions as well as emissions from electricity use and upstream inputs) up to the point of metal production (copper cathode, ferronickel, nickel pig iron, nickel metal, or nickel sulphate). However, exploration activities, land-use changes and bulk transport are excluded. The estimates also consider the main primary sources (sulfide/oxide ore for copper and sulfide/laterite ore for nickel) and processing routes.[7]

2.1.1. The technology mix and demand required for the global energy transition

Most 1.5°C-aligned scenarios agree on the need for increased electrification (e.g., switching to electric vehicles (EV)), with massive deployments of solar PV and wind energy (Figure 1). The International Energy Agency's Net Zero Energy by 2050 scenario (hereafter the IEA NZE scenario) was selected as the basis for the copper and nickel demand estimates. This scenario aligns with the broad consensus of

[7] The processing routes considered are sulfide smelting for both copper and nickel; heap leach (of oxide ore) with solvent extraction and electrowinning (SX-EW) for copper only; and high-pressure acid leach (HPAL), rotary kiln electric furnace (RKEF), and blast furnace treatment of laterite ores for nickel only.

1.5°C scenarios and provides a middle ground compared with other globally recognized models and forecasts in terms of demand growth, electrification, solar and wind penetration.

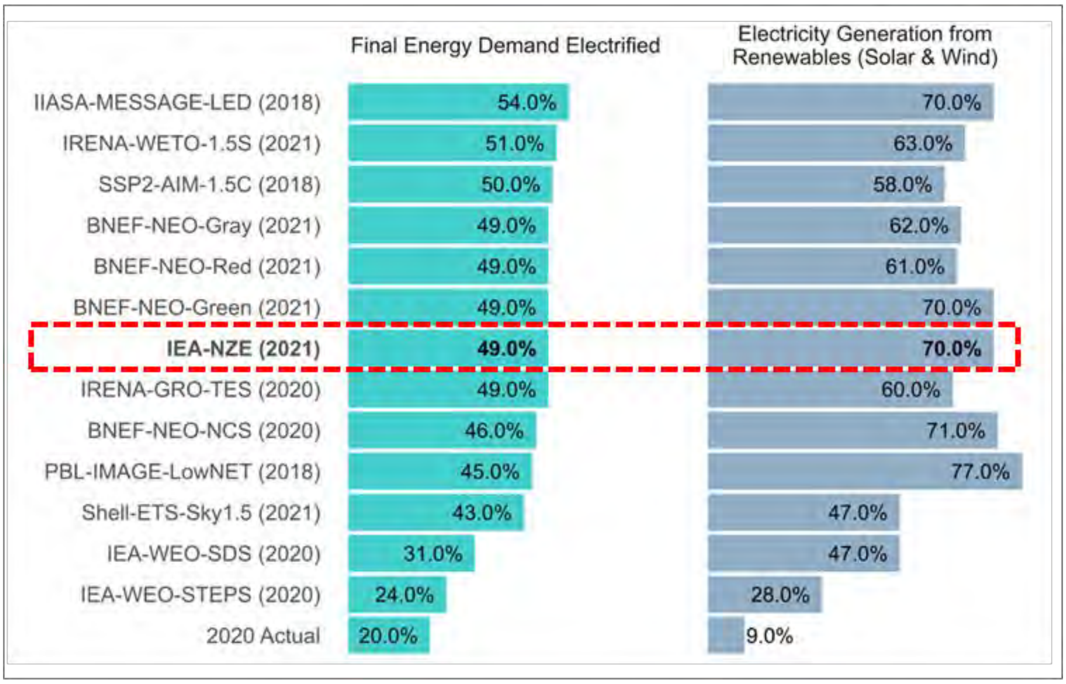


Figure 1: Comparison of 2050 global technology mix forecast scenarios

Achieving IEA's NZE 1.5°C trajectory requires rapid growth in several renewable energy and low-carbon technologies (Figure 2). In the short-term (2020 – 2030), the transition primarily relies on solar PV and wind energy deployment (from ~250 GW/year to ~1,000 GW/year), and EV production (from ~3 million cars/year in to ~54 million cars/year). Other key technologies presented in Figure 2, such as hydrogen electrolyzers and carbon capture and storage (CCS), start off with a lower installed base and, therefore, have a higher compound annual growth rate in the short-term (2020-2030). In absolute terms, however, solar PV, wind and EV batteries see greater deployment.

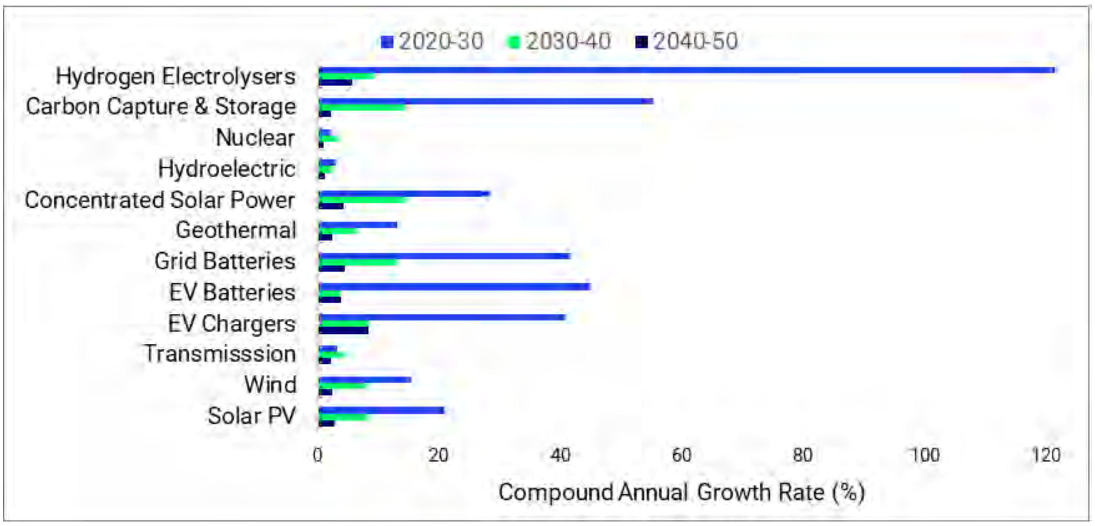


Figure 2: Projected growth rates for key energy transition technologies[8]

[8] Projected growth rates for key energy transition technologies base don IEA NZE Scenario

Copper and nickel (in addition to other ETMs) are key inputs for these renewable energy and low-carbon technologies. Copper is crucial input for solar PV, wind, batteries, transmission and carbon capture and storage technologies. Nickel is a critical input for various battery technologies and geothermal technologies (Table 2). The GET will inevitably increase demand for these technologies, and the ETMs used to produce them.

Table 2: Copper and nickel intensity for key transition technologies

Technology	Copper	Nickel
Hydrogen Electrolyzers	Low	Moderate
Carbon Capture and Storage	High	Low
Nuclear	Moderate	Moderate
Hydroelectric	Moderate	Low
Concentrated Solar Power	Moderate	Moderate
Geothermal	Low	High
Grid Batteries	High	High
EV Batteries	Moderate	High
EV Chargers	High	Low
Transmission	High	Low
Wind	High	Moderate
Solar PV	High	Low

Key: Material intensity for each technology

Low: *Moderate:* *High:*

Future demand for copper and nickel will also be driven by economic growth and increasing demand in existing uses for each metal. Currently, copper is used extensively in electrical applications, such as wiring, plumbing, electric motors, and electronic devices. It is also used as an alloying element to produce metals for building materials and other applications (Figure 3). Nickel is primarily used to produce stainless steel for construction, industrial, and transport applications (Figure 3). Demand associated with these existing uses for both metals will continue to increase with global economic development and population growth.

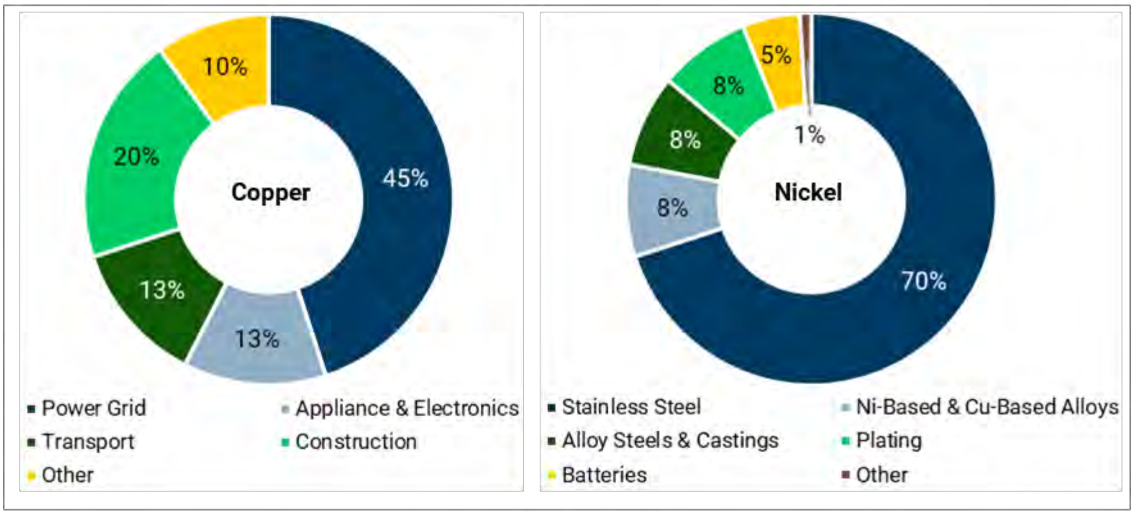
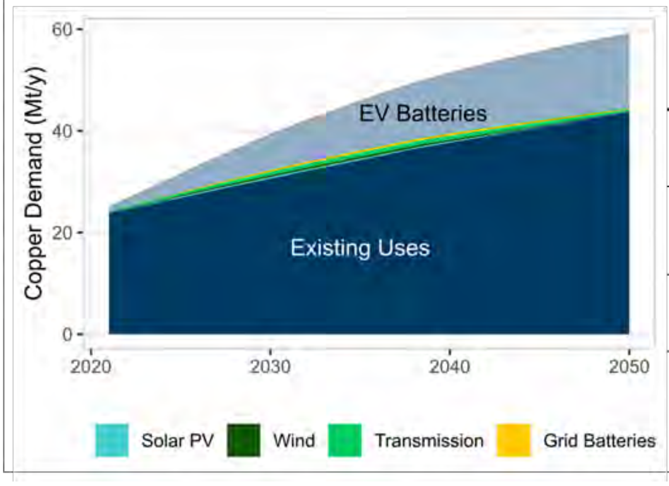


Figure 3: Existing copper and nickel uses

2.1.2. Copper demand forecast

The total annual demand for copper projected to **increase by 156% by 2050**, relative to a 2020 baseline, at compound annual growth rate **(CAGR) of 3.3%** (Figure 4). Roughly 25% of copper demand in 2050 will be driven by renewable energy and low-carbon technologies, equivalent to 70% of current total demand. Demand from existing copper uses will account for 74% of 2050 demand.

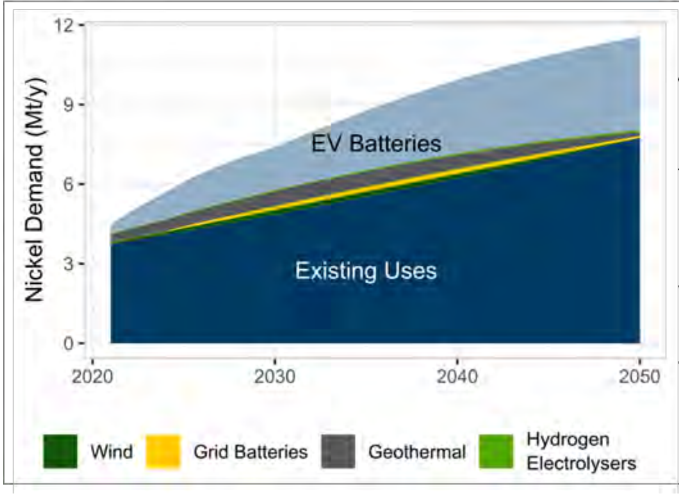


Copper demand	2020	2050	CAGR (%)
Total (Mt/y)	23	59	3.3
Energy transition (Mt/y)	1.4	15	2.2
Existing uses (Mt/y)	21.6	44	8.7

Figure 4: Copper demand forecast

2.1.3. Nickel demand forecast

The total annual demand for nickel is projected to **increase by 208% by 2050**, relative to a 2020 baseline at a **CAGR of 4%** (Figure 5). Roughly 33% of nickel demand in 2050 will be driven by renewable energy and low-carbon technologies, which is higher than today's total demand for nickel. Demand from existing nickel uses will account for 67% of total 2050 demand.



Nickel demand	2020	2050	CAGR (%)
Total demand (Mt/y)	3.7	11.5	4.0
Energy transition (Mt/y)	0.1	3.8	3.0
Existing uses (Mt/y)	3.6	7.7	6.0

Figure 5: Nickel demand forecast

2.1.4. Demand forecast uncertainty due to potential technology shifts

There is a degree of uncertainty surrounding the energy transition, particularly with regards to how renewable energy and low-carbon technologies will be manufactured. This will have implications for the confidence of copper and nickel demand forecasts. For example, the solar PV market is currently dominated by crystalline silicon (c-Si) panels, which are copper-intensive to manufacture. However, there is potential for thin-film technologies[9], which are less copper-intensive, to increase in overall market share and replace c-Si panels as the preferred solar PV technology.

In the copper demand forecast above, these thin-film technologies gain market share from ~5% in 2020 to 15% in 2050 (Figure 6) on the assumption that thin-film technologies remain deployed in niche applications where lower weight or greater flexibility are required. This change in market share would reduce cumulative copper demand *for solar PV panels* by ~4% in 2050, relative to a scenario where today's market share was maintained.

In a more bullish scenario where thin-film technologies achieve a 50% market share by 2050, cumulative copper demand *for solar PV panels* would decline by ~20%. However, because solar PV panels represent a small part of overall copper demand (Figure 6), this would only reduce total 2050 copper demand to by ~0.1%.

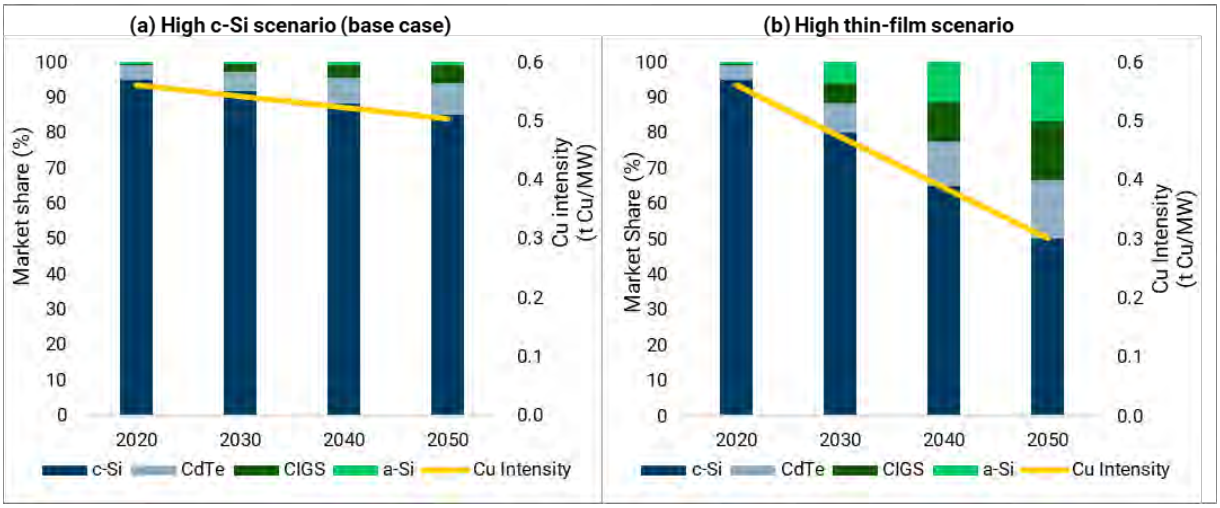


Figure 6: Copper demand impacts from different solar PV technology scenarios

Conversely, because EV batteries represent a larger share of both copper and nickel demand, any material intensity uncertainty in battery technologies will have a much larger impact on demand forecasts. Typical automotive Li-ion batteries contain lithium, cobalt, manganese, and nickel in the cathode; graphite in the anode; and aluminum and copper in the other cell and pack components. Recently, EV manufacturers have been shifting towards higher nickel cathode chemistries. This is primarily to avoid the use of cobalt, which is both high-cost and associated with poor labor practices in Sub-Saharan Africa. This could lead to increased use of nickel in EV battery technologies and a high-nickel scenario (Figure 7a).[v]

Alternatively, EV manufacturers, such as Volkswagen and Tesla,[vi] could use lithium ferrophosphate (LFP) batteries for entry-level EV models (due to lower energy density and cost). Nickel-rich cathodes, such as nickel-cobalt-aluminum (NCA) or nickel-manganese-cobalt (NMC) variants, would be used in

[9] These technologies include cadmium telluride (CdTe), copper indium gallium selenide (CIGS), and amorphous silicon (a-Si).

high-end models. This could lead to a reduced use of nickel for EV batteries and a low-nickel scenario (Figure 7b).

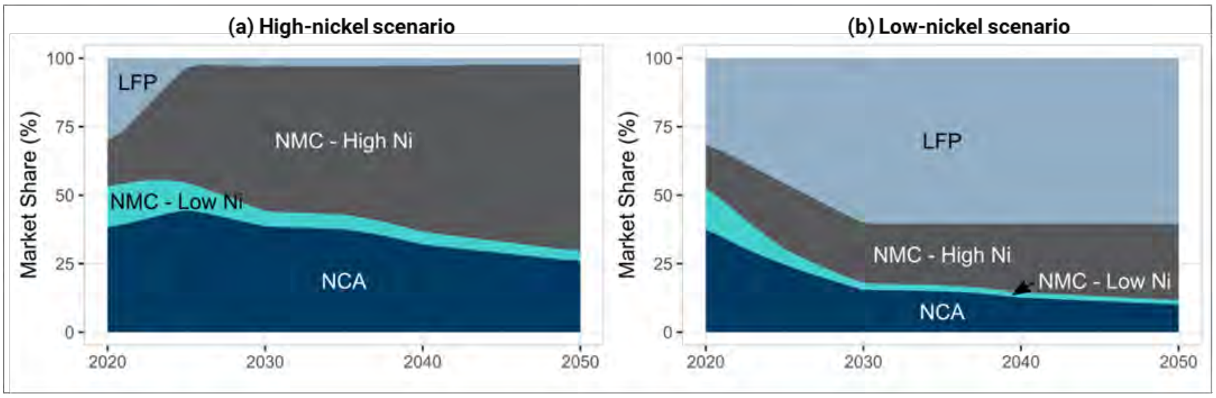


Figure 7: EV battery market share by technology type under two scenarios

The high-nickel scenario increases the cumulative nickel demand *for EV batteries* by ~137% by 2050 (Figure 8**Error! Reference source not found.**b). The impact on copper demand from shifting cathode chemistry is much smaller, because copper is used in auxiliary components and not the cathode itself. The high-nickel scenario results in a ~13% decrease in copper demand *for EV batteries* due to the impacts of higher energy density, requiring fewer battery cells per vehicle (Figure 8a).

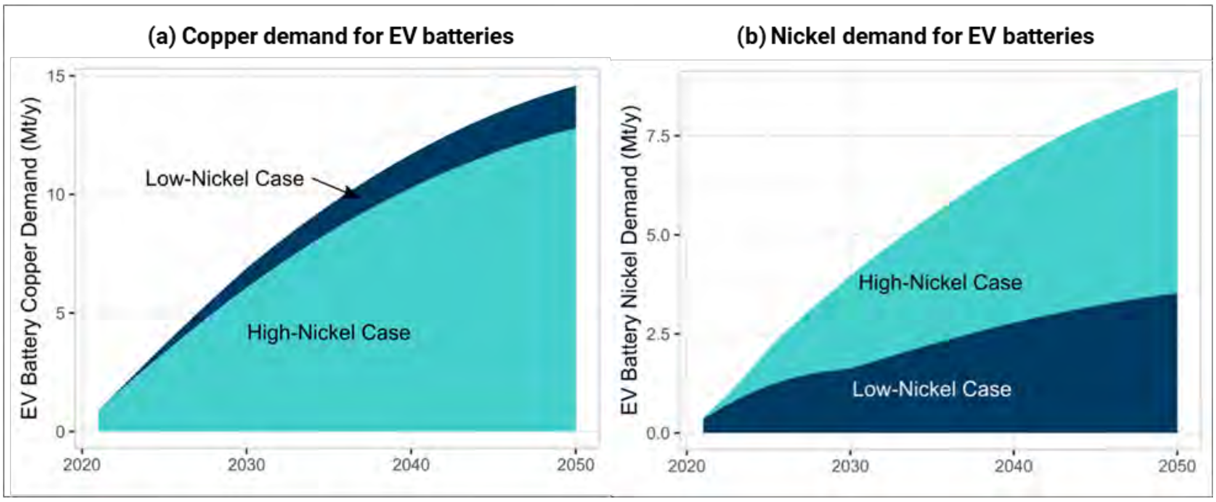


Figure 8: Copper and nickel demand under different EV battery technology scenarios

The "baseline" demand forecast for copper and nickel (Figure 4 and Figure 5) are based on the low-nickel scenario illustrated in Figure 8, given that it aligns with some automakers' stated strategies. The scenario analysis above highlights the impact of the battery chemistry uncertainty on copper and nickel demand. The high-nickel case could cause copper demand for low-carbon technologies to decrease by ~3%, while potentially increasing nickel demand for low-carbon technologies by as much as 45% in 2050. However, significant uncertainties associated with cell and pack design (e.g., alteration of connector thickness), which are not considered here, may shift the copper demand for EV batteries. Demand estimates for both minerals could be further impacted in later years (post-2030) by battery technology shifts that have not yet demonstrated commercial viability, such as solid-state (with lithium metal anodes) or lithium-air technology.

2.2. Future copper and nickel supply

Future copper and nickel demand will be met through a mix of primary (mined) and secondary (recycled) sources. Meeting demand using secondary sources has the advantage of producing fewer GHG emissions, relative to primary sources. For example, producing 1 kg of copper from primary sources (mining) typically results in ~4.5 $kgCO_2e$ in GHG emissions. This emissions footprint decreases to ~1.5 $kgCO_2e$ when producing 1 kg of copper from secondary sources (recycled copper from post-consumer waste / final product end-of-life).[vii]

It is estimated that currently ~30% of copper and ~65% of nickel in post-consumer waste streams are recycled.[viii] Increasing these recycling rates could increase the share of secondary sources available to meet growing copper and nickel demand. Increased recycling rates could be supported by economic factors (as primary extraction costs increase with declining ore grades) as well as greater environmental (e.g., emissions savings and waste minimization), social (e.g., job creation) and regulatory emphasis on circularity.

The Roadmap modelled share the potential future demand for copper and nickel that would be met from secondary sources. It suggests that there is still scope for improving recycling rates given that a large portion of material is still sent to landfill rather than being recycled (Figure 9).

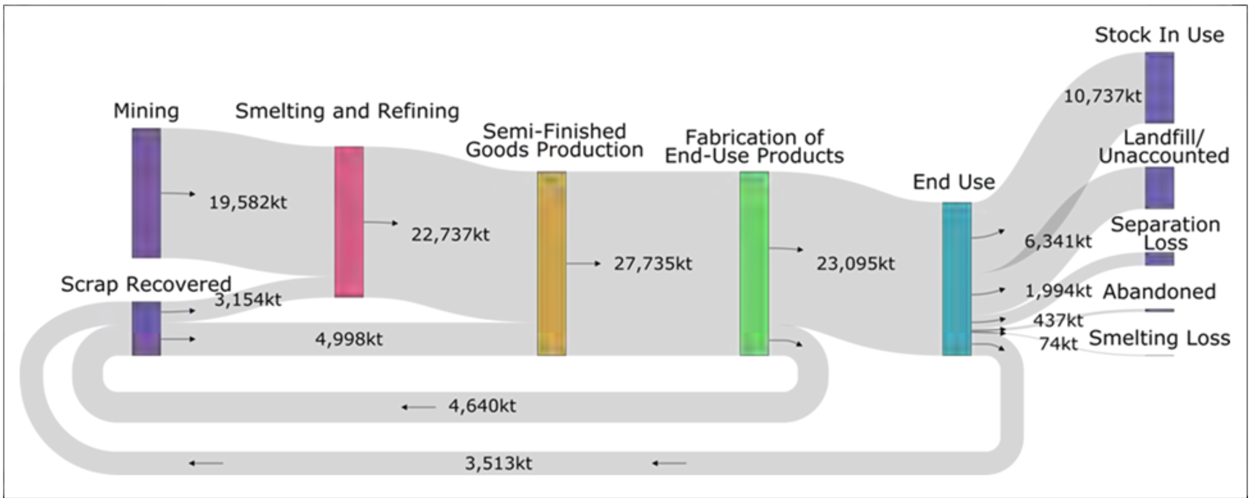


Figure 9:The copper lifecycle in 2020

Despite the scope for improved recycling, the share of copper and nickel supply from secondary sources is expected to decrease between 2020 – 2030 (Figure 10). This is due to two interrelated factors. The first is that primary producers are in a better position to increase supply short-term relative to secondary producers. The second is that there is roughly a 10-year lag time for primary or “virgin” products to reach their end-of-life and become available for secondary use/recycling. This means there is less material available for recycling in the short-term.

High future growth in the use of different technologies will exacerbate this trend. For example, global EV sales in 2011 were only ~40 000 units compared to ~3 million units in 2021.[ix] This means the amount of used batteries available for recycling is much lower in the short-term (assuming an approximate 10-year life) than the material demand for new EV batteries.

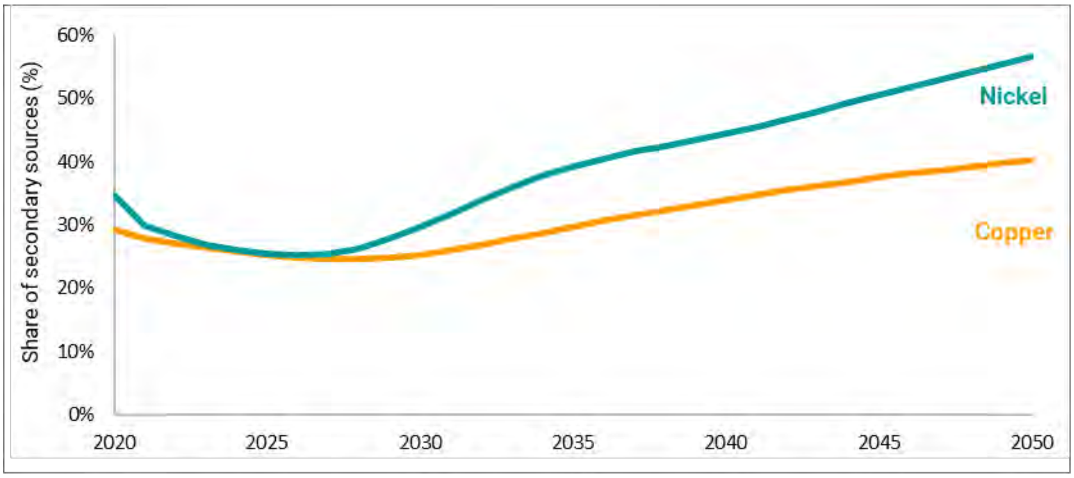


Figure 10: Secondary sources as a share of total copper and nickel production

However, as more secondary copper and nickel material becomes available (as more low-carbon technologies reach their end-of-life post-2030), and recycling rates improve, the share of secondary supply will increase post-2030. The model estimates that the share of secondary supply will increase to approximately 40% and 57% of total copper and nickel demand respectively by 2050 (Figure 10).

Specifically, it is expected that recycling of EV batteries will play a significant role in providing a source of secondary inputs. Today, ~50% of Li-ion batteries are recycled.[x] This occurs even though most of these are small-format (e.g., phone and laptop) batteries, which increase costs relating to collection and sorting.

In the future, the larger format of EV batteries will lower these costs, further improving the economics for recycling. This is evidenced by recycling of other materials from end-of-life vehicles. For example, the steel recycling rate from cars in the United States is currently more than 90%,[xi] whilst lead-acid battery recycling rates (supported by regulatory mechanisms) are ~99%.[xii] Research commissioned by the Swedish Energy Agency also found that most markets currently have more capacity to recycle Li-ion batteries than the amount reaching end-of-life.[xiii] In addition, several companies have announced intentions to invest in additional capacity to process EV batteries in the future.[xiv] Therefore, based on these considerations, the Roadmap model assumed that 90% of copper and nickel in EV batteries would be recovered and used as a secondary input. This leads to the medium- (2030 – 2040) and long-term (2040 – 2050) increases in the share of secondary sources for copper and nickel in Figure 10.

2.3. GHG emissions forecast from primary copper and nickel production

Increased demand for copper and nickel threatens to increase GHG emissions associated with carbon-intensive primary production. The Roadmap modelled the potential “business-as-usual” (BAU) increase in GHG emissions associated with the copper and nickel demand forecast. The BAU GHG emissions forecast only considered emissions from primary production and excluded emissions from secondary production of copper and nickel or GHG emissions from land-use change. The model also accounted for BAU declines in grid-based electricity emissions intensity and declining ore grades. Since the underlying scenario for the Roadmap forecasts were based on technology deployment required for a 1.5°C trajectory, grid-based electricity emissions intensities were assumed to decline by 57% decline by 2030 and 96% by 2050). Copper and nickel ore grades were assumed to decline from 0.9% to 0.3%, and from 1.4% to 0.4% respectively between 2020 and 2050. [xv]

The results indicate that **absolute GHG emissions from BAU primary production of copper and nickel increase by 125% and 90% respectively**. It is likely that the emissions *intensity* per weight of copper and nickel produced might also increase due to declining ore grades at new and established mine sites. This increase will be at least partially offset by decreasing emissions intensity of grid-delivered electricity—which is the current source of a large portion of the energy requirements for copper and nickel production.

2.3.1. Copper GHG emissions forecast

Absolute GHG emissions from primary copper production are expected to increase by 125% between 2020 and 2050, at a CAGR of 2.7% (under a BUA scenario – "combined impact of declining ore grade and decarbonizing electricity grids" in Figure 11). However, copper value chain actors will need to support grid decarbonization to ensure GHG emissions growth does not exceed 125%. Without aggressive grid decarbonization, GHG emissions could increase by as much as 437% by 2050 ("impact of declining ore grade" scenario in Figure 11). If current emissions intensities remain constant (no decline in ore grade), GHG emissions form copper production could increase by as much as 108% ("current emissions intensity" scenario in Figure 11).

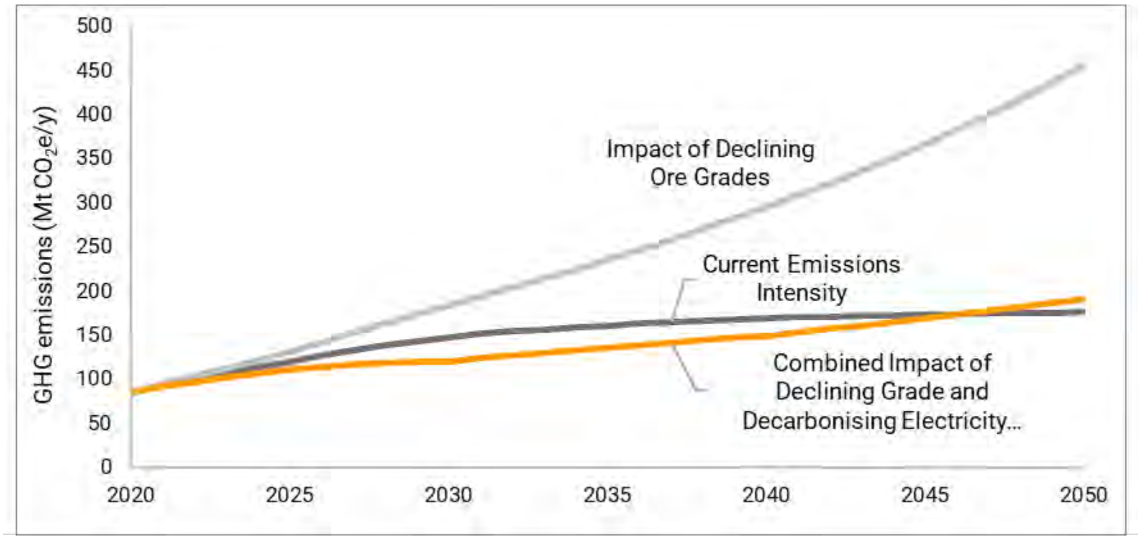


Figure 11: GHG emissions forecast for primary copper production

Declining ore grades, mine type and processing rout can also influence GHG emissions intensity of copper (Figure 12). Most GHG emissions from copper come from mine and concentrator emissions and, therefore, a decline in ore grade could increase the emissions intensity per unit output of copper. For example, the emissions intensity for an open-pit operation with a 0.8% head grade would increase by ~28% if the grade were reduced to 0.6%. Emissions intensity is also influenced by mine type and processing route. For example, an underground mine is less emissions intensive than an open-pit mine. While underground mines use electricity for ventilation, and open-pit mines do not, underground operations tend to use a more selective mining method, resulting in higher ore grades and lower emissions intensity relative to open-pit mining (Figure 12).

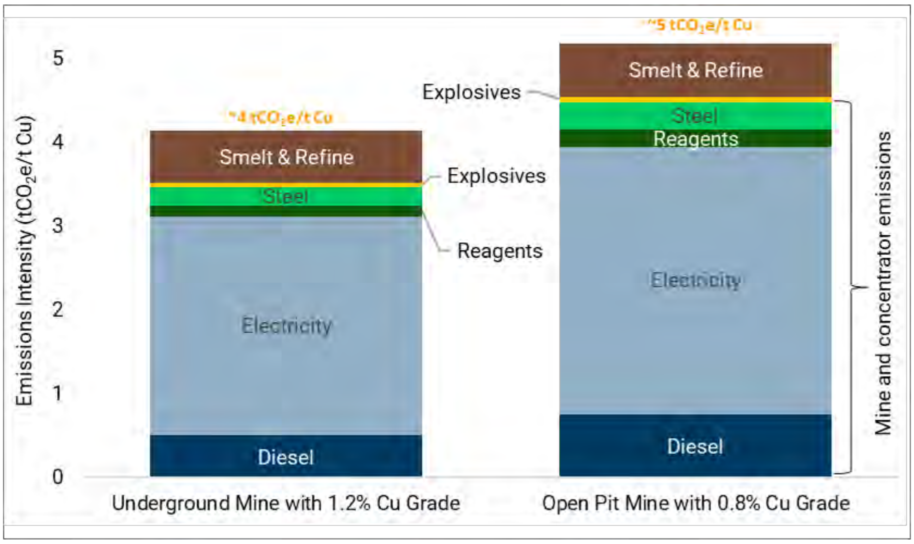


Figure 12: GHG emissions intensity for underground and open-pit copper mining

2.3.2. Nickel GHG emissions forecast

The trends are similar for nickel – **absolute GHG emissions from primary production increase by 90% between 2020 and 2050, at a CAGR of 2.2%** (under a BUA scenario – "combined impact of declining ore grade and decarbonizing electricity grids" scenario in Figure 13). Nickel value chain actors will need to support grid decarbonization to ensure GHG emissions growth does not exceed 90%. Without aggressive grid decarbonization, GHG emissions could increase by as much as 164% by 2050 ("impact of declining ore grade" scenario in Figure 13). If current emissions intensities remain constant (no decline in ore grade), GHG emissions form nickel production could increase by as much as 77% ("current emissions intensity" scenario in Figure 13).

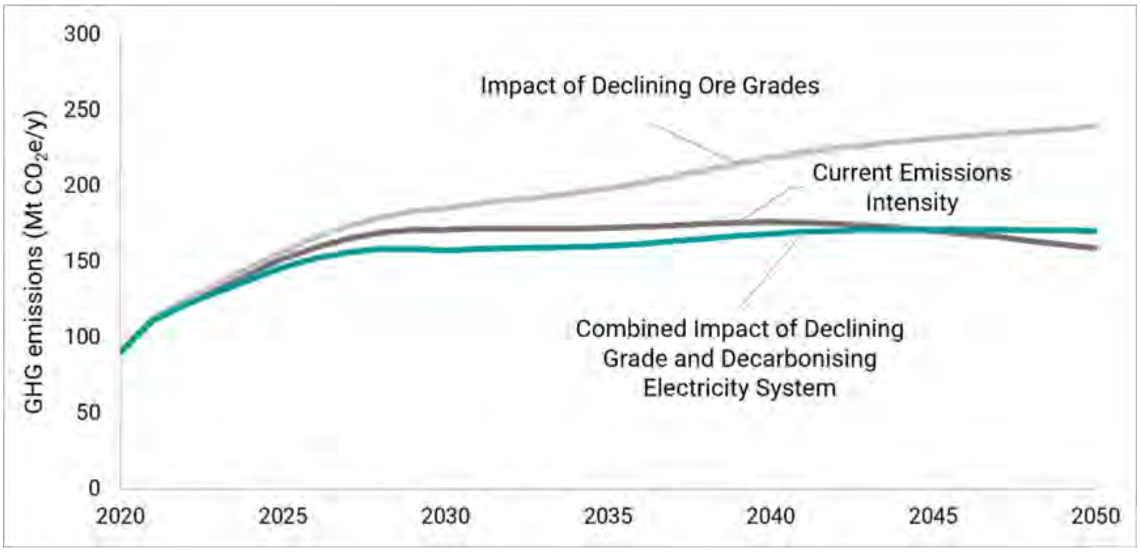


Figure 13: GHG emissions forecast for primary nickel production

Declining ore grades, mine type and processing rout can also influence GHG emissions intensity of nickel (Figure 14). However, declining ore grades have a smaller impact on nickel emissions intensity, relative to copper, because a greater proportion of nickel emissions come from downstream processing rather than the mine and concentrator. Processing routes have significant impacts on emissions intensity for nickel. Given that a large portion of nickel (~70%) is used to produce stainless steel, it is not necessary to separate nickel from iron, resulting in a market for combined ferronickel products. These products (referred to as Class 2 nickel) are produced via pyrometallurgical routes and thus tend to rely on coal as a fuel source and reducing agent. This results in these nickel processing routes having a higher emissions intensity, relative to other nickel processing routs. Because battery-grade nickel (i.e., nickel sulphate chemical) is only produced from Class 1 nickel (Figure 14),[10] which tends to have lower emissions intensities, the growth in nickel emissions is also reduced as more production switches to these routes to satisfy the demand from EV batteries.

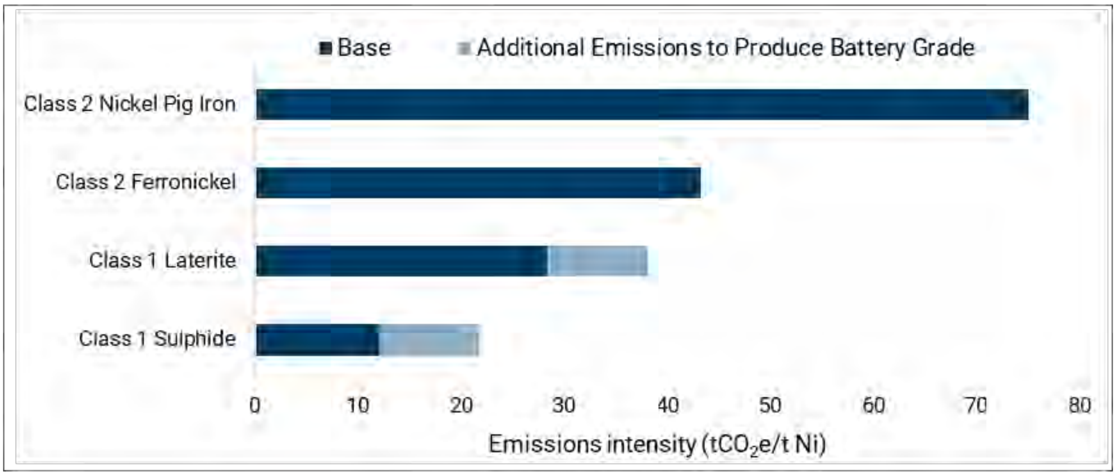


Figure 14: GHG emissions intensity for different nickel production routes[xvi]

[10] Class 1 sulphide refers to open-pit mining with sulphide smelting and refining; Class 1 laterite refers to a high-pressure acid leach; Class 2 ferronickel refers to a rotary kiln and electric furnace process for laterite ore; and Class 2 nickel pig iron refers to blast furnace processing of laterite ore.

2.4. Land-use change risks from increasing copper and nickel demand

Under a 1.5°C scenario, copper and nickel demand is expected to increase by 156% and 208% respectively by 2050 (including demand for clean energy technologies and existing uses). This unprecedented increase in demand threatens to perpetuate negative environmental and socio-economic impacts associated with direct and indirect land-use change from copper and nickel mining.[xvii] Indirect land-use change impacts (e.g., peri-urban sprawl, agriculture, hunting etc.) from increased migration to mining regions can potentially outpace and outlast the direct footprint from mining value chain activities. More importantly, unsustainable land-use practices could contribute to the dual global crises of climate change and biodiversity loss. The Roadmap specifically focused on how copper and nickel mining might contribute to the global climate change and biodiversity crises through unsustainable land-use change. Other ESG risks, particularly water in the context of copper, were regarded as more regionalized risks and therefore not a priority for the Roadmap. However, minoring companies are encouraged to ensure they address all ESG risks and strive for net-positive ESG outcomes.

Box 2: Direct vs indirect land-use change[xviii]

Land-use change is defined as a process by which human activities (e.g., mining, agriculture and urbanization etc.) transform the natural landscape. In the context of the Roadmap, land-use change refers to a change in land-use from natural ecosystems to cleared land for mining activities and respective infrastructure (e.g., extraction, processing and supporting infrastructure for transportation and energy).

Direct land-use change results from mining value chain activities directly owned and/or controlled by a mining company/value chain actor (e.g., "scope 1 activities" that cause land-use change, such as extraction, storing of mine waste and land clearing for processing infrastructure).

Indirect land-use change result from supporting activities associated with mining value chain activities and are not owned and/or controlled by the mining company/value chain actor (e.g., "scope 3 activities" that cause land-use change, such as urban and agriculture development, transport and energy infrastructure etc.).

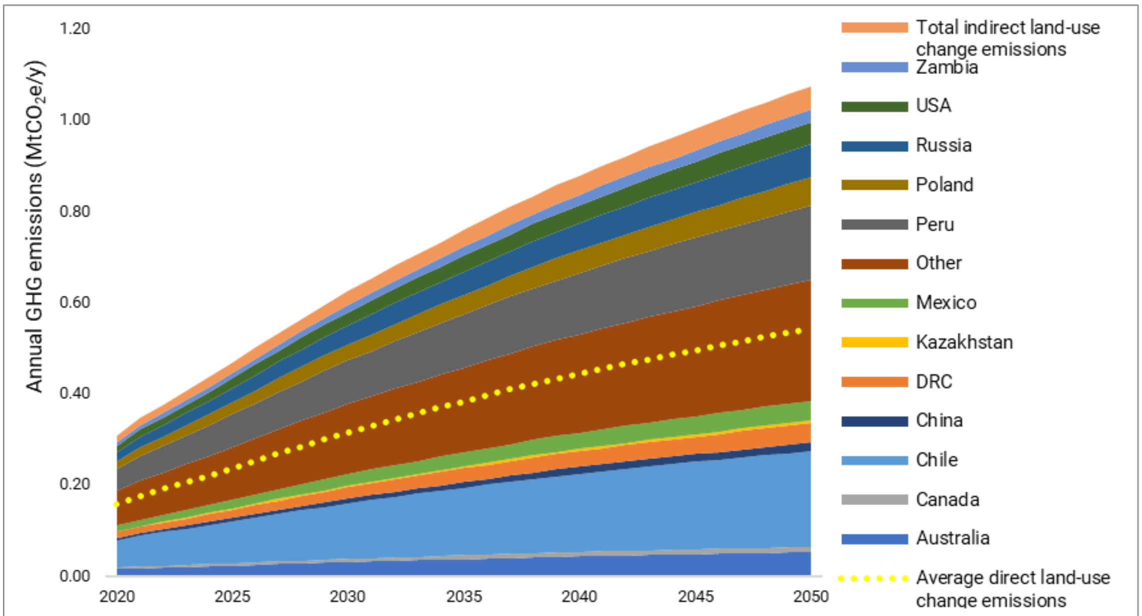
The assumption is that increased demand for copper and nickel will increase new mine (and supporting infrastructure) development in natural habitats (with relatively little human influence) to access new ore reserves. Other mining scenarios might exist where expansion of existing mining value chain activities might also lead to an increase in land-use change and associated impacts. Therefore, the environmental and socio-economic baseline conditions at a particular site will influence land-use change impacts and the scope of necessary mitigation measures.

Good land-use governance is critical for mitigating negative land-use change impacts and capitalizing on sustainable land-use opportunities for additional, net-positive environmental and social outcomes. There is generally a difference in pre- and post-mining landscapes and land-uses, with the most common post-mining land-use being agriculture; forestry; recreation; construction; lakes and conservation[xix]. While perceptions of post-mining land-use is often negative, it can provide positive environmental and socio-economic benefits, depending on the post-mining land-use itself and degree of impact from mining operations. Post-mining land-use is influenced by economic, legal, regulatory, social and technical factors, including zoning and planning laws, pre-mining environmental and socio-economic baseline conditions, current land-use surrounding the mine site (e.g., infrastructure, agriculture) and post-mining environmental conditions. Therefore, post-closure land-use management would differ across regions and site-specific contexts (e.g., in remote forests of Indonesia, the focus might be to remediate and restore lands to as close to the pre-miming state as possible. In Minas Gerais in Brazil, post-mining land-use might support a mix of sustainable, nature-based uses and commercial repurposing to retain the land's economic value and productivity for alternative uses).

The following section assessed two critical environmental risks associated with direct and indirect land-use change from increasing copper and nickel mining value chain activities: (i) gross GHG emissions from land-use change caused by copper and nickel mining value chain activities (referred to as "land-use change emissions"), and (ii) biodiversity risks from land-use change caused by copper and nickel mining value chain activities (referred to as "biodiversity risks"). Recommendations are put forward for mitigating land-use change emissions and biodiversity risks. While the focus of this section is on environmental land-use change risks, other environmental (e.g., water consumption) and socio-economic risks (e.g., gender inequality) should also be monitored and mitigated by copper and nickel mining value chain actors.

2.4.1. Climate change risks from unsustainable land-use change

Land-use change emissions, under a 1.5°C demand scenario for copper, could double by 2030 and almost quadruple by 2050, causing a cumulative increase in gross GHG emissions of ~22.7 $MtCO_2e$ between 2020 and 2050 (Figure 15). This equates to an additional ~0.6 $MtCO_2e$ per annum (~0.5% of total projected emissions) by 2030 and 1.1 $MtCO_2e$ per annum (~0.6% of total project emissions) by 2050[11] with similar increases in the emissions intensity of copper cathode production.



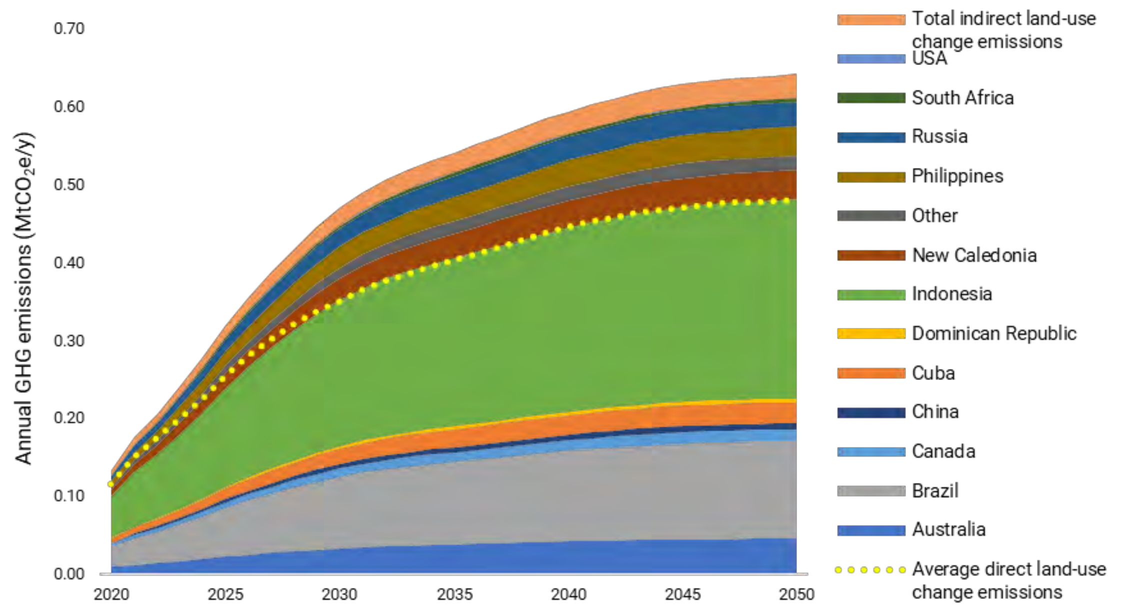
Annual emissions (2020)	Annual emissions (2030)	Annual emissions (2050)	Cumulative emissions (2020 – 2050)
0.3 $MtCO_2e$	0.6 $MtCO_2e$	1.1 $MtCO_2e$	**~22.7 $MtCO_2e$**

Figure 15: Upper estimate of gross annual GHG emissions from land-use change associated with increased copper mining under a 1.5°C demand scenario

[11] These estimates are upper estimates and represent the potential maximum GHG emissions resulting from land-use change associated with increased copper mining.

While land-use change is a small contributor to overall GHG emissions (relative to other sources, such as fossil fuels), it is a critical source of addition environmental and socio-economic impacts that can compound climate change and climate vulnerability. Therefore, mining value chain actors are encouraged to prioritize land-use change risks.

Under the same scenario, land-use change emissions from increased nickel production could be four times higher by 2030 and more than 6 times higher by 2050, with a cumulative increase in gross GHG emissions of ~15 $MtCO_2e$ between 2020 and 2050 (Figure 16). This equates to an additional ~0.45 $MtCO_2e$ per annum (~0.3% of total projected emissions) by 2030 and ~0.65 $MtCO_2e$ per annum (~0.4% of total projected emissions) by 2050[12], with similar increases in the emissions intensity of nickel products.



Annual emissions (2020)	Annual emissions (2030)	Annual emissions (2050)	Cumulative emissions (2020–2050)
0.15 $MtCO_2e$	0.45 $MtCO_2e$	0.65 $MtCO_2e$	**~15 $MtCO_2e$**

Figure 16: Upper estimate of gross annual GHG emissions from land-use change associated with increased nickel mining under a 1.5°C demand scenario

Therefore, like copper, increased land-use change is a small contributor to overall GHG emissions associated with nickel mining value chains. However, land-use change is a critical source of addition environmental and socio-economic impacts that can compound climate change and climate vulnerability, and, therefore, needs to be prioritized by nickel mining value chains.

Land-use change emissions are unevenly distributed across copper and nickel mining regions, with Chile, Peru, Brazil and Indonesia identified as high-risk regions. GHG emissions from land-use change depend on a combination of different factors, including: the geology and soil carbon stock; ecosystem and vegetation type (and their associated carbon stock); abundance and grade of ore reserves; mining type (open pit mining disturbs a greater area of land relative to underground mining, therefore has higher

[12] These estimates are upper estimates and represent the potential maximum GHG emissions resulting from land-use change associated with increased copper mining.

land-use change emissions); mine waste and tailings volume, storage method and location; and the spread and intensity of supporting mining infrastructure contributing to indirect land-use change emissions. Therefore, different copper and nickel mining regions are exposed to varying levels of risk associated with land-use change emissions. Copper mining in Chile and Peru, and Nickel mining in Brazil and Indonesia, stand out as areas at risk of higher land-use change emissions given the combination of influencing factors in those countries.

Unsustainable land-use change can increase climate change vulnerability, despite accounting for a smaller portion of total emissions relative to fossil fuel-based emissions. While land-use change emissions for both copper and nickel mining value chains are lower, in absolute terms, relative to other emissions sources, it is a critical source additional environmental and social impacts that cannot be ignored. In addition, land-use change emissions will increasingly make up a greater portion of unavoidable emissions as companies increasingly reduce other GHG emissions. Destruction of natural ecosystems, particularly those with high carbon stocks, sequestration potential and biodiversity (e.g., rain forests), negatively impacts on supporting and regulating ecosystem services (Box 3), reducing the Planet's ability to regulate the climate. This can create a knock-on effect that indirectly contributes to climate change, ecosystem degradation, and climate vulnerability[xx] (with associated socio-economic impacts). Therefore, minimizing land-use change emissions is not only critical for achieving net zero absolute emissions across the value chain, but for maintaining the resilience of broader global environmental/natural systems.

Box 3: Ecosystem services[xxi]

Ecosystem services are benefits that people obtain from a healthy, functioning natural environment and are critical for livelihoods, human health, well-being and resilience. They are divided into four categories: *provisioning* services (e.g., water, food, drugs and genetic resources); *regulating* services (e.g. flood attenuation, climate regulation, pest control and pollination); *supporting* services (e.g. primary production, nutrient cycling, including the carbon cycle) and *cultural* services (e.g. recreational, spiritual and cultural benefits).

2.4.2. Biodiversity risks from unsustainable land-use change

Biodiversity – the diversity within species, between species and of ecosystems – is critically important for sustaining and providing various ecosystem services, upon which the global economy and human livelihoods depend. It provides the air, water and soil that we depend on for human health, food security, livelihoods and economic activity. Biodiversity also regulates the climate, provides pest and pollution control, and protects against natural disasters.

However, the overexploitation of plants and animals is increasingly reducing the Planet's ability to provide these ecosystem services, making "biodiversity loss" the third most severe global risks in the World Economic Forum's 2022 Global Risk Report.[xxii] Therefore, in meeting increased demand for copper and nickel, it is critical that their extraction and production does not exacerbate the global biodiversity crisis. Doing so will not only increase each mineral's direct impact on biodiversity, but also contribute indirectly to other negative environmental and socio-economic impacts of mining.[xxiii]

Mining value chain activities can negatively impact biodiversity in several different ways (refer to Table 17 in the Appendix for further detail). Land-use change, habitat destruction and pollution from waste and hazardous materials can directly impact biodiversity. Indirect impacts to biodiversity result from the influx of people to mining regions, growth, and development of supporting infrastructure, peri-urban sprawl and increase agriculture and hunting, for example.

In terms of species richness – a measure of biodiversity based on the number of different species within a given area – copper was found to have moderate-biodiversity risks, while nickel had high-biodiversity risks, given the *number* of ore deposits located in moderate- and high- biodiversity zones respectively. Figure 17 compares the global distribution of copper and nickel ore deposits with global biodiversity zones[13] to identify and map potential biodiversity risks associated with each mineral (in terms of their potential impact on species richness). It was assumed that the greater number of ore deposits located within higher biodiversity zones, meant the greater number of species were at risk for each hectare of land-use change, and, therefore, the higher the biodiversity risk for that mineral.

This high-level analysis suggests that most copper deposits (~50%) are found in "moderate-biodiversity zones", a third (~30%) in "low-biodiversity zones" and the least (~20%) found in "high-biodiversity zones". Most nickel deposits (~65%), on the other hand, are found in "high-biodiversity zones", with a third (~ 33%) in "moderate-biodiversity zones" and very few (~2%) in "low-biodiversity zones". Therefore, based on the assumption above, nickel mining value chains face "high-biodiversity risks", while copper mining value chains face "moderate-biodiversity risks". This conclusion is supported by findings from the literature.[xxiv]

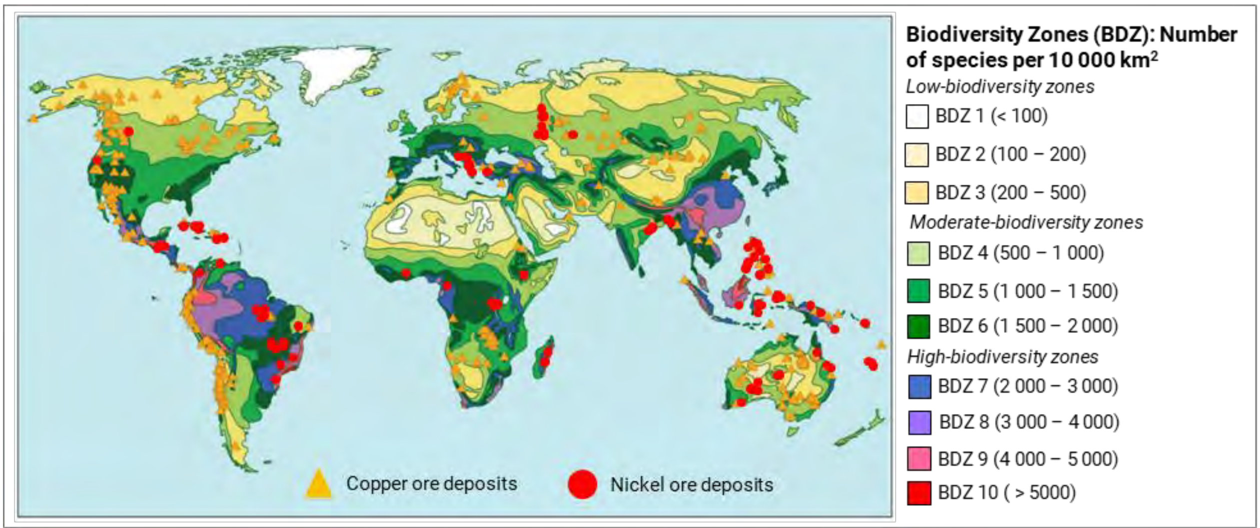


Figure 17: Map of copper and nickel ore deposits, and biodiversity zones[xxv]

Biodiversity risks for both minerals are unevenly distributed, with higher risks to species richness in tropical, rainforest and island environments and lower risk in sub-tropical, arid environments. Copper and nickel mining in the Pacific Islands (Indonesia, Philippines, New Caledonia); Central Africa (Cameroon, DRC, Rwanda, Burundi, Zambia) and Latin America (Peru, Mexico, Brazil, Cuba, Dominican Republic) face relatively higher biodiversity risks in terms of species richness relative to other regions in lower biodiversity zones.

However, measuring biodiversity risk in terms of species richness only, is an overly narrow assessment. Mining value chain actors are encouraged to account for wholistic measures of biodiversity risk. Like land-use emissions, several factors contribute to biodiversity risks. The degree and intensity of land-use change is influenced by the geology, ore grade and mine type (e.g., open pit mining is generally more

[13] The assessment was limited to terrestrial biodiversity zones and excludes marine biodiversity zones. Biological Diversity Zones are measured as the number of plant species per 10 000 km^2 and is, therefore, a measure of species richness. Plant diversity (number of species of vascular plants) is used as a proxy indicator for animal and ecosystem diversity, assuming a greater number and diversity of plant species supports a greater number and diversity of animal species and ecosystems. "High-Biodiversity Zones" are defined as regions with >2000 species per 10 000 km, while "moderate- and low-biodiversity zones" are defined as regions with between 500 to 2000 and <100 to 500 species per 10 000 km respectively.

land-use intensive relative to underground mining), and the volume and location of mine waste and tailings dams. The "degree" of "level" of biodiversity at a given location, measured in terms of species richness, abundance, and diversity[xxvi] is another contributing factor. Further consideration must also be given to the number of vulnerable and threatened species (as per the IUCN Red List[xxvii]); the number of endemic and invasive species and the ecological importance or functional significance of different species (e.g., umbrella species support a variety of other species) within a given ecosystem.[xxviii]

There are several best practice methodologies that mining value chain actors can use for assessing and mitigating their biodiversity risks.[xxix] One such methodology from the United Nations Environmental Programme (UNEP) is summarized in Figure 18. Others applicable to mining value chains include: the ICMM's Good Practice Guidance for Mining and Biodiversity; the Cambridge Institute for Sustainable Leadership's (CISL) Healthy Ecosystem Metric; the International Union for the Conservation of Nature's (IUCN) Biodiversity Indicator and Reporting System; the LandScale assessment tool; and the Cross Sector Biodiversity Initiative's (CSBI) Mitigation Hierarchy and Good Practice for Collection of Biodiversity Baseline Data documents.

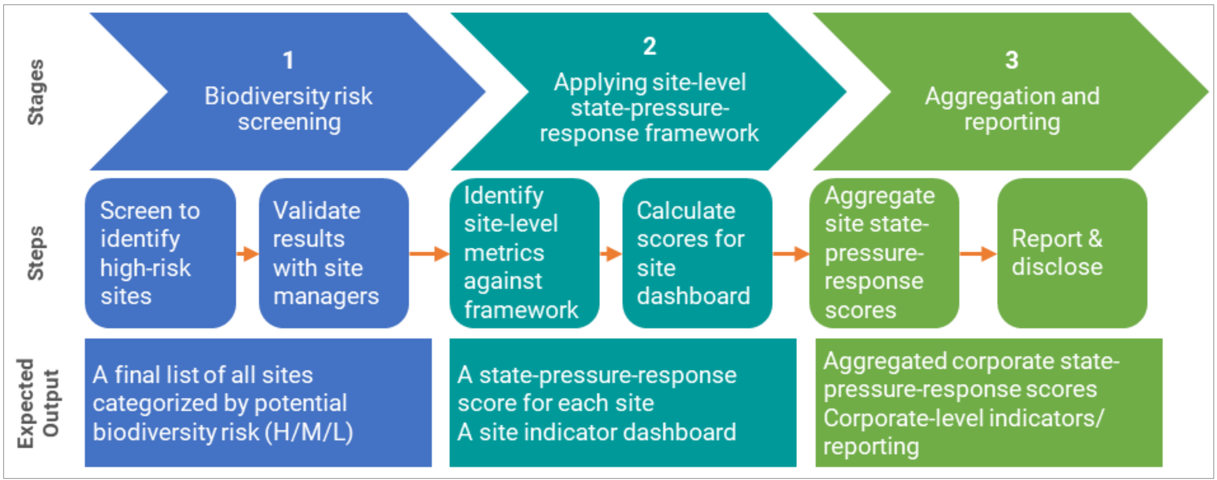


Figure 18: Process for site prioritization and tailoring of biodiversity indicators[xxx]

2.4.3. Recommendations for enabling sustainable land-use

Copper and nickel mining value chain actors are encouraged to adopt and implement the following best practice recommendations for addressing land-use change induced GHG emissions and negative biodiversity impacts:[14]

Mining value chain actors are encouraged to consider adopting and adhering to responsible mining standards and guidelines for minimizing negative environmental and socio-economic land-use change impacts. These include, for example: (i) the World Bank's Climate-smart and Forest-smart Mining guidelines; (ii) the ICMM's Mining Principles for "environmental performance" and "conservation of biodiversity", their Closure Management Tool and the Good Practice Guide for Mining and Biodiversity; (iii) RMI's 2019 Risk Readiness Assessment; (iv) the Initiative for Responsible Mining Assurance (IRMA) Standard for Responsible Mining, and (v) the IFC's Performance Standard on "biodiversity conservation"[xxxi].

[14] Best practice recommendations focus on minimising land-use change emissions and biodiversity impacts from mining and do not include recommendations for addressing other socio-economic impacts associated with mining-induced land-use change.

Companies are encouraged to adhere to the mitigation hierarchy when addressing land-use change emissions and biodiversity impacts:

1. ***Monitor and report* land-use change emissions and biodiversity impacts**, including historical (from existing mines) and future (from new mines) impacts. Collect, maintain, and share accurate land-use data and geospatial information to support good land-use governance and strengthen land-use decision-making and planning. Developing interoperable land administration systems to ensure availability of accurate and up-to-date data (that reflects the reality "on the ground") is critical for supporting land-use decision-making. Include land-use change emissions in carbon accounts to be balanced and include a range of biodiversity metrics, at different scales, when assessing biodiversity risks (see best practice methodologies above).

2. ***Avoid and minimize* land-use change impacts:** Ensure good land governance by engaging with value chain actors, national and local governments, and local communities on local spatial and development planning. Strategic spatial planning and good land governance are critical foundations for mitigating any potential long-term implications associated with land-use change, and to strengthen climate change adaptation and resilience. Effective spatial planning can prevent mining activities and peri-urban and rural sprawl from exacerbating land-use change emissions and biodiversity risks.

   Good land governance/regulatory frameworks and well enforced laws, particularly around land ownership, land-use, spatial planning, zoning, etc. can make a significant difference in mitigating both direct and indirect land-use change impacts. Inadequate planning for infrastructure and built environment can also contribute to the severity of climate change impacts (e.g., flooding and drought) on mine and processing sites; local communities; transport networks and supporting infrastructure, all of which contribute to poor climate change adaptation and climate vulnerability.[xxxii]

   Implement a *lifecycle management strategy* to promote good land governance and minimize negative environmental and socio-economic impacts from land-use change. Ensure due diligence is carried out during all mine lifecycle phases through the development and implementation of a holistic lifecycle management strategy.[xxxiii] Include direct and indirect land-use change emissions in scope 1 and 3 emissions accounting frameworks (as per forth coming best practice guidance from the GHG Protocol). Include land-use change risks in carbon and biodiversity management strategies.

   Prioritize underground mining and/or high-grade ore bodies over open pit mining and/or low-grade ore bodies. Minimize mine waste by back-filling mines with waste rock, recycling mine waste or selling waste to other sectors as secondary raw materials (e.g., rock waste for construction).

   Encourage greater circularity, reuse and recycling of copper and nickel by downstream actors at end-of-life to maximize use of secondary material and reduce the demand for virgin copper and nickel and, therefore, land-use change.

   Avoid and minimize the intensity of biodiversity risks by not mining in or near protected areas and World Heritage sites.

3. ***Offset and restore* unsustainable land-use change through sustainable land-use practices, mine rehabilitation and post-closure livelihood plans.** Sustainable land-use management can provide environmental and socio-economic safeguards and co-benefits to ensure the future sustainability and resilience of both the local environment, community livelihoods and social

license to operate. Value chain actors must ensure the implementation of, and financing for, sustainable land-use activities that support climate change mitigation, offset and adaptation strategies, mine rehabilitation programs and post-closure socio-economic plans. Examples of sustainable land-use management include:

Invest in ecological infrastructure and Nature-based Solutions (NBSs) (e.g., wetlands, forests). These can provide various ecosystem services and climate change adaptation benefits (e.g., flood mitigation). These also present unique carbon and biodiversity offset opportunities (measurable conservation outcomes or "credits" designed to compensate for negative and unavoidable environmental impacts from projects) for self-development or purchasing off the market *(refer to* *Section 3.4. Net Zero-aligned Carbon Offset Strategies – page 41* *– for more information on offsets)*.[xxxiv]

Dry stack tailings and mineralization of tailings (particularly nickel tailings) are two interventions that can support sustainable land-use and mine rehabilitation programs, while avoiding tailings risks and minimizing waste. They also have the potential to offset both land-use change emissions and biodiversity impacts[xxxv]. These interventions can be used as self-developed carbon/biodiversity insetting projects by mining value chain actors for own-use in offsetting their land-use change impacts. In addition, any excess credits from self-developed carbon/biodiversity projects can be sold to other value chain actors, sectors, or offset markets as an alternative revenue source for funding mine rehabilitation and post-closure plans.

Sustainable and Climate Smart Agriculture (CSA) provides both environmental and socio-economic benefits, such as food security, livelihood opportunities, and improves water security.

Marginal land can be used to support low-carbon energy production and storage, including energy crops for sustainable biofuels, wind and solar energy production and gravity-based energy storage, using either towers or water reservoirs (noting that these might have their own unintended negative impacts)

Balance trade-offs between environmental and socio-economic co-benefits associated with different sustainable land-use opportunities using a weighted prioritization and decision-making framework. Such frameworks should be site-specific and account for local community needs and pre-mining baseline conditions (e.g., should land-use be converted back to its pre-mining state, where it provides ecosystem services, or should it be used to support sustainable economic activities, such as renewable energy generation).

3. A NET ZERO ROADMAP FOR COPPER AND NICKEL MINING

Under a 1.5°C scenario, total annual demand for copper and nickel is expected to increase by 156% and 208% by 2050 respectively (including demand for clean energy technologies and existing uses). Meeting this increased demand, using BAU primary production processes, is expected to increase GHG emissions by 125% and 90% by 2050 for copper and nickel respectively. If copper and nickel mining value chains do not reach net zero emissions by 2050, increasing demand will threaten to perpetuate the climate crisis.

To reach net zero emissions[xxxvi] and align with a 1.5°C temperature trajectory, mining value chain actors will need to reduce their absolute GHG emissions by ~50% by 2030 and by ~90% by 2050, from 2020 levels. This equates to an average reduction rate of ~4.2% per annum (from a 2020 baseline). A suite of cost-effective low-carbon technologies are already available for avoiding and reducing GHG emissions, including energy efficiency interventions; autonomous and digital solutions; renewable energy (e.g., solar, wind, battery storage); fuel switching opportunities (e.g., sustainable biofuels, green hydrogen), and electrification solutions (e.g., BEVs, trollies, conveyors). These are discussed in more detail throughout the chapter.

Carbon removal offsets will then be required to "neutralize" the remaining ~10% of residual, hard-to-abate GHG emissions to balance the net zero equation up to 2050 and beyond. While carbon removal offsets are critical for achieving net zero emissions, they must be used in-line with best-practice to avoid unsustainable land-use and negative environmental and socio-economic impacts, such as maladaptation.

The following chapter provides a Roadmap for copper and nickel value chains to reach net zero emissions by 2050. It begins with an overview of the mitigation hierarchy and identifies key GHG emissions sources across copper and nickel mining value chains. A technoeconomic assessment of low-carbon technologies required to avoid and minimize GHG emissions is then provided. This includes an assessment of ESG considerations for deploying low-carbon technologies and avoiding any unintended negative impacts in doing so (e.g., unintended impacts on water resources or biodiversity when deploying certain low-carbon technologies). The chapter concludes with a review of carbon offset risks and opportunities, and best-practice recommendations for net zero-aligned carbon offset strategies for reaching net zero emissions.

3.1. The mitigation hierarchy

Mining value chain companies are encouraged to adhere to the mitigation hierarchy when transitioning to net zero GHG emissions (Figure 19). This means:

i. **Monitor, report and set GHG emissions reductions targets:** monitor and report GHG emissions, including land-use change emissions, to identify key emissions sources and mitigation options. Set and communicate ambitious and transparent science-based targets for reducing absolute Scope 1, 2 and 3 emissions. This should form part of a broader Monitoring and Evaluation (M&E) system that established baselines and tracks progress toward net zero targets. A broader M&E system should also consider carbon removal offset demand, potential offset risks, and the delivery of environmental and socio-economic co-benefits throughout the lifecycle of offset projects.

ii. **Avoid and minimize absolute GHG emissions:** avoid emissions through efficiency improvements (e.g., energy efficiency, process optimization), and minimize or eliminate emissions through low-carbon energy sources (e.g., renewable energy for Solar PV, green hydrogen).

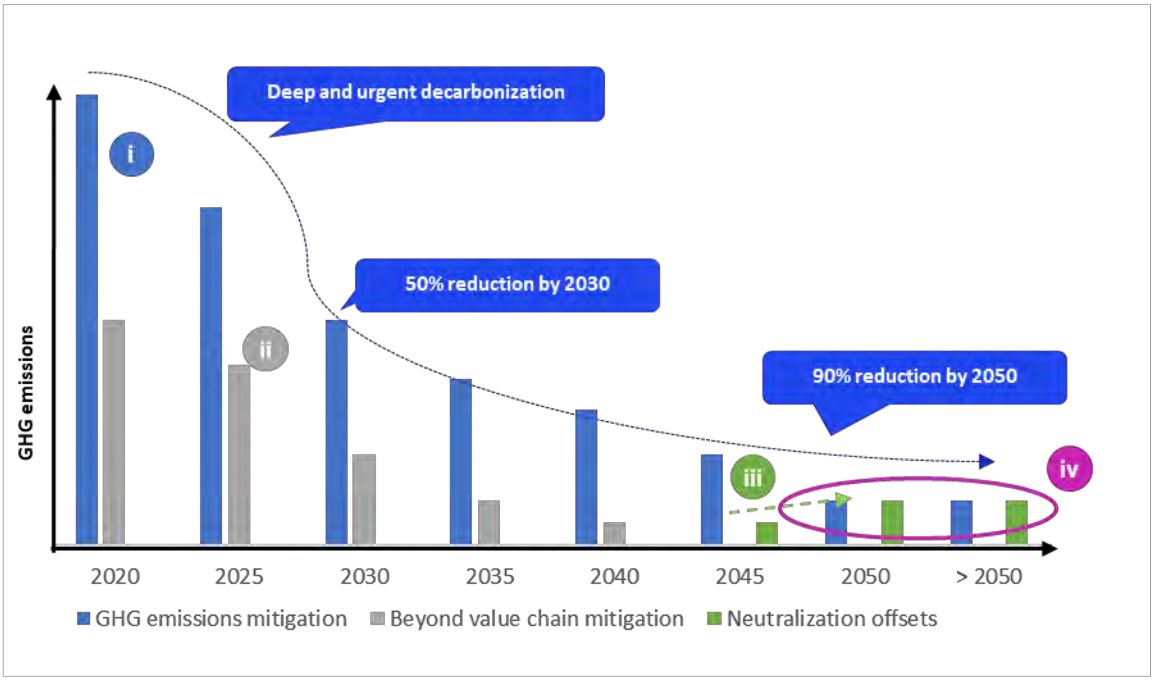


Figure 19: Net zero-aligned mitigation hierarchy

iii. **Invest in "Beyond value chain mitigation":** To support urgent global decarbonization, companies should consider investing in credible carbon offset projects outside of a company's value chain during their mitigation journey (between 2022 and ~2035/40). This should be done in addition to, not instead of, absolute emissions reductions. This is to avoid becoming over-reliant on carbon offsets and exposing companies to market and pricing risks, while also ensuring absolute emissions reductions are aligned to a 1.5°C trajectory. The nature and scope of these investments should be recorded annually pending further best practice guidance. According to the Science-Based Targets initiative (SBTi) "beyond value chain mitigation" offsets and other investment in beyond value chain actions are voluntary but considered best practice.[xxxvii]

iv. **Neutralize residual, hard-to-abate emissions:** Using quality carbon removal offsets, neutralize residual and hard-to-abate emissions in the long-term (2040-2050) to reach net zero emissions by 2050.[xxxviii]

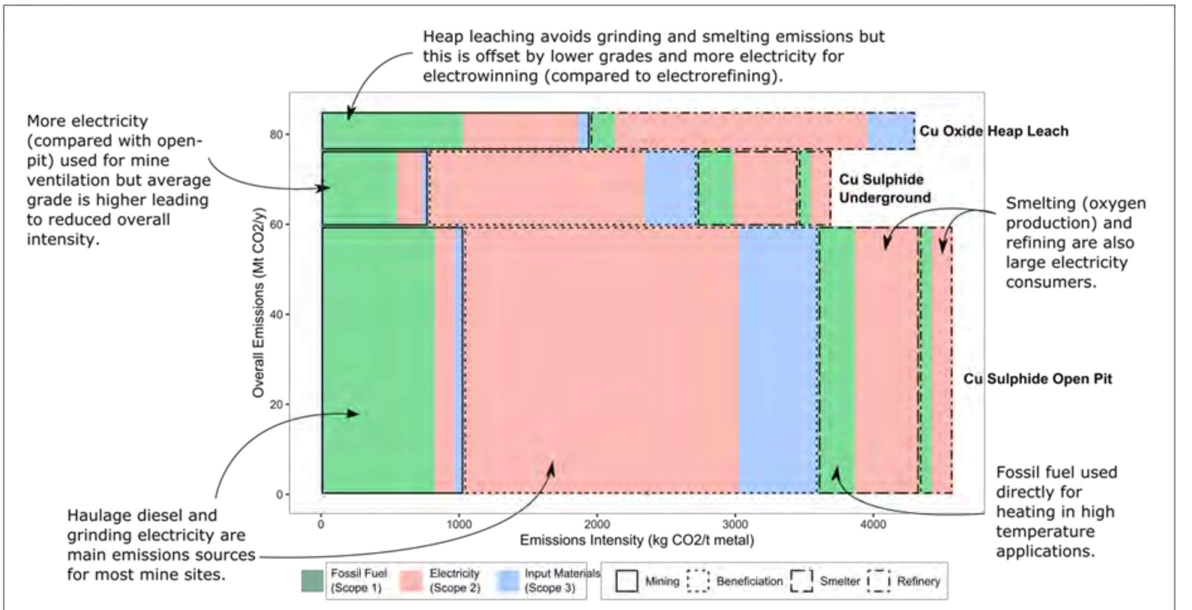
v. **Balance the net zero equation beyond 2050:** Continue using high-quality carbon removal offsets to balance any GHG emissions beyond 2050 and remain at net zero emissions (~10% residual emissions = carbon removal offsets).

3.2. Monitor, report and set emissions reduction targets

Mining value chain actors are encouraged to monitor and report their GHG emissions (across Scopes 1, 2 and 3). This first step on the net zero journey is critical for establishing baselines (against which to establish reduction targets and monitor progress) and identifying key GHG emissions sources from a company's activities. Identifying emissions sources is also important for identifying appropriate mitigation interventions. It is recommended that companies follow best-practice guidance for monitoring and reporting their GHG emissions, such as the GHG Protocol or ISO 14064.

3.2.1. Copper emissions sources

Most GHG emissions from copper mining value chains stem form electricity usage (Scope 2) for ventilation, grinding for concentration and electrowinning/refining activities (Figure 20). Other significant emissions sources are those from direct fossil fuel consumption (Scope 1) for haulage and process heat in smelting. There are, however, variations in the intensity of different emissions sources depending on the specific copper processing rout (copper oxide vs copper sulfide and open-pit vs underground mining). Scope 3 emissions are another important source but can vary depending on the context of a particular company and its value chain. Figure 20 highlights Scope 3 emissions from input materials (category 1: purchased goods and services) but other scope 3 categories could also be material sources (e.g., capital goods, downstream transportation etc.).

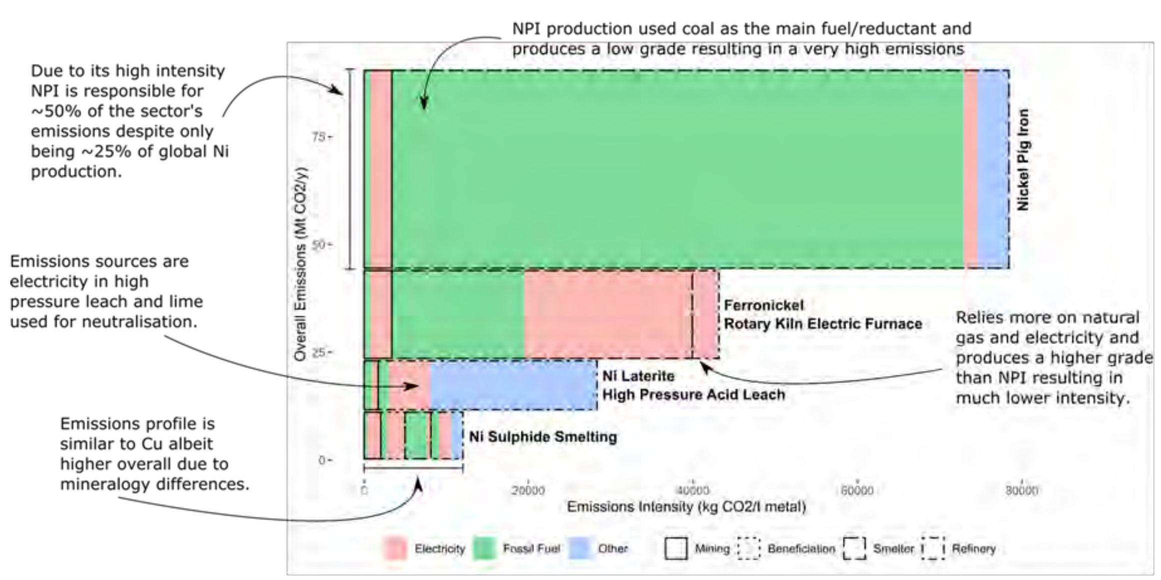


**Scope 3 emissions estimates are limited category 1 (purchased goods and services) and category 9 (downstream transport of concentrates). The full Scope 3 boundary is dependant on the context of a particular company and its value chain*

Figure 20: GHG emissions sources across the copper mining value chain *(RMI analysis[xxxix])*

3.2.2. Nickel emissions sources

Most emissions from nickel mining value chains stem from fossil fuel usage (Scope 1), particularly from the use of coal as a heat source/reductant for Nickel Pig Iron (NPI) and Ferronickel (Figure 21). Purchased electricity (Scope 2) is another significant emissions source, especially for Ferronickel. Scope 3 emissions are another important source but can vary depending on the context of a particular company and its value chain.



**Scope 3 emissions estimates are limited category 1 (purchased goods and services) and category 9 (downstream transport of concentrates). The full Scope 3 boundary is dependant on the context of a particular company and its value chain*

Figure 21: GHG emissions sources across the nickel mining value chain *(RMI analysis[xl])*

3.2.3. Setting ambitious GHG emissions reduction targets

After measuring and verifying a company's GHG emissions, it is best practice to establish science-based reduction targets. This can be done by:

- Issuing a pledge from the corporation's senior leadership to reach net zero emissions across their critical mineral and metal value chains by 2050 at the latest.
- Developing tangible emissions reduction strategies and action plans, with short- and medium-term goals, for Scope 1, 2 and 3 emissions.
- Setting ambitious science-based targets for absolute emission reductions and removals and provide details on offsets. Companies can also set emissions intensity targets, but they must prioritize absolute emissions reduction targets.
- Sharing information on emission reduction measures to facilitate good practice replication.

3.3. Low-carbon technologies for avoiding and minimizing emissions

There is a suite of cost-effective low-carbon technologies which are already available for avoiding and reducing GHG emissions across copper and nickel mining value chains. This section provides a technoeconomic assessment of identified low-carbon technologies, including their mitigation potential, cost effectiveness, technology maturity, and scalability. It also identifies and maps potential environmental and socio-economic risks and co-benefits associated with the deployment of low-carbon interventions, while acknowledging key governance requirements for mitigating risks and enhancing co-benefits. Recommendations are later provided in the form of an implementation roadmap (based on the results of these assessments) in terms of technology availability and mining-company actions to enable decarbonization.

3.3.1. Low-carbon technology investment horizons

Investments in low-carbon technology interventions should focus on three broad time horizons:

1. **Incremental and continuous efficiency improvements (deployment in <5 years):** Quickly implementable technologies that focus on improving GHG emissions intensity per unit output of copper and nickel. These include operational energy efficiency interventions that reduce energy demand and process optimization interventions (for which implementation may extend beyond the next 5 years) that increase production without a corresponding increase in energy demand. These interventions should be the initial focus to both reduce emissions intensity in the short-term, and act as a key enabler for renewable energy (RE) interventions by reducing the size (and therefore upfront cost) of future RE deployments.
2. **Direct emissions reductions (short-term investment with deployment in 5 – 15 years):** Capital investments in RE and energy storage technologies, hydrogen-based fuel switching, and electrification of processes (e.g., trolley-assist, battery electric vehicles, process heat, etc.). Some initial RE deployments, such as standalone solar PV on remote mines or power-purchase agreements (PPAs) for grid connected sites, might be executable within the next 5 years.
3. **Research and development (short- to medium-term investment with deployment in 15+ years):** Continuous investments in research, development, and deployment (RD&D) for innovative yet immature technologies (e.g., fast charging battery technology, in-situ recovery).

3.3.2. Technoeconomic assessment of low-carbon technology interventions

Energy efficiency interventions, including efficient operational equipment (e.g., energy efficient heating, ventilation and air conditioning, best-in-class electric motors[xli]) and comprehensive mining process optimizations (e.g., mine-to-mill, high-intensity selective blasting, coarse ore flotation, ore sorting, [xlii] etc.), directly reduce emissions intensity and are a key enabler for RE deployment. These technologies can reduce energy consumption and associated emissions, while also reducing the capital hurdle of RE deployment. Most energy efficient technologies were found to be mature and cost-effective. For process optimizations, however, applicability is dependent on the circumstances of each mine. Therefore, energy reductions and costs should be evaluated using a whole-of-site optimization.

Digitization and automation technologies can provide additional emissions and cost savings from improvements in energy efficiency and process optimization. These technologies can, therefore, support further integration of RE but are not a stand-alone solution for reducing emissions. Technology maturity and affordability ranges depending on the specific digital and automated technology. Energy reductions and costs should be evaluated using a whole-of-site optimization.

Renewable energy technologies (solar PV, wind, and battery technologies[xliii]) are mature and continue to see price declines, allowing for fossil fuel-based electricity emissions to be reduced at low (or negative) abatement cost. As a result, 5 GW of RE projects on mine sites have already been announced or commissioned.[xliv] Alternative financing models can further accelerate implementation. For example, a capital lease from independent power producers (IPPs), can be used to shift capital requirements (which can be ~300% higher for a 100% RE system[15]) off balance sheet. Additional options, such as power purchase agreements (PPAs), are available for grid-connected sites, although the contribution of these instruments toward eliminating grid emissions should be considered.

The roadmap to 100% RE for each site could also consider value creation after cessation of mining. For example, RE deployed during the mine operations could provide value to surrounding communities post-closure by utilizing exhausted mine pits as pumped storage to provide dispatchable power.[xlv]

Unique energy-storage and load-shifting opportunities should also be considered to increase the pace of RE deployment on-site. Satisfying demand during periods of lowest RE resources can add 50% to the cost of deployment.[16] Mining operations have distinctive opportunities to shift demand and avoid these costs. For example, stockpiling ore to reduce the hydrogen demand of the haul fleet and potentially converting hydrogen back to electricity during times of low solar or wind resources.[xlvi] Similarly, there may be unique energy-storage options beyond batteries. For example, the presence of industrial infrastructure onsite can enable the use of compressed[xlvii] or liquid[xlviii] air-based storage. Hybridization with diesel generators may be required in the short-term to avoid these variability and reliability of supply concerns associated with RE. Even in these cases, significant (e.g., ~70%[xlix]) emissions reductions can still be achieved. Until cost declines allow for elimination of hybridization, substituting diesel with sustainable biofuels can provide further interim emissions reductions.

Natural gas is unlikely to reduce overall GHG emissions unless upstream methane leakage risks are addressed and is, therefore, not considered a robust decarbonization strategy. This is based on case study analysis of heavy duty (290t) haulage emissions, assuming a 15% reduction in engine efficiency for natural gas compared to diesel and a 1.4% upstream methane leakage rate, which results in 15% more emissions than a baseline diesel case. Similar results have been found by other lifecycle analyses.[l]

Green hydrogen can be a cost-competitive (on a total cost of ownership basis) haulage fuel-switching (from diesel) strategy at ~US$4/kg (depending on current diesel prices). Assuming a hydrogen power haul truck drivetrain efficiency of 50%, compared to 36% for diesel[li], means that ~0.2 kg of hydrogen is required to replace each liter of diesel. This results in a fuel-only (i.e., before considering the increased cost of the haul truck drivetrain) crossover price of US$4.10/kg of hydrogen, assuming a US$0.88/L price of diesel.

Green hydrogen is also cost-competitive in many regions that have favorable RE capacity factors (e.g., Chile). This is based on a "cost of green hydrogen production model", which determines the optimal mix of solar PV, wind, batteries, and hydrogen electrolyzers in a location, considering the costs for each component and the available solar and wind resource. The locations considered in the model were Chile, Democratic Republic of Congo, USA, Mongolia, Indonesia, and Poland. The prices considered in the model were US$800/kW for solar PV; US$1,100/kW for wind; US$700-1400 for proton exchange

[15] Based on a case study analysis of 44 MTPA mine based in Chile comparing a traditional diesel generator system against a combined solar PV, wind, and biomass system. Pricing is based on US$1,250/kW for solar PV, US$1,970/kW for wind, $550/MWh for batteries, $500/kW for diesel generator capital costs and US$1/L for diesel fuel.
[16] Based on the same case study above considering the costs for a system with a criteria of <2% unmet demand compared with a system which has up to 5% unmet demand.

membrane (PEM) electrolyzers/fuel cells; US$150-300/kWh for li-ion batteries and $US585/kg for pressurized hydrogen storage. The resulting green hydrogen prices (US$3-8/kg) were used in a haulage cost case study analysis, which was based on a 44 Mt/y mine using a diesel price of US$0.88/L, escalating at 4% a year (based on US Energy Information Administration historical data) with 290t haul trucks. The drivetrain for the modified haul trucks was assumed to be an 800 kW fuel cell, 1100 kWh battery pack and 840 kg of hydrogen storage.

Green hydrogen components (i.e., electrolyzers) are available commercially but have not achieved significant scale, which might restrict full-scale deployment in the short-term (2020 – 2030). With further anticipated cost declines in hydrogen electrolyzers, it is expected to be 15% - 20% cheaper than using diesel for haulage. This is based on the same case study as above, except with a US$200/kW electrolyzer price. These cost declines are estimated based on the observed 18% learning rate for PEM electrolyzers and the 45 GW of electrolyzer capacity announced to be installed in the next 5-years by members of the Green Hydrogen Catapult.[lii] The cost for a green hydrogen deployment strategy is dependent on site-specific conditions relating to RE resources and haulage type/size. In addition, the total cost for a green hydrogen strategy is highly dependent on the haul route.[liii] The haul route topology sets the size of battery required to maximize the use of regenerative braking, which, in turn, determines the overall drivetrain efficiency. In the extreme case of hauling material downhill, regenerative braking can provide all the required energy negating the need for hydrogen. A whole-of-site optimization strategy for each asset is recommended to ensure the optimal haulage strategy is coupled with the RE deployment roadmap.

Battery Electric Vehicles (BEVs) are already suitable for small haulage vehicles, particularly those used in underground mines where hydrogen is not appropriate due to risks from using a flammable gas in confined spaces. The business case for BEVs in underground applications is also supported by reductions in ventilation requirements and, as a result, have already been deployed at sites.[liv] Electrification of haulage can also be supported by maximizing conveyor use[lv] and implementing trolley assist systems. Trolley assist can be installed for diesel-electric haul trucks to reduce diesel consumption by 20-30%.[lvi]

BEVs for large haul trucks is not yet scalable due to low-energy density barriers. For example, the equivalent weight battery to a diesel engine and fuel tank in a 290t haul truck is only sufficient to operate for ~4 hours (compared with >24 hours for diesel or hydrogen). However, battery energy density has improved ~20% over the last decade[lvii] with further gains possible through additional technology advancements. Together with **new charging technologies**[lviii] (e.g., in-haul charge) this will allow deployment of BEVs in these larger size classes. It is anticipated that these new charging technologies will be available in the near-term at which point BEVs will likely have a cost advantage over green hydrogen due to higher efficiency.

Electrifying process heat or fuel-switching to green hydrogen can eliminate GHG emissions from smelting of sulfide ores (i.e., new burner designs[lix]). Nickel-ferroalloy production uses fossil fuels for both heat and reduction. These processes are analogous to the steel industry and will require similar technologies (e.g., green hydrogen reduction, carbon capture and storage) to decarbonize.[lx]

Transport emissions reductions[17] can be achieved by optimizing logistics and deploying electrification and fuel-switching interventions for road, rail and shipping fleets. Optimizing logistics should aim to reduce copper and nickel emissions intensity by:

1. Shifting to more efficient modes of transport where possible (e.g., road to rail)
2. Increasing the efficiency of current transport (e.g., increasing back-haulage, load capacity and load factors)
3. Reducing the distance that mineral concentrates travel (e.g., co-locating mines and processing plants where possible).

Co-locating mines and processing plants can reduce transport emissions by avoiding fossil fuel-based shipping and, in some cases, utilizing more sustainable sources of energy for processing. It can also support green industrialization in developing countries. However, several technoeconomic and geopolitical barriers might reduce the viability of co-locating mines and processing plants, such as economies of scale; technology and skills availability; labor market considerations, amongst others.[lxi] Electrification (e.g., BEVs) and fuel-switching interventions (e.g., green hydrogen-based fuels[18]) should also be applied to road, rail and shipping fleets to minimize transportation emissions. Further guidance for reporting and reducing transport emissions can be sourced at the Global Logistics Emissions Council (GLEC) and the Low Carbon Freight program of the Low Carbon Technology Partnerships initiative (LCTPi).[lxii]

Circular economy interventions can support deep emissions reductions across copper and nickel mining value chains. Increased circularity and metal recovery from post-consumer scrap can reduce emissions by ~50%, relative to primary metal production[lxiii] (and help avoid other ESG risks). Tailings minimization (e.g., reprocessing, and dry stack tailings interventions) can also support circularity by increasing metal recovery and reducing tailings waste and associated ESG risks. Adopting product-service business models and adhering to the waste mitigation hierarchy will also help value chain actors improve the circularity of their operations. This includes redesigning, reducing, repairing, and reusing all mineral and non-mineral waste, before recycling and disposing of waste (e.g., Anglo American Platinum's target of "zero waste to landfill by the end of 2020" saw them achieve a 92% reduction in their annual waste sent to landfill through different circular economy strategies[lxiv]).

Mining and processing companies can also generate value from mineral waste and support decarbonization in other sectors through circular economy interventions (e.g., waste rock, slags and sludges can be used as inputs for low-carbon cement and other construction applications, such as roads or railways). Adopting circular economy interventions can also future proof mining value chains against the likelihood of increasing circular economy requirements, either legal (e.g., the European Commission's mandatory requirements for all batteries placed on the EU market, including requirements on recycled content, and meeting collection and recycling targets, among others[lxv]) or voluntary (e.g., recycled content requirements by downstream customers).

---

[17] The scope of the Roadmap includes three value chain phases: extraction, processing and transport. The transport phase is limited to the transportation of mineral concentrates for further processing into cathodes and excludes the transportation of upstream value chain inputs (e.g., capital and purchased goods, such as equipment, fuels, cement, steel etc.) and downstream outputs (e.g., transporting copper cathodes for processing into copper pipes, wires, solar panels etc.).
[18] A distinction is made here between green hydrogen and green hydrogen-based fuels because international shipping, in particular, is likely to use ammonia produced from green hydrogen as a fuel, rather than green hydrogen directly.

Box 4: The waste mitigation hierarchy[lxvi]

1. Avoid and reduce waste by rethinking and redesigning products to improve their circularity (repairability, reusability and recyclability)
2. Repair and reuse products to extend their life span
3. Recycle waste into secondary products
4. Recovery value from waste than cannot be recycled (e.g., energy recovery from waste)
5. Dispose of unavoidable waste responsibly

Invest in RD&D for several alternative, innovative technologies that could fundamentally alter the current paradigm of emissions but are not yet mature or cost competitive (or pose other environmental risks). Such innovative technologies include, for example, in-situ recovery[lxvii] and high voltage pulse[lxviii], amongst others.

The technoeconomic assessment of identified low-carbon technologies is summarized in Table 3 on the following page. Findings suggest that several cost-competitive (depending on location and mine life), high-abatement technologies can be deployed across the copper and nickel value chain in the short-term (i.e., <5 years). This provides an opportunity for producers to position themselves as market leaders and ensure that their copper and nickel products have the competitive advantage in a low-carbon future. To achieve this, companies are encouraged to develop their own technology deployment roadmaps based on the specific context of their operations and value chains (e.g., solar and wind resources at different mine sites). These roadmaps should detail the pathway to 100% RE and whole-of-site optimization strategies (to lower energy demands and facilitate RE deployment) for each asset, as well as supporting RD&D efforts on technologies with a longer-term horizon for abatement impact.

3.3.3. Bringing it all together

Figure 22 and Figure 23 provide hypothetical examples of how a copper mine and a nickel mine might deploy some of the low-carbon technologies discussed above. Each are based on different scenarios (described below each Figure) regarding mine type, location, and geology. In reality, the unique circumstances of individual mining operations will dictate the most suitable mix of technologies to be deployed for minimizing GHG emissions. Technology deployment should be informed by whole-of-site optimization strategies.

Table 3: Technoeconomic assessment of low-carbon technologies

Low-carbon technology	Technology readiness	Cost competitive	Available at Scale	Emissions abatement potential*	Notes / examples
Efficient Equipment			Now	5-10%	Best-in-class motors, variable speed drives
Process Optimization			<5 years	10-20%	Mine-to-mill, high intensity selective blasting, coarse ore flotation & ore sorting
Digitization & Automation			<5 years	5-10%	Haul truck automation to reduce fuel use
Renewable Energy			Now	70-100%	Onsite RE hybridized with diesel can provide 70% emission reduction
Energy Storage			<5 years	100%	Enables complete RE penetration. Mines have unique storage options (compressed /liquid air)
Sustainable Biofuels			Now	30-70%	Even without blending ~30% of emissions remain, typical 20-30% premium
Green Hydrogen			5-10 years	100%	Used in large haul truck (fuel cell electric vehicles) or for high temperature heat. Already cost competitive with diesel in some locations but not available at scale
Battery Electric Vehicles			Underground: Now Open Pit: 5-10 years	100%	BEVs already deployed in underground mines to eliminate emissions. Larger sizes for open pit applications in development
Conveyors & Trolley Assist			Now	~30%	Mature, cost competitive haulage electrification. Cannot replace all trucks at most mines

Key

High Moderate Low

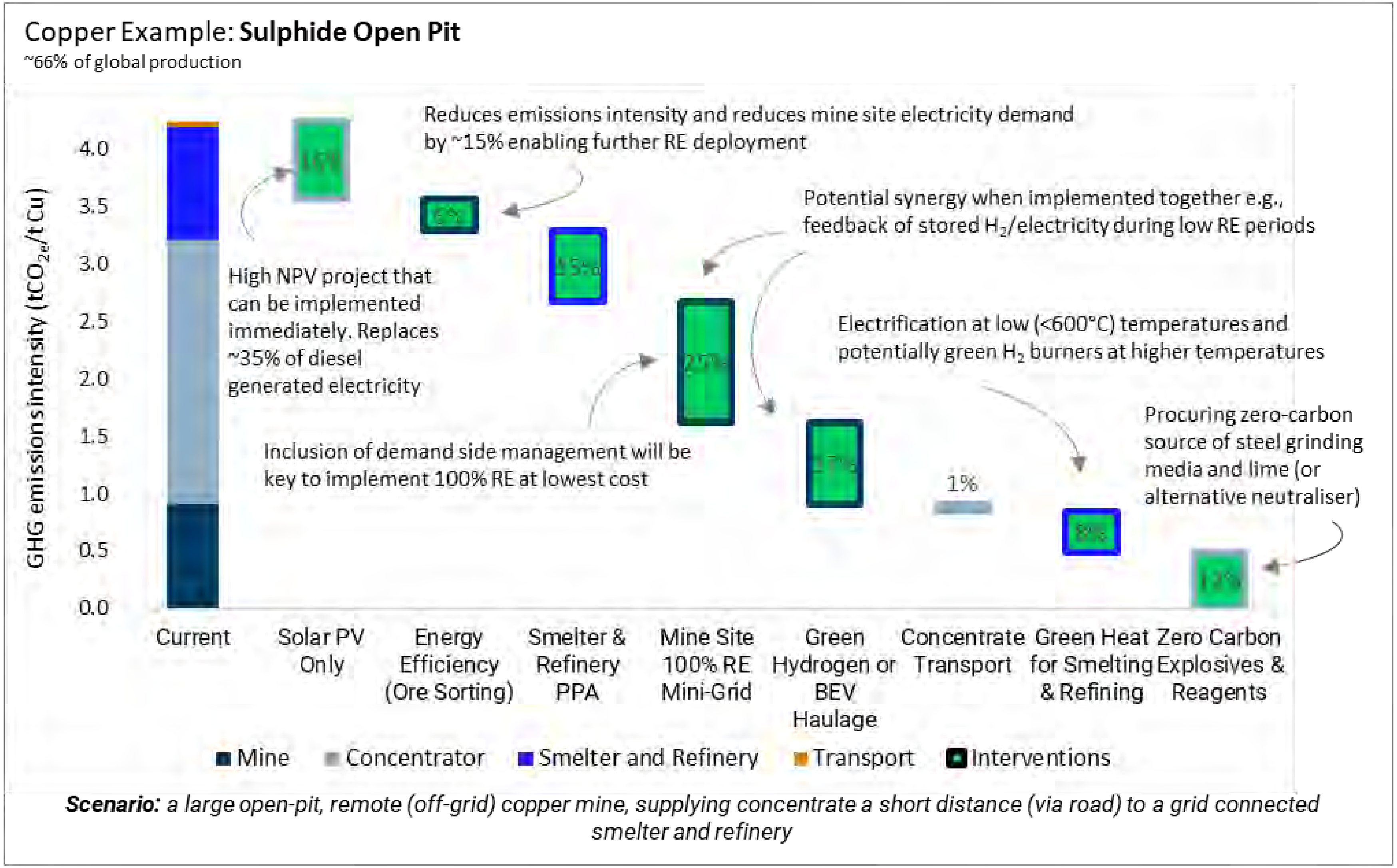
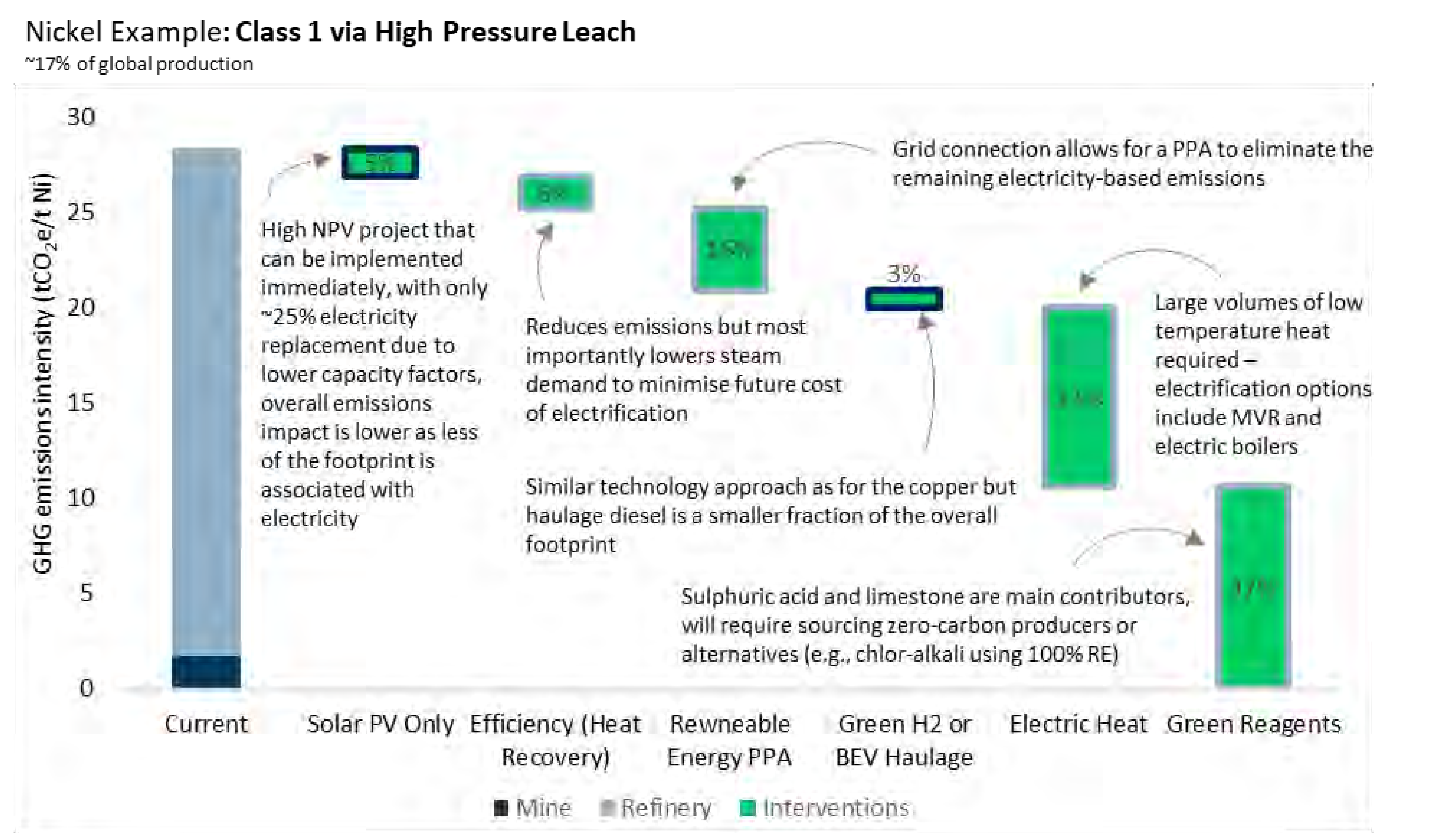


Figure 22: Low-carbon technology interventions for minimizing copper GHG emissions



Scenario: *a nickel laterite operation using high pressure acid leach to produce Class 1 nickel at a grid connected mine site*

Figure 23: Low-carbon technology interventions for minimizing nickel GHG emissions

3.4. ESG considerations associated with low-carbon technologies

Deploying low-carbon technology interventions could have unintended negative environmental and social impacts (e.g., autonomation could lead to job losses for low-skilled workers). They could, however, also have additional co-benefits that support sustainable environmental or social outcomes elsewhere (e.g., installing floating solar PV on water storage dams could reduce evaporation and improve water-use efficiency). To avoid potential negative impacts and capitalize on co-benefits, the Roadmap identified key environmental and social considerations for the deployment of low-carbon technology interventions. It also acknowledged key governance requirements for mitigating risks and enhancing co-benefits. The following section discusses these key ESG considerations associated with low-carbon technology interventions.

Box 5: The ESG assessment methodology

Potential ESG risks, trade-offs and co-benefits associated with the deployment of low-carbon technology interventions were identified via a high-level, top-down assessment and extensive literature review before being validated by technical experts. A baseline ESG risk assessment of copper and nickel mining value chains was also conducted to identify the significance of potential risks, trade-offs or co-benefits associated with different low-carbon technologies. *Please refer to the Appendix: Baseline ESG risk assessment – page 108 – for more information and a summary of the baseline assessment results.*

3.4.1. Governance considerations

Governance is a cross-cutting element at the core of environmental and social risks, making it a critical success factor for net zero mining value chains.[lxix] Research suggests that larger companies, with the resources to develop and enforce good governance mechanisms, generally perform better against various ESG metrics, relative to smaller companies. Companies that do not develop and implement good governance mechanisms perform worse, negatively impacting firm value, investment performance and access to finance.[lxx]

Addressing "generic" company-level governance risks is only one side of the governance coin. Attenuating environmental and social risks via effective governance structures (e.g., governing purpose, accountability of governing bodies, etc.) ensures a "do no harm" or "leave no one behind" outcome – a net-neutral outcome aligned to the requirements of sustainable environmental taxonomies.[lxxi] Significant efforts across copper and nickel mining value chains are still required to address governance risks and ensure do no harm outcomes by mining value chain activities.

However, emerging sustainable social taxonomies[lxxii] require *additional*, net-positive social outcomes (e.g., maximizing co-benefits and opportunities rather than simply avoiding risks). This requires ***"governance for additionality***[19]*"*, together with proactive decision-making by company leadership, to ensure mining value chain actors go one step further, from a "do no harm" and "leave no one behind" approach to one that "uplifts lives and livelihoods". Governance for additionality, therefore, should not only be about avoiding risks but should also aim to provide mining value chains and their stakeholders with *additional* co-benefits and opportunities (both from a healthy environment and inclusive socio-economic perspective). This is critical for positively contributing to SDGs and to an inclusive, just transition to net zero mining value chains and global economy.

[19] The principle of governance for additionality is discussed in more detail in Chapter 4: Enabling a just transition

3.4.2. Environmental and social considerations

Table 4 provides a summary of key environmental and social considerations for deploying low-carbon technology interventions.

In general, low-carbon technologies were found to have positive co-benefits across most environmental criteria in addition to reducing GHG emissions. Energy efficiency (both operational and process optimization interventions) and RE interventions generally mitigate other environmental risks, such as pollution from waste and hazardous materials, energy demand management and water management risks (e.g., solar panels can be installed on water storage dams and canals to reduce evaporation).

Some interventions provide health and safety benefits by reducing pollution or removing people from the dangerous situations. For example, automation avoids health and safety risks (e.g., air pollution, rock falls, shaft collapses etc.) by removing people from high-risk situations. Electrification avoids harmful air pollution associated with the combustion of fossil fuels, particularly in underground mines. Environmental co-benefits can provide indirect social co-benefits to employees and local communities, particularly with regards to health and safety; livelihoods; human rights and security metrics (e.g., reducing air pollution or water consumption, reduces health and safety, and water security risks for employees and local communities).

Interventions that require additional supporting infrastructure are likely to increase certain environmental risks due to increased land-use change. For example, on-site RE infrastructure can cause unsustainable land-use change, with potentially negative implications for ecosystems, biodiversity, and local community relationships. In such circumstances, alternative solutions that provide co-benefits should be explored (e.g., installing solar panels above community crops to provide shade and reduce evapotranspiration, improving the sustainability o and water-use efficiency of those crops. This can support local community livelihoods, food, and water).

Most interventions are likely to create employment trade-offs. Automating haulage vehicles will lower the demand for low-skilled labor, while simultaneously increasing the demand for high-skilled labor to install, operate and maintain digital and automated systems. It is important to monitor current and future skills and job requirements to mitigate employment risks and contribute to a just transition for workers.

Producing, installing, maintaining and/or disposing of low-carbon technology interventions provides opportunities to support local employment, economic development, and gender equality. Mining value chain actors are encouraged to prioritize local procurement of technologies where possible, and local employment (of women and youth) for the installation, operation, maintenance, recycling and/or final disposal of technologies. This contributes positively to broader socio-economic development, economic inclusion and a just transition.

Most of the opportunities for providing *net-positive* and *additional* socio-economic co-benefits are unlikely to materialize simply from the deployment and use of low-carbon interventions alone. Stakeholder dialog and decisive leadership by mining decision-makers is needed to deploy interventions in a way that maximizes their co-benefits. For example, mining value chain actors are encouraged to collaborate with local governments (through public-private partnerships) and deploy enough RE capacity to provide mining value chain activities, workers, and local communities with affordable clean energy. This will enable net-positive outcomes that improve livelihoods, human health, well-being, and resilience for a just transition.

Table 4: Summary of key environmental and social considerations for low-carbon technology interventions[20]

Low-carbon interventions	Environmental Metrics							Social Metrics						
	GHG & air pollution	Water management	Energy demand management	Waste & hazardous materials	Ecosystems & Biodiversity	Climate risk & adaptation	Mine rehabilitation & restoration	Health & Safety	Employment, livelihoods & decent work	Security (food, energy, water)	Human rights	Equality, diversity & inclusivity	Community relationships	Post-closure viability
Energy efficiency: Operational efficiency	↘	↘	↓	↘	↘	↘	→	↘	↔	→	→	→	→	→
Energy efficiency: Process optimization	↘	↘	↓	↘	↘	↘	→	↘	↔	→	→	→	→	→
Automation & digitization	↘	↘	↘	↘	→	→	→	↘	↗	→	→	→	→	→
Renewable energy (solar & wind)	↓	↘*	→	↘	→	↘*	→	↘	↔	↓*	↓*	↓*	↓*	↓*
Energy storage (batteries)	↔	↔	↘	↔	↔	↔	→	↔	↔	↓*	↓*	↓*	↓*	↓*
Fuel switching: Sustainable biofuels	↘*	↔	→	→	→	↔	→	↘	↔	↔	↘*	↘*	↘*	↘*
Fuel switching: Green Hydrogen	↓	↔	↘	↘	↘	→	→	↘	↔	↓*	↓*	↓*	↓*	↓*
Electrification: Trollies, BEVs & conveyors	↓	→	↘	↔	↔	→	→	↔	↔	→	→	→	→	→

Key: Significance of risk / co-benefit		*Change relative to baseline risk assessment*	
	Significantly positive co-benefit	↓	*Significant decrease*
	Moderately positive co-benefit	↘	*Marginal decrease*
	Uncertain due to competing risks & co-benefits	→	*No change*
	Moderately negative risk	↗	*Marginal increase*
	Significantly negative risk	↑	*Significant increase*
	No or uncertain risk / co-benefit	↔	*Trade-off between risk & co-benefit*

* Potential co-benefits assuming appropriate governance decisions are made to ensure additional positive environmental and socio-economic outcomes

[20] The findings summarised in Table 4 were based on an extensive literature review of each of the low-carbon technology and their potential environmental and social risks, trade-offs, and co-benefits. These were also validated by technical experts in the Technical Working Group and Steering Committee.

In general, most companies' GHG emissions and ESG footprint exists within their supply chain[21], both up and downstream (e.g., scope 3 emissions).[lxxiii] Copper and nickel mining value chain actors are, therefore, reminded that additional risks, trade-offs, and co-benefit opportunities exist within each low-carbon intervention's own supply chain – i.e., in their production, transportation and final disposal. Battery storage technologies, in particular, have significant environmental and social risks associated with their production, recycling and disposal,[lxxiv] hence the "uncertain" ranking for most metrics in Table 4. To ensure indirect supply chain emissions and other environmental and social risks and co-benefits are managed effectively, mining value chain actors are encouraged to: (i) collaborate with suppliers and customers for knowledge sharing and awareness raising, and (ii) adapt procurement policies, contractual agreements, and operational procedures to incentivize behavior change across their supply chains (both upstream and downstream).

ESG risks also vary across regions and countries and need to be accounted for when deploying low-carbon technologies.[lxxv] For example, Chile is a water-stressed copper mining region, therefore, water impacts would need to be prioritized. New nickel mining is likely to face high-biodiversity risks, given that most ore deposits are in very rich biodiversity regions (e.g., south Pacific islands). Socio-economic risks are potentially higher in Latin America, particularly in countries with a history of community opposition to mining projects, while governance risks (e.g., security risks and exposure to corruption) are generally higher in central and sub-Saharan Africa. Therefore, given the highly contextual nature ESG risks (across regions and low-carbon technologies) it is recommended that value chain actors conduct bottom-up environmental and social impacts assessment and implement their recommendations accordingly.

Careful planning, informed by stakeholder engagement (e.g., social dialog and inclusive engagement with workers and local communities), is important for avoiding unintended negative environmental and social impacts, while also maximizing co-benefits from the deployment of low-carbon technologies. Adopting international best-practice can support good governance and the identification and management of environmental and social risks and co-benefits. There are several best practice frameworks and standards for supporting responsible and sustainable mining, including the Copper Mark; the International Council Mining and Metals' Mining Principles; the World Bank's Climate Smart and Forest-Smart Mining initiatives; the IFC's Performance Standards and the Equator Principles, amongst others.

---

[21] Mining supply chains are differentiated from mining value chains in that they include all upstream and downstream activities and actors outside of the defined mining value chain (extraction and processing). Supply chains provide inputs into the extraction and processing stages of the mining value chain, as well as purchase copper and nickel to further process into finished goods (e.g., copper wire, solar panel etc.).

3.5. Net zero-aligned carbon offset strategies

Carbon removal offsets are critical for achieving net zero emissions, but they must not be used as a substitution for absolute GHG emissions reductions. While implementing low-carbon technology interventions will minimize absolute GHG emissions, there will inevitably be some degree of unavoidable, hard-to-abate residual emissions[22] (~10% or less of 2020 levels[lxxvi]). To reach net zero emissions by 2050, any residual emissions will need to be "neutralized" using carbon *removal* offsets.[lxxvii] Other carbon offset types that *avoid* or *reduce* emissions can be used in the short- to medium-term (e.g., 2020 to ~2035/40) to support "beyond value chain mitigation" during a company's mitigation journey. This will support urgent global decarbonization and take advantage of sustainable land-use opportunities and various co-benefits that such offset types provide (e.g., ecosystem services, energy access). While "beyond value chain mitigation" investments are considered best-practice, they should not be counted towards a company's emissions reduction targets in the short- to medium-term, pending additional best-practice guidance.

Offsets should be used in line with best-practice to avoid various risks associated with carbon offsets and any net-negative outcomes, such as maladaptation.[23] Carbon offsets face several risks that can lead to net-negative environmental and socio-economic outcomes and contribute to unsustainable land-use and maladaptation[lxxviii] (e.g., reforesting an area of land as part of a carbon offset project, using a single, non-native species, resulting in negative biodiversity and water impacts). Adhering to best-practice and international voluntary carbon offset standards can help ensure carbon offset risks are minimized or avoided, while maximizing opportunities for sustainable land-use and its associated environmental and socio-economic co-benefits.

The following section provides a high-level overview of best practice for utilizing carbon offsets (as per the IPCC; SBTi Net zero Standard and Oxford Principles for Net zero aligned carbon offsetting[lxxix]) and different offset project types, their maturity, market cost and associated risks and co-benefits. The section concludes with a carbon offset strategy framework for achieving net zero copper and nickel mining value chains.

3.5.1. An overview of carbon offsets, their risks, and co-benefits

There are several different categories and types of carbon offsets. Depending on how they address and store GHG emissions, and how they should be used during a company's mitigation journey to achieve net zero emissions, carbon offsets can be divided into two broad categories:

1. **Those that *avoid* or *reduce* emissions** (with and without emissions storage) outside a company's own mitigation efforts or value chain (e.g., renewable energy, energy efficiency or fuel switching offset projects). These offset types are best suited for *"beyond value chain mitigation"*[lxxx] to support urgent climate change action more broadly across the global economy, during a company's mitigation journey. These should be used in addition to, rather than instead of, GHG emissions reduction interventions within a company's value chain (i.e., value chain actors should prioritize the reduction of Scope 1, 2 and 3 emissions over the short- (2022-2030) to medium-term (2030—2040) *and* can simultaneously support beyond value chain mitigation

---

[22] Hard-to-abate residual emissions are those that cannot be mitigated due to technology or economic limitations.
[23] Maladaptation is defined as action taken to avoid or reduce climate vulnerability that perversely impacts on other systems, sectors or social groups, thereby increasing climate vulnerability. For example, reforesting an area as part of a carbon offset project, using a single, non-native species (referred to monocultures), resulting in negative biodiversity and water impacts, and land grabs from local communities.

using avoidance and/or reduction offset types). Companies should monitor and report annually on the nature and scale of their "beyond value chain" investments pending further best-practice guidance[lxxxi].

2. **Those that *remove* or *sequestrate* emissions** from the atmosphere with both short- and long-term storage (e.g., afforestation; direct air capture and storage, and mineralization technologies). While these offset types can also be used for "beyond value chain mitigation", they are best suited for use as *"neutralization or carbon removal offsets"* to neutralize any remaining residual or hard-to-abate emissions and achieve net zero emissions in the long-term (by 2050).

Box 6: What are carbon offsets and carbon offset credits?[lxxxii]

The terms *carbon offset* and *carbon offset credit* are generally used interchangeably, though they can mean slightly different things. A carbon offset broadly refers to a *reduction, avoidance, or removal* of GHG emissions, that is used to compensate for emissions that occur elsewhere. A *carbon offset credit* is a transferrable instrument certified by governments or independent certification bodies to represent an emission reduction, avoidance, or removal of one metric tonne of CO_2 equivalent GHG emissions. The purchaser or developer of an offset credit can "retire" it to claim the underlying reduction, avoidance, or removal towards their own GHG reduction goals. However, there are nuances with regards to "beyond value chain mitigation" offsets and carbon removal offsets for reaching net zero emissions in the long-run (~2045 – 2050).

Carbon offsets also provide opportunities for sustainable land-use during the lifecycle of a mine and across the rest of the mining value chain. For example, solar PV (as a renewable energy offset project) built over low-light crops provide clean energy, reduce evapotranspiration, and improve water-use efficiency, support sustainable and climate smart agriculture practices. Climate smart agriculture is also a potential carbon offset opportunity. Other carbon offsets that enable sustainable land-use include: (i) biofuel feedstock crops and bioenergy with carbon capture and storage (BECCS); (ii) afforestation and REDD+ projects; (iii) soil carbon enrichment and agri-forestry projects; (iv) mangrove and coral reef rehabilitation projects; and (v) tailings mineralization and enhanced weathering projects.

Nature-based solutions vs engineered solutions

Offset projects can be further classified into either nature-based solutions (NBSs) or engineered solutions, each with their own cost, maturity, and governance trade-offs.

Nature-based solutions: NBSs are generally more mature offset opportunities (e.g., REDD+ reforestation, ecosystem rehabilitation, soil carbon enrichment projects) but have a higher governance burden (e.g., on-going environmental stewardship) to ensure their permeance and avoid any negative environmental and socio-economic risks, such as maladaptation[lxxxiii].

Engineered solutions: These range in their technology readiness levels (TRL), maturity and cost. Those that *avoid* emissions (e.g., renewable energy, energy efficiency projects) are generally mature and cost-effective. Technologies that *remove* emissions with short- or long-lived storage – referred to as **Negative Emissions Technologies (NETs)** – are less mature and relatively more costly (e.g., end-of-pipe or post-combustion carbon capture and storage (CCS) and direct air capture and carbon storage (DACCS)). The key advantage of NETs is that they can (generally) sequester more emissions per land area, and store GHG emissions for a lot longer, and at lower risk of reversal, than NBSs, (except for carbon mineralization and enhanced weathering).[lxxxiv] While NETs generally have a lower governance burden, they require investments into research and development (R&D) in the short- to medium-term to ensure their long-term viability and success[lxxxv].

Carbon offset risks

Carbon offset – either NBSs or other engineered solutions – face a variety of risks at a project level and to companies using them as a GHG mitigation tool. These risks include:

1. **Greenwashing risk:** Carbon offsets have been used as a greenwashing tool by business and industry to continue emitting GHG emissions and avoid material emissions reductions (e.g., fossil fuel companies committing to a net zero target, overusing offsets to meet the target, and yet continue to explore for new fossil fuel reserves). This not only threatens business reputation but can lead to continued contributions to climate change and failure to meet the Paris Agreement temperature target[lxxxvi].
2. **Over-reliance risk:** Companies can become over-reliant on offsets to compensate for GHG emissions, without undertaking absolute emissions reductions. This can lead to additional risks, including the lock-in of carbon-intensive/fossil fuel infrastructure (and associated value chain environmental and socio-economic risks), grandfathering of emissions, limited action against climate change and overshooting the 1.5°C temperature target.
3. **Offset quality risks:** Quality risks refer to the failure of the offset project to adhere to minimum offset requirements and best-practice principles, leading to poor quality and low credibility of offsets. These include additionality, permanence/emissions reversal, double counting, and carbon leakage[lxxxvii].
4. **Implementation and eligibility risk:** Inadequate capacity and capabilities of project developers can lead to poor governance and mismanagement of offset projects, threatening their effective implementation and causing additional environmental and socio-economic risks to local communities. Different offset project types can also face eligibility limitations under different voluntary standards (e.g., The Gold Standard has limitations on grid-based renewable energy offset projects in developing countries with 5% or more penetration of grid-based renewable energy)[lxxxviii].
5. **Validation risk:** Implementation and eligibility risks can lead to validation risks where offset projects are not accepted or validated by relevant carbon offset standards. It also refers to potential time delays during validation processes with standards bodies that can last for months, and sometimes years.
6. **Market risk:** Access to carbon offset markets is not guaranteed, both in terms of selling and purchasing the desired quality and type of offset credits, at an affordable price. Market risk is expected to grow significantly as demand for offset credits is likely to outpace the supply of credible offset credits. This is expected to increase the cost of credits from US$1/t$CO_2$e to as much as US$120/tCO_2e[lxxxix].
7. **ESG risks:** Failure of offset project developers to conduct comprehensive due diligence to prevent potential negative environmental and socio-economic impacts across the offset project lifecycle. Offsets also face the challenge of providing and balancing both carbon sequestration and tangible sustainable development/socio-economic co-benefits[xc]. Poor governance can lead to negative impacts on ecosystem functioning, biodiversity, water and food security, human rights, and livelihoods. (e.g., inappropriate tree planting and monocropping on natural grassland can add more GHG emissions to the atmosphere then they sequester and reduce biodiversity and water availability of the region, leading to maladaptation).
8. **Pricing risks:** Offset pricing complexities can present challenges around local community and offset developer remuneration, and the potential for skewed value (and benefit) from offset

projects in developing countries. Therefore, socio-economic development imperatives, and principles of equity, must be prioritized when developing or purchasing carbon offsets in developing countries.

9. **Reputation risk:** All these risks can lead to reputational damages to companies if announced plans do not play out, or if ESG risks are realized. This can materialize for either an individual offset project or an entire offset portfolio.

Carbon offset co-benefits

Carbon offsets can provide opportunities for sustainable land-use, with additional environmental and socio-economic co-benefits beyond their GHG emissions benefits:

1. **Environmental co-benefits:** NBSs can provide environmental co-benefits by supporting biodiversity, improving soil and water quality, and strengthening the provisioning of ecosystem services – a key advantage over NETs. These co-benefits can enhance the Planet's resilience to anthropogenic shocks and offset some of the land-use change impacts associated with mining value chains. NETs, however, do not necessarily provide the same degree of environmental co-benefits beyond those related to GHG emissions.

2. **Socio-economic co-benefits:** NBSs can provide direct socio-economic co-benefits by providing income to communities for social upliftment (e.g., forestry-based carbon offset projects in Madagascar generated enough carbon revenues for local communities to build three new schools).[xci] They can also provide indirect socio-economic benefits by restoring natural ecosystems upon which local livelihoods depend; contributing to climate change adaptation and resilience; promoting gender equality, human rights and inclusive economies. Engineered solutions can provide co-benefits related to energy efficiency, improved access to clean energy, better air quality and human health.

Carbon offset sourcing models

Carbon offsets, or carbon offset credits, can be sourced in different ways, either by purchasing credits from the market, or self-developing offset credits for own use. Self-developing carbon offset or carbon inset projects could offer the most benefit to copper and nickel mining value chain actors. Value chain actors can source carbon offsets via four broad sourcing models, including:

1. **Self-develop inset/offset projects:** Develop, validate, and register own inset/offset projects, for own use in achieving net zero emissions targets. Any excess credits could then be sold to value chain partners, other sectors or to carbon markets.

2. **Contract for delivery with offset project developers:** Establish long-term contracts with credible offset project developers to secure and access carbon credits from a range of different projects.

3. **Contract for delivery with offset market retailers:** Purchase small amounts of offset credits quickly from contracted retailers, who would source and retire offset credits from a diverse range of offset projects.

4. **Purchase from an exchange or spot-market:** Purchase offset credits from offset exchanges or spot markets, sourced from a wide variety of offset projects.

Box 7: Carbon offsets vs carbon insets[xcii]

The difference between carbon offsets and carbon insets is broadly based on where the projects take place. Insetting generally refers to projects that occur within a company's value chain or sphere of influence and are generally self-developed for own use. Offsetting broadly refers to projects outside a company's value chain or sphere of influence and can include self-developed projects or credits purchased off the market.

Each sourcing model has its own advantages and disadvantages and exposes value chain actors to different risks (Table 5). Value chain actors will need to evaluate each sourcing model and decide which of them is best suited to meet their offset requirements and risk exposure. It is recommended that value chain actors look to prioritize self-developing their own inset/offset projects to meet their projected offset demand - given the greater ability to influence the quality of, and co-benefits from such projects. Purchasing offset credits from retailers, exchanges, or spot-markets, should ideally only be done for neutralizing unexpected fluctuations in residual emissions as they occur.

Table 5: Advantages and disadvantages of different offset sourcing models[xciii]

	Self-develop inset/offset projects for own use	Contracting with offset project developers	Contracting from offset market retailers	Purchasing from offset exchange/spot market
Ability to influence or evaluate offset quality	High potential	Medium potential	Medium – low potential	Low potential
Ability to influence co-benefits	High potential	Medium potential	Medium potential	Low potential
Cost of offset credits	Low	Low	High	High
Security of offset credit supply	High / secure	Moderate / secure	Low / insecure	Low / insecure
Transaction costs & administrative burden (time, resources, expertise)	High	High	Low	low
Lead time before offset credits become available	3 – 5 years	3 – 5 years	Immediate	Immediate
Purchase agreement timeframe	Long-term	Long-term	Short-term	Short-term

Mining value chain actors are encouraged to integrate carbon offset/inset planning into mine development and financial planning processes. The development phase of a typical mine lifecycle (planning and developing the mine) can take between 4 and 12 years[xciv], a relatively similar time scale for self-developing inset/offset projects. It is, therefore, recommended that offset/inset planning be including in the development phase of the mine lifecycle. Including environmental and social impact assessments of the projects themselves, and within treasury and finance planning for existing and new mine developments. This will ensure offset credits and finance for project development are secured for neutralizing emissions when operations begin.

3.5.2. Best practice recommendations for using net zero-aligned carbon offsets

Mining value chain actors are encouraged to adopt the following best-practice recommendations for net zero-aligned carbon offsetting strategies. Companies should also note that best-practice is always evolving, and they will need to constantly review and align their GHG mitigation and carbon offset strategies accordingly (e.g., the SBTi is expected to provide best practice guidance for "beyond value chain mitigation" offsets later in 2022 or in earl 2023).

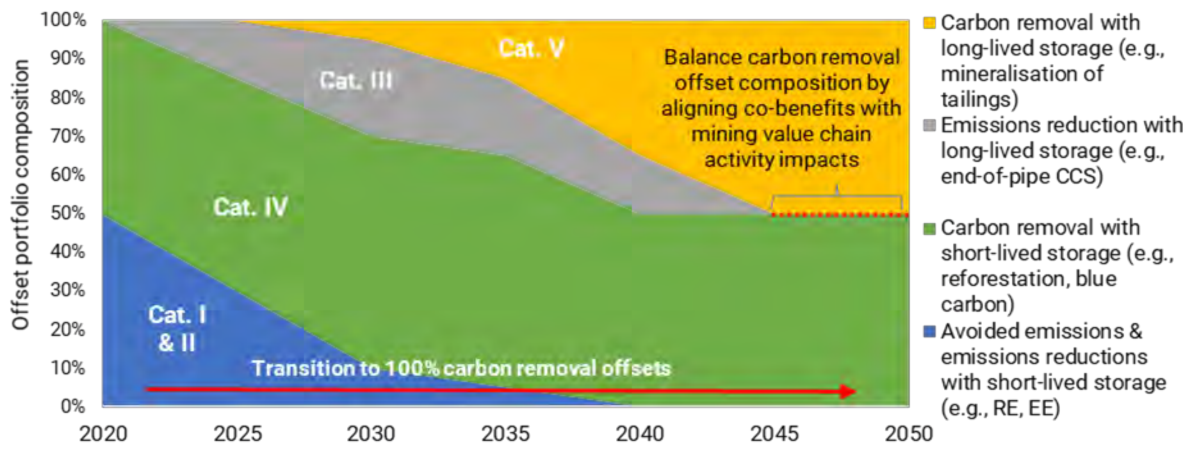
Adhere to the mitigation hierarchy and prioritize absolute emissions reductions before using carbon removal offsets to "neutralize" any residual emissions. During their mitigation journey (between 2022 and ~2035/40), mining value chain actors are encouraged to invest in "beyond value chain mitigation" offset opportunities outside of their value chain to support urgent global decarbonization. This should be done in addition to, not instead of, absolute emissions reductions. This is to avoid becoming over-reliant on carbon offsets and exposing companies to market and pricing risks, while also ensuring absolute emissions reductions are aligned to a 1.5°C trajectory. The nature and scope of these investments should be recorded annually pending further best practice guidance. According to the SBTi "beyond value chain mitigation" offsets are voluntary but considered best practice.[xcv]

Develop a coherent, company-wide carbon offset strategy with decentralized offset plans that align to climate change mitigation, adaptation, carbon offset, spatial planning, and economic developmental policies in host countries. Developing a company-wide carbon offset strategy will provide high-level direction and key principles for governing the use of carbon offsets. Decentralized carbon offset plans, at a country/regional level, will allow for flexibility in prioritizing different carbon offset project types, based on the alignment between their sustainable land-use co-benefits and climate change and development policies in host countries. This will help ensure that value chain actors are directly contributing to host country policy agendas, a just transition and addressing environmental and socio-economic impacts beyond GHG emissions, all while strengthening their reputation, stakeholder relationships and securing their social license to operate.

Transition carbon offset portfolio composition to 100% carbon removal offsets by 2050. To ultimately achieve net zero emissions, value chain actors will require offsets that remove/sequester residual, hard-to-abate emissions. It is, therefore, recommended that copper and nickel value chain actors transition their offset portfolios from a mix of avoided and reduced emissions offset types (i.e., beyond value chain mitigation offsets) in the short- to medium-term (~2020 – 2030/40), to 100% removal offsets from ~2045 onwards (Figure 24). This will align offset portfolios with the recommendations of the IPCC, SBTi Net zero Standard and Oxford Principles for Net zero aligned offsets and achieve Net zero emissions by 2050.

Align offset co-benefits with negative environmental and social impacts form mining activities to balance a company's carbon offset portfolio composition of short- and long-lived carbon removal offsets (green and yellow in Figure 24). The IPCC and SBTi advocate for the prioritization of NBSs with short-lived storage offset types (e.g., reforestation, blue carbon stocks etc.) due to their various environmental and socio-economic co-benefits[xcvi]. However, these offset types generally face permanency risks and require ongoing environmental stewardship. The Oxford Principles, on the other hand, advocate for the prioritization of long-lived storage offset types, due to their permanency benefits[xcvii]. However, these generally do not offer the same degree of co-benefits.

To balance these trade-offs, it is recommended that value chain actors create risk-weighted criteria to inform decision-making and align offset co-benefits with negative environmental and socio-economic impacts from mining value chain activities in host countries (as identified in environmental and socio-economic impact assessments). This approach will support a “do no harm” principle and help to achieve net-positive environmental and socio-economic outcomes across different mining locations (e.g., offsets with high biodiversity and ecosystem service co-benefits should be prioritized in regions where mining has significant biodiversity impacts. Conversely, where mining has little biodiversity impacts, value chain actors could prioritize long-lived storage offset types in those regions).



Category I	Category II	Category III	Category IV	Category V
Avoided or reduced emissions **without storage**	Emissions **reductions** with **short-lived storage**	Emissions **reduction** with **long-lived storage**	Emissions **removal** with **short-lived storage**	Emissions **removal** with **long-lived storage**
~US$15/$tCO_2e$	**~US$15/$tCO_2e$**	**~US$60/ tCO_2e**	**~US$66/$tCO_2e$**	**~US$372/$tCO_2e$**
• Renewable energy and energy efficiency projects • Fuel switching projects • Gas recovery or destruction projects • Energy crops	• Conservation-based projects (e.g., REDD+) • Sustainable agriculture projects (e.g., climate smart agriculture) • Agri-forestry projects	• “End-of-pipe” Carbon Capture and Storage (CCS) on industrial facilities or power plants	• Ecosystem rehabilitation projects (e.g., afforestation,) • Soil carbon enrichment projects • Blue carbon projects • Biochar projects	• Direct Air Carbon Capture and Storage (DACCS) • Bioenergy with Carbon Capture and Storage (BECCS) • Mineralisation & enhanced weathering

Average prices based on Carbon Trust Analysis.

Figure 24: Net zero-aligned carbon offset portfolio composition[xcviii]

Only use certified carbon offsets that meet minimum credibility requirements should be used to achieve net zero emissions. There are various international voluntary carbon offset standards (e.g., Gold Standard; Verified Carbon Standard – Verra; Voluntary Offset Standard; Climate, Community and Biodiversity Standards; the International Carbon Reduction & Offset Alliance (ICROA) and the Oxford Principles for Net-Zero aligned carbon offsets, amongst others), each with their own specific requirements for credible offsets. Increasingly more companies are conducting their own or obtaining third-party due diligence on their carbon offset developments/purchases. However, all offset projects should, as a minimum requirement, adhere to best-practice principles (which themselves can become risks to offset projects)[xcix]

Box 8: Minimum requirements for credible carbon offsets

Additionality: Offset projects are additional if they *would not* have occurred in the *absence* of a market for offset credits. If the project would have happened, regardless of the opportunity to sell offset credit (e.g., installing renewable energy to mitigate fossil fuel-based emissions), then it is not addition and claiming neutralization from such projects would only add to climate change.

Quantification and leakage: Avoid overestimation of GHG emissions avoided or removed by ensure accurate measurements of: (i) baseline emissions; (ii) actual emissions avoided or reduced and (iii) any emissions-leakage from the offset project.

Permanence: Ensure the longevity of the project and minimize the risk of reversal (re-releasing offset emissions). GHG emissions can exist in the atmosphere for hundreds of years. To compensate for this, offsets must achieve similar avoidance or removal of emissions that are similarly permanent (e.g., renewable energy projects that avoid fossil fuel usage or carbon sinks with long-lived storage of emissions.

Exclusive claim to GHG reductions: Prevent double counting of offset credits (i.e., emissions avoided or removed by an offset project) by multiple stakeholders.

Avoid environmental and social harm: Adhere to a "do-no-harm" principle and strive for "net-positive" environmental and socio-economic outcomes. The offset project should not exacerbate other environmental or socio-economic risks (e.g., biodiversity loss or negatively impact on livelihoods) in trying to avoid or remove GHG emissions.

Use end-of-pipe carbon capture and storage (CCS) technologies (Category III in Figure 24) as "transitionary inset intervention" in the short- to medium-term only. Value chain actors are cautioned not to become over-reliant on end-of-pipe CCS technology as a GHG emissions mitigation intervention. Since end-of-pipe CCS does not remove GHG emissions from the atmosphere but, at best, only prevents some emissions entering the atmosphere, it carries significant risks associated with: (i) the lock-in of carbon-intensive infrastructure and grandfathering of emissions (e.g., fossil fuel value chains and associated environmental and socio-economic risks); (ii) stranded offset assets; (iii) risk of emissions leakage and continued release of GHG emissions, failure to reach net zero emissions and overshoot of the 1.5°C target, and (iv) greenwashing.[c] There is also a risk that offset standards will disqualify these as credible offset opportunities in the medium- to long-term (e.g., additionality and eligibility risks), as has been the case with some grid-based renewable energy projects[24]. However, the value of such technology for supporting the mitigation journey is recognized and, therefore, end-of-pipe CCS technology should be used only as a transitionary instrument while cleaner energy options are deployed at scale.

Invest in R&D for carbon removal with long-lived storage offset opportunities (Category V in Figure 24) in the short-term (2022 – 2030) for future long-term success. particularly carbon mineralization and enhanced weathering. The mining sector is significantly well positioned to self-develop carbon mineralization and enhanced weathering inset opportunities, particularly using mine waste and tailings from nickel mines. Mineralization and enhanced weather can reverse land degradation by neutralizing acid soils, which in turn has benefits for biodiversity and food security[ci]. Further, these offset opportunities can not only meet miners' own offset requirements but can potentially be used as a new, innovative business model for supplying credible carbon offset credits to other mining value chain actors and sectors. This could have the added benefit of potentially providing a new revenue stream to support tailings management, mine rehabilitation and post-closure socio-economic plans. These

---

[24] For example, the Gold Standard has limitations on grid-based renewable energy offset projects in developing countries with 5% or more penetration of grid-based renewable energy

interventions can offset land-use change emissions and biodiversity impacts and contribute to a just transition.

Table 6 brings all these carbon offsetting considerations together by providing:

1. **A high-level evaluation of selected offset project types**, including their TRL/maturity; average market price; implementation and quality risks; environmental and socio-economic co-benefits, and environmental and socio-economic risks.
2. **Best practice recommendations** on the most appropriate time frames, use and sourcing model for each offset category.

These recommendations should be implemented within the ambit of a comprehensive and credible carbon offset strategy.

Table 6: Carbon offset opportunities, risks, and recommendations[cii]

	Offset project	Offset type	TRL / maturity	Average offset credit cost	Implementation & quality risk	E&S Co-benefits	E&S Risks	Recommendations: Implementation strategy & portfolio composition
Cat. I	Renewable energy	NET	7-9	Low	High	Moderate	Moderate	• Purchase offset credits in the short-term (2022-2035/40) to support mitigation beyond the mining value chain during the mitigation journey. • Potentially self-develop inset projects within mining communities to take advantage of clean energy access & human health co-benefits (with potential indirect contributions to post-closure livelihood plans and a just transition). • Phase out the use of these offsets from ~2035/40, in favor of Cats. IV & V offsets, as they may no longer hold additionality or increasingly face eligibility risks.
Cat. I	Energy Efficiency	NET	7-9	Low	High	Low	Low	
Cat. I	Fuel Switching	NET	7-9	Low	High	Moderate	High	
Cat. I	Gas recovery/destruction	NET	7-9	Low	Moderate	Moderate	Moderate	
Cat. I	Energy crops	NBS	7-9	Low	Moderate	Moderate	High	
Cat. II	Avoided damage to ecosystems (incl. REDD+)	NBS	7-9	Low	High	High	High	• Take advantage of biodiversity & ecosystem service co-benefits to offset land-use change emissions and biodiversity impacts simultaneously (with potential indirect socio-economic & just transition benefits). • Contract with developers or purchase credits from retailers or spot markets in the short- to medium-term. • Some potential for insetting projects, particularly in and around mine sites in high-biodiversity regions. • Phase out & substitute for Cats. IV & V offsets projects from ~2035
Cat. II	Sustainable agriculture practices (e.g., climate smart agriculture)	NBS	7-9	Low	High	High	Moderate	
Cat. II	Agri-forestry	NBS	7-9	Low	High	High	High	
Cat. III	End-of-pipe CCS on industrial facilities	NET	4-6	Medium	Moderate	Low	High	• Self-develop in the short- to medium-term and utilize as a “transitionary inset intervention” to offset emissions from operations during mitigation journey. • Start phasing out as operations transition to cleaner energy sources. • Substitute for Cat. IV & V projects from ~2040/45
Cat. IV	Afforestation/ reforestation & ecosystem rehabilitation	NBS	7-9	Medium	High	High	High	• Take advantage of E&S co-benefits to offset land-use change emissions & biodiversity impacts simultaneously, particularly in high-biodiversity regions. • Self-develop inset projects or contract with development partners. Only purchase credits as a last resort to overcome any shortfalls from self-developed/contracted projects. • Despite permanence risks, these offset projects should make up the bulk of an offset portfolio between ~2030 & 2050, given their co-benefit potential. • Invest resources into environmental stewardship and good governance of these projects.
Cat. IV	Blue carbon stocks	NBS	4-6	Medium	High	High	High	
Cat. IV	Biochar production	NBS	4-6	Medium	Moderate	Moderate	Moderate	
Cat. V	Direct Air Carbon Capture (DACCs)	NET	4-6	High	Moderate	Low	Moderate	• Invest in R&D and begin piloting these offset technologies in the short-term (~2022 – 2030) for long-term success. • Begin prioritizing these offset projects from ~2035/40 to make up the bulk of an offset portfolio by 2050, given their sequestration and permanence potential. • Self-develop for own use as part of mine rehabilitation & post-closure plans. Potentially sell any excess credits as an alternative revenue stream to finance mine rehabilitation & post-closure plans.
Cat. V	Bioenergy with Carbon Capture & Storage (BECCs)	NET	4-6	High	Moderate	Moderate	High	
Cat. V	Carbon mineralization & enhanced weathering	NBS	1-3	High	Moderate	Moderate	Moderate	

Key

Technology Readiness Level (TRL)	*Average offset credit cost*	*Implementation and quality risk*	*Environmental & Social (E&S) co-benefits*	*Environmental & Social (E&S) risks*
7-9	*Low: ~$1-25/tCO_2e*	*Low: 1-2 potential risks, with low probability*	*High: >4 potential co-benefits*	*Low: 1-2 potential risks*
4-6	*Medium: ~$25-100/tCO_2e*	*Moderate: 3-4 potential risks with moderate probability*	*Moderate: 3-4 potential co-benefits*	*Moderate: 3-4 potential risks*
1-3	*High: >$100/tCO_2e*	*High: >4 potential risks with high probability*	*Low: 1-2 potential co-benefits*	*High: >4 potential risks*

Net zero-aligned carbon offset strategy framework

To support the credible use of net zero-aligned carbon offsets, Table 7 provides a carbon offset strategy framework that copper and nickel mining value chain actors can use to guide the development of their own offset strategies.

Table 7: Net zero-aligned carbon offset strategy framework

A carbon offset strategy should be aligned with the mitigation hierarchy, only using credible offsets to neutralize residual emissions and not as a substitute for absolute emissions reductions	
1. Determine strategic objectives for company-wide offset strategy, with decentralized offset plans	• Define strategic outcomes and objectives for the carbon offset strategy and communicate these both internally and externally. Align these to best-practice and corporate sustainability goals. Build a Theory of Change to help identify the types of carbon offset projects that contribute to the achievement of the defined strategic outcomes and objectives. • Defining strategic offset objectives facilitates a more coherent and credible offset portfolio & helps streamline implementation processes & communication. • Develop explicit offset principles and criteria that clearly define offset project priorities (e.g., co-benefit maximization; long-term storage; sequestration potential). • Develop decentralized carbon offset plans for different operating regions/host countries. These should align with the overall strategic outcomes & objectives, while also considering host countries' climate change and economic developmental policy goals. • Determine preferred offset sourcing model based on their relative advantages and risk exposures and how they align to the strategic objectives.
2. Identify and map carbon offset opportunities and standards requirements	• Develop carbon offset project prioritization criteria, with both negative filtering criteria to ensure they meet minimum strategic requirements (e.g., a disqualification process for those that do not meet strategic objectives, decentralized plans, or voluntary offset standard requirements), and a maximization framework to understand which short-listed projects maximize overall quality and impact (co-benefits). • Investigate and shortlist opportunities for self-developed insetting & offsetting projects that align to the strategic objectives, decentralized plans, and prioritization criteria. Note their locations, risks, co-benefits, and potential alignment to environmental and socio-economic impacts caused by mining value chain activities. (e.g., transition offset portfolio composition to 100% carbon removal offsets by ~2045 and balance potential co-benefits to value chain environmental and socio-economic impacts). • Identify and engage with potential offset development partners; retailers; exchanges and spot-markets. Investigate the availability (market supply) of offset credits that align to the strategic objective and offset focus areas as a stop-gap for any unforeseen increases in residual emissions). • Invest in R&D in the short-term for immature carbon removal offset opportunities for long-term success (e.g., mineralization and enhanced weathering).
3. Establish risk mitigation measures	• Establish mechanisms to review and identify offset project exposure to various offset risks (e.g., additionality, permanence, implementation, eligibility, validation risks etc.). • Implement due diligence and risk management measures throughout all phases of an offset project to identify, assess and mitigate potential environmental and socio-economic risks associated with the offset project.
4. Ensure highest quality offsets are developed or purchased	• prioritize the highest quality (not lowest cost) offset projects, from the short-listed opportunities, to be developed or purchased. Employ the most robust standards, vet offset projects, and avoid cheap credits (price can be an indicator of quality).

3.6. The Net zero Roadmap

3.6.1. Internal enabling interventions

To support and facilitate the transition towards net zero emissions, value chain actors are encouraged to implement various internal enabling interventions:

Governance structures:

- Ensure Executive oversight & accountability for implementing a just transition to Net zero emissions & improved ESG performance
- Adopt principle of governance for additionality & strive for net-positive outcomes
- Adapt procurement policies to prioritize low-carbon goods & services, sourced from local producers; develop & implement risk mitigation mechanisms; stakeholder engagement strategies etc.

Develop a net zero company-wide strategy with medium- & long-term milestones and targets:

- Set company-wide Scope 1, 2 and 3 targets for 2030; 2040 & 2050
- Set asset-level Scope 1 & 2 targets as appropriate
- Develop a company-wide carbon offset strategy, with decentralized offset plans

Establish internal carbon management function:

- Internal carbon management functions would be responsible for oversight of mitigation strategies, and working with departmental champions & external stakeholders
- Implement scope 1, 2 & 3 emissions strategies, including emissions reduction interventions and carbon offsets

Establish an internal carbon price:

- Internal carbon prices can help inform procurement policies & encourages more sustainable decision-making
- Companies are encouraged to aim for a 1.5°C-aligned internal carbon price of ~US$210/t$CO_2$e by 2030 and ~US$315/tCO_2e by 2050[ciii] (reported in 2022 prices[25])

Future proof net zero strategies:

- Continually identify & invest in RD&D for emerging & alternative technologies for emissions reductions & carbon removals; good ESG performance & a just transition

3.6.2. Low-carbon technology and carbon offset deployment Roadmap

The Net zero Roadmap for Copper and Nickel brings all the mitigation elements discussed throughout the chapter into one succinct action plan for transitioning to net zero emissions by 2050 (Table 8). The Roadmap includes recommendations for:

1. Absolute GHG emissions reduction targets over time
2. Low-carbon technology deployment and RD&D for avoiding and minimizing absolute GHG emissions
3. Supporting beyond value chain mitigation in the short- to medium-term
4. Balancing the net zero equation by neutralizing any residual, hard-to-abate emissions using credible carbon removal offsets

---

[25] Carbon prices required for a 1.5°C temperature target were identified from the literature and converted into 2022 prices using an average US$ inflation rate of 2.17% p.a.

Table 8: 2050 Net zero Roadmap for Copper and Nickel

Roadmap elements	Now (2020 baseline)	Short-term (2023 – 2030)	Medium-term (2030 – 2040)	Long-term (2040 – 2050)
Absolute emissions reduction targets	• ~85 $MtCO_2e/y$ of Cu • ~88 $MtCO_2e/y$ for Ni (depending on the process route)	**35 – 50% reduction** • Cu: ~55 - 43 $MtCO_2e/y$ • Ni: ~57 - 44 $MtCO_2e/y$	**70 – 80% reduction** • Cu: ~26 - 17 $MtCO_2e/y$ • Ni: ~26 - 18 $MtCO_2e/y$	**>90% reduction** • Cu: ~8.5 $MtCO_2e/y$ = offset demand • Ni: ~8.8 $MtCO_2e/y$ = offset demand
Avoid and reduce GHG emissions (Low-carbon technology deployment)	• Conduct whole-of-site (mine, processing, and transport) optimization to determine energy saving opportunities • Evaluate opportunities for commercially available process optimization technologies • Develop renewable energy (RE) deployment (e.g., solar, wind) and low-carbon haulage strategy • Conduct environmental & social impact assessments for the on-site deployment of low-carbon technologies	• Continually improve energy efficiency • Begin execution of RE and low-carbon haulage interventions • Begin piloting of green hydrogen and battery electric vehicles (BEV) • Investigate circular economy (CE) opportunities across operations • Invest in RD&D for medium- and long-term technologies • Continually evaluate and optimize transport and logistics	• Continually improve energy efficiency • Execute 100% RE deployment • Deploy full-scale low-carbon haulage strategy • Pilot automation for processes and systems that rely on software controls • Pilot process heat and alternative reductants in pyrometallurgical processing • Scale up CE opportunities across mining value chain operations	• Continually improve energy efficiency • Complete deployment and scaling up of process heat and alternative reductants • Explore the implementation of new technologies (e.g., in-situ leaching) and their associated ESG impacts • Explore unconventional mineral extraction/processing from new reserves, tailings, and sources • Scale up automation for processes or systems that rely on software controls • Support industrial-scale CE programs
Remove residual emissions (Carbon offsets and sustainable land-use)	• Develop a coherent, company-wide carbon offset strategy with decentralized offset plans • Invest in RD&D for carbon removal offset technologies	• Support "beyond value chain mitigation" by investing in credible carbon offset projects that are outside a company's value chain • Utilize end-of-pipe Carbon Capture and Storage (CCS) technologies as "transitionary offsets" • Invest in RD&D for carbon removal offset technologies	• Support "beyond value chain mitigation" • Phase out end-of-pipe CCS technologies and "transition offsets" • Pilot carbon removal offset technologies for own mitigation	• Transition offset portfolio to 100% carbon removal offsets • Neutralize residual, hard-to-abate emissions using credible carbon removal offsets to reach Net zero emissions by 2050

4. DELIVERING A JUST TRANSITION

The GET will significantly increase demand for energy transition metals (ETMs), which if left unmanaged, could exacerbate existing environmental and social risks. Copper and nickel are two key ETMs necessary for making the renewable energy and low-carbon technologies needed to help mitigate climate change. Their value chains provide multiple socio-economic benefits such as, employment and livelihood opportunities, infrastructure development, and a strong contribution to host country GDP. Copper and nickel mining value chains also pose environmental, social and governance (ESG) risks (e.g., GHG emissions, pollution, biodiversity loss, human rights violations). If unmanaged, ESG risks could be exacerbated by significant increases in the demand for and supply of copper and nickel.

The net zero mining transition is expected to create multiple environmental and socio-economic benefits but also presents risks to mining stakeholders. Without sufficient safeguards in place, the costs and benefits of the transition may not be distributed evenly between regions, sectors, and social groups. The transition may exacerbate existing and historical inequalities, such as access to decent livelihoods, a healthy environment, and economic opportunities for *at-risk* stakeholders.

A just transition can ensure that stakeholders are better off because of the increased demand for ETMs and the transition to net zero mining. Ensuring a just transition is a shared responsibility between mining value chain actors, governments, suppliers, workers, labor, civil society, and local communities. Inclusive collaboration between these stakeholders is critical to facilitating a just transition.

The following sections explore different interpretations of a just transition, including differences in *scope, intention, and ambition* across the "just transition spectrum". Just transition threats and opportunities are then reviewed before deep diving into a skills and job gap assessment for future net zero copper and nickel mining value chains. A *Just Transition Toolkit* to support value chain actors' understanding of, and contribution to, a just transition is also provided.

4.1. Understanding a just transition

There are several interpretations of a just transition, from a narrow focus on workers and employment impacts to a broader focus that includes environmental sustainability, human well-being, and regional resilience building. A narrow interpretation of a just transition focuses on employment impacts from climate change and climate change policies, labor market policies, decent work, and minimizing negative impacts on workers. The Paris Agreement notes "*the imperative of a just transition of the workforce and the creation of decent work and quality jobs in accordance with nationally defined development priorities*"[civ].

A broader interpretation of a just transition goes beyond employment impacts[cv] and considers wider environmental sustainability, peoples' livelihoods, human health, well-being, autonomy and resilience. The International Labour Organisation (ILO), states that: "*a just transition for all towards an environmentally sustainable economy needs to contribute to the goals of decent work, social inclusion, and the eradication of poverty. Managed well, transitions to environmentally and socially sustainable economies can become a strong driver of job creation, job upgrading, social justice and poverty eradication. Greening all enterprises and jobs by introducing more energy and resource efficient practices, avoiding pollution, and managing natural resources sustainably leads to innovation, enhances resilience and generates savings which drive new investment and employment*".[cvi] In other words, **a just transition is**

the "connective tissue" between each of the SDGs – between a mine, the environment, the community and a vibrant local economy.[cvii]

Box 9: Critical aspects of a just transition

Livelihoods refers to how people secure access to their basic needs, such as food, water, shelter, and clothing. Livelihoods, therefore, includes aspects related to formal and informal employment; entrepreneurship, and subsistence activities (e.g., a person's job at a mine or processing plant; an entrepreneur who sells food to mine workers; or local subsistence farmers). Each of these are influenced directly and/or indirectly by access to a healthy environment and markets.

Human health and well-being include various aspects related to peoples' basic needs and human rights, such as nutritional diets; physical and mental health; physical security, clothing, and shelter; access to a healthy environment, and access to recreational, spiritual, religious, and cultural activities.

Autonomy refers to people's ability or freedom to make their own decisions, shape their own lives and withstand external shocks and changes. Autonomy includes access to decision-making platforms that have influence over an individual's livelihood, health, and well-being (e.g., the right to free, prior, and informed consent).

Resilience speaks to an individual's or communities' ability to adapt to external shocks, such as climate change; economic recessions; pandemics and mine closures, and maintain or improve their access to livelihoods, health, and well-being (i.e., to maintain their standard of living following a severe flood).

Common foundations of a just transition are:[cviii]

- The transition to net zero emissions should, as a minimum, be managed to avoid negative consequences and provide additional, net-positive co-benefits to marginalized and at-risk stakeholders
- Social dialog and inclusion are integral to the just transition, as are people's health, well-being, and resilience
- Workers and communities - and at a broader level, society at large - are involved in the decision-making processes that affects their lives
- Justice, equality, equity, and fairness are representative of the "just" part of the just transition
- Transparency, accountability, and inclusivity are core to a just transition

A just transition can be understood as a spectrum of strategic options with trade-offs in scope, intention, and ambition[cix] (Figure 25):

- **Scope of a just transition:** Speaks to (i) the number of different stakeholders and (ii) number of different risks or impacts that are considered (e.g., focusing on workers and employment risks only; or including workers, communities, and supply chain actors[26], in addition to employment, gender, human rights, and environmental risks they all face). A broad understanding of a just transition extends beyond directly impacted workers and communities to include all at risk stakeholders that may be affected directly and indirectly.
- **Intention of a just transition:** Sets out the purpose and desired end goal of a just transition that can be achieved through a set of actions. Intention can be considered as a continuum from marginal reform, through structural reform, to system transformation. Marginal reform focuses

[26] Mining supply chain actors are those upstream and downstream of the defined mining value chain (extraction and processing). They provide inputs into the extraction and processing stages of the mining value chain, as well as purchase copper and nickel to further process into finished goods (e.g., copper wire, solar panel etc.).

on achieving change within an existing social and economic system, while structural reform seeks change through inclusive and empowering processes. For example, marginal reform of employment policies would prioritize the employment of more women, while structural reform would completely overhaul employment and operational polices to ensure additional gender inequalities are addressed, such as pay-gaps and women-focused health services. System transformation, on the other hand, achieves change by overhauling existing social and economic systems that are incompatible with sustainable development and social equity, such as transitioning from a capitalist to a socialist economic system.

- **Ambition of a just transition:** Speaks to the desired degree of *just* results. Ambition can be understood as a progression from *procedural justice* (e.g., including and empowering stakeholders), to *distributive justice* (e.g., understanding who is responsible for mitigating risks and who benefits from the transition) to *restorative justice* (e.g., addressing past, present and future impacts on stakeholders).

Figure 25 provides a framework for understanding each of these key elements of the just transition spectrum. It is not conclusive and only serves to illustrate the spectrum of a just transition is wide and can occur at multiple scales.

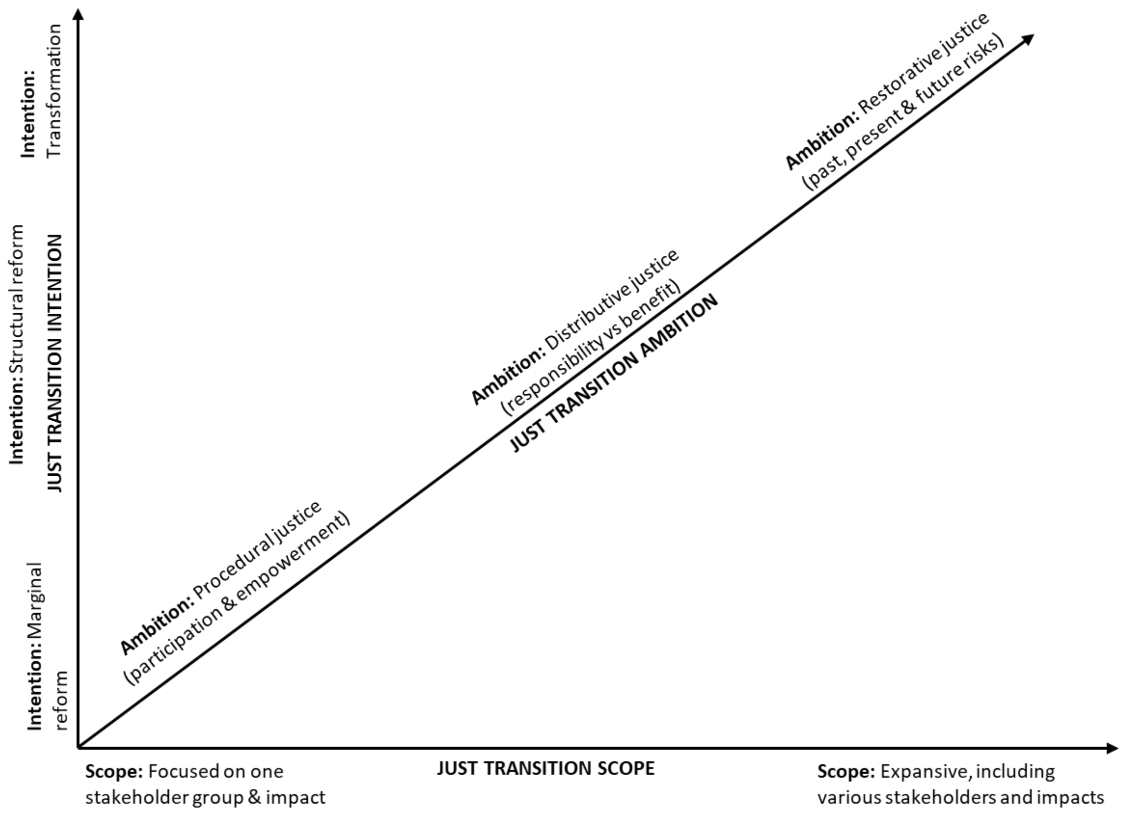


Figure 25: A framework for understanding the spectrum of a just transition[cx]

Box 10: Three degrees of just transition ambition

Just transition ambition can be contextualized using three forms of justice, namely procedural justice, distributive justice, and restorative justice:

Procedural justice focuses on inclusion and facilitating an inclusive decision-making process (e.g., engaging with workers to understand their transition needs & requirements). Procedural justice is often limited to a reform approach, where change is made within existing systems. However, procedural justice is a precursor for a transformative approach. System transformation cannot occur without social inclusion. Procedural justice is also a precursor for distributive and restorative justice.

Distributive justice deals with the distribution of risks and responsibilities and focuses on addressing the direct impacts resulting from the transition process (e.g., providing income support for job losses and providing compensation for environmental damage). Distributive justice begins to bridge the inequality gap between the resilient and the vulnerable. However, without procedural and transformative intention it cannot not achieve full system transformation.

Restorative justice considers past, present, and future damages that have occurred against individuals, communities and the environment and provides a framework to rectify or ameliorate the situations of harmed or disenfranchised communities (e.g., including workers, community members, woman & youth in decision-making processes to co-develop their own training, reskilling, retention, severance support, employment, and economic support options). Restorative justice is more likely to achieve system change, when combined with elements of procedural and distributive justice.

4.1.1. A just transition to net zero copper and nickel mining value chains

Unless actively governed, the costs and benefits of the GET and increased demand for copper and nickel, will be unevenly distributed across regions, sectors, and social groups.[cxi] People, communities, companies, and countries have different abilities to respond and adapt to the disruption from the GET, including ESG risks associated with increased demand for copper and nickel, and the decarbonization of these value chains.

An ambitious and just transition for copper and nickel mining value chains should be broad and governed "for additionality" with net-positive environmental and socio-economic outcomes for all stakeholders. A new paradigm is required to facilitate a just transition to net zero emissions. One that means mining value chains use resources sustainably and prioritize environmental and social stewardship for stakeholders affected by mining activities and their necessary decarbonization journey. A just transition must ensure mining value chain stakeholders are better off because of the transition. It should safeguard stakeholders who have limited capacity to withstand disruptions and take advantage of opportunities presented by the transition.[cxii]

Each stakeholder's needs in a just transition, how these are met (e.g., implementation mechanisms) and measured (e.g., success criteria) will vary based on their vulnerability, specific context, and location in the value chain. Mining value chain actors should include a broad range of stakeholders when pursuing a just transition (e.g., workers, communities, local suppliers and SMMEs, government, labor, civil society). This means going beyond directly impacted workers and communities, and includes all vulnerable stakeholders who may be affected, directly and indirectly, by the net zero transition and increasing demand for copper and nickel.[cxiii] At-risk stakeholders include workers, and community members, suppliers, and distributors at a local, national and global level.

Strategic benefits of delivering a just transition

A just transition has multiple strategic benefits for mining value chain actors:

- **Act as a change agent improving regional resilience:** Enabling access to basic services and supporting food, energy and water security helps improve stakeholder and regional resilience.
- **Improved productivity:** Healthier and safer workers and communities have reduced absenteeism and improved morale that enhances productivity within the business and the local value chain.
- **Enhanced social license to operate:** A just transition strengthens relationships with workers, communities, labor, and government, and assists in securing a company's social license to operate.
- **Improved public perception and reputation:** Growing consumer preferences for sustainable, equitable and transparent goods and services means that delivering a just transition improves company reputation, its bottom-line and its ability to attract and retain talent.
- **Avoid legal burdens:** Positively contributing to environmental and social outcomes for a just transition avoids legal (e.g., human rights violations) and social (e.g., protests) burdens and costs.
- **Contribute to the SDGs:** Pursuing a just transition delivers positive outcomes across many SDGs.
- **For host governments, a just transition is critical for addressing sustainable development challenges**, such as inequality, poverty, and unemployment. Host nations cannot afford for the net zero transition, or the expansion of copper and nickel mining value chains, to perpetuate existing socio-economic challenges. A just transition is a key driver for ensuring the net zero transition and expanding copper and nickel mining value chains, contribute positively to the SDGs.

4.2. Enabling a just transition across copper and nickel value chains

"Managing the downside risks that accompany energy transition metal (ETM) extraction sits at the core of a just transition - a transition designed to address climate change while respecting the rights of workers and communities and protecting the environment".[cxiv]

Delivering a just transition for ETMs requires clarity on the threats and opportunities that will result from:

1. The GET and increasing demand for and production of copper and nickel.
2. Transitioning copper and nickel mining value chains to net zero emissions.[cxv]

Effective, good governance that strives for additionality is needed to ensure a just transition where net-positive co-benefits and opportunities are maximized, and threats are minimized.

4.2.1. Assessing threats to a just transition

Just transition threats are environmental and socio-economic outcomes that negatively affect people's livelihoods, health, well-being, autonomy, and resilience. These outcomes stem from transition/decarbonization risks, and ESG risks. Within the broad scope of a just transition, threats can take many forms and impact various stakeholders in different ways and scales. Increasing demand for and supply of copper and nickel exacerbates existing ESG risks across value chains.[cxvi] Such risks are often interconnected and interventions to address them should also be interconnected (e.g., reskilling workers should include women and youth from different socio-economic backgrounds). If not governed well, ESG risks would lead to environmental and socio-economic impacts on workers and communities, negatively affecting their livelihoods, health, well-being, autonomy, and resilience. Negative environmental and socio-economic outcomes prevent a *just* transition to net zero copper and nickel mining value chains and global economy.[cxvii] Applying a just transition lens to net zero transition and ESG risks can help to better understand how these might impact different stakeholders and threaten a just transition.[27]

Good governance[28] is essential for achieving environmental and socio-economic benefits whilst minimizing negative impacts from mining value chains; and thus is an important success factor for delivering a just transition.[cxviii] Companies that do not implement good governance generally perform poorly against ESG metrics. Poor ESG performance increases the likelihood & severity of negative environmental and socio-economic impacts[cxix] on stakeholders' livelihoods, health, well-being, and resilience.

Environmental risks associated with mining value chain activities[cxx] can negatively impact ecosystem services from which workers, communities and regions derive benefit. Ecosystem services[cxxi] are benefits that people obtain from a healthy, functioning natural environment and are critical for livelihoods, human health, well-being, and resilience. They are divided into four categories: *provisioning* services (e.g., water, food, drugs, and genetic resources); *regulating* services (e.g., flood attenuation, climate regulation, pest control and pollination); *supporting* services (e.g., primary production, nutrient cycling, including the carbon cycle) and *cultural* services (e.g., recreational, spiritual and cultural benefits). When mining activities impact ecosystem service (e.g., water pollution) they have negative implications for livelihoods, human health, well-being, and resilience, with a disproportional impact on at-risk stakeholders. In addition, biophysical impacts from climate change, such as, droughts, floods, fires, extreme temperatures also present a threat to livelihoods, human health, well-being, and resilience.

Box 11: Wastewater from copper mining threatens water security and a just transition

A copper mine in Basse Kando in the DRC discharged wastewater into a local river, polluting the river and making it unfit for use by local communities. This negatively impacted access to water and water-dependent activities, including drinking, washing, and irrigating farmlands.[cxxii]

Social risks from mining value chains can cause negative socio-economic impacts and threaten a just transition.[cxxiii] They can manifest as direct or indirect impacts affecting workers and communities. Direct impacts result from internal, company-level social risks,[cxxiv] such as retrenchment of workers; unsafe working conditions, long hours, and low pay; forced resettlement of local communities, amongst others. Indirect socio-economic impacts stem from social risks that are not within a company's direct control[cxxv] such as an increased spread of communicable diseases from an influx of people to mining regions/communities.

[27] While this chapter specifically focuses on just transition, the Roadmap, in its entirety, must be understood and implemented within a just transition context.
[28] Governance refers to company-level governance and is differentiated from policy and regulation. It includes aspects related to a company's governing purpose, accountability of governing body, transparent disclosures, internal policies, risk management systems etc.

Box 12: Livelihood impacts from community resettlement

The establishment of the Sentinel copper mine in Zambia required the resettlement of around 4000 people, most of who were subsistence farmers and beekeepers. Despite providing resettlement support, such as new housing, subsistence farmers had limited access to markets because the resettlement area was located far from a main road or market. Resettlement negatively impacted their livelihood[cxxvi].

Decarbonizing copper and nickel mining value chains to achieve net zero could cause negative environmental and socio-economic outcomes which threaten a just transition.[cxxvii] Automation and digitization interventions present a threat to lower-skilled labor, while deployment of renewable energy infrastructure, if not managed responsibly, can increase land-use change with potential negative outcomes on local ecosystems and communities.[cxxviii] Carbon offset projects can have negative, unintended environmental and socio-economic impacts, such as maladaptation[cxxix] or the perpetuation of existing inequalities. In addition, the scale and urgency of the net zero transition is, itself, a threat. Value chain actors could prioritize emissions reductions at the expense of a just transition. Unintended impacts associated with the deployment of low-carbon technologies and carbon offset projects also present threats to a just transition, if not managed responsibly.

If mining value chains fail to deliver net zero emissions, they will face increasing transition risks that threaten a just transition. Failure by one or more companies in the value chain to achieve net zero emissions will cause harm to the entire mining value chain, such as: (i) market risks (e.g., changing consumer preferences, mineral substitution); (ii) policy, regulatory and legal risks (e.g., carbon pricing policies, mandatory ESG regulations); (iii) finance risks (e.g., limited access to capital at acceptable cost), and (iv) reputational risks.[cxxx] Transition risks can lead to reductions in competitiveness, revenue and market share, which reduces a company's ability to fund good governance of just transition threat.

Box 13: Supporting small-scale and artisanal miners

Interventions necessary to achieve Net zero emissions in a just and inclusive manner might not be available to small-scale and artisanal miners. Some regulations could pose an economic burden that could leave out of the market. For example, certification and compliance costs are relatively higher for small-scale miners, placing a greater administrative and economic burden on them. While these miners may have smaller environmental and social impacts, they might not necessarily have the resources to establish good governance mechanisms to manage them. Further, the collective impact of unabated impacts from small-scale miners could outweigh impacts from larger companies. Therefore, larger multi-national mining value chain actors, in collaboration with industry associates (e.g., ICMM, ICA, NI), should support small-scale and artisanal miners implement a just transition to more sustainable mining. This could be done in the same way companies might engage with and support their own local suppliers and SMMEs.[cxxxi]

Just transition threats at a company-level (e.g., for workers) and value chain-level (e.g., for communities) coalesce as national or global unemployment, inequality, and poverty challenges.[cxxxii]

4.2.2. Opportunities for delivering a just transition for all stakeholders

Adoption of governance best-practice (Box 14) is an impactful first step to manage environmental and socio-economic risks that threaten a just transition. Significant effort is required across both copper and nickel mining value chains to improve ESG performance[cxxxiii], minimize environmental and socio-economic impacts, and, at a minimum, to ensure a just transition "leaves no one behind". Mining value chain actors should adopt best practice guidelines and standards for good governance to efficiently manage common risks (e.g., diversity, accountability of governing bodies; ethical business practices;

transparent public disclosures.). Adopting such best practice helps mitigate ESG risks and minimizes negative environmental and socio-economic impacts.

Box 14: Best practice frameworks and guidelines

While there is a significant body of best practice guidelines, standards and frameworks, the following is a selection that can best support a just transition: United Nations Guiding Principles on Business and Human Rights (UNGP); OECD Due Diligence Guidance for Responsible Supply Chains of Minerals frameworks[cxxxiv]; ICMM's mining principles; Copper Mark; IFC's Performance Standards; RMF's Responsible Mining Index; ILO's Guidelines for a just transition; and the Responsible Minerals Initiative's Risk Readiness Assessment.

Ambitious governance striving for "***additionality***"[cxxxv] is an enabler of a wide, impactful just transition. Mitigating ESG risks aligns to the requirements of sustainable environmental taxonomies[cxxxvi] for "do no harm" and "leave no one behind" outcomes but this would deliver the narrowest of just transitions. Mining value chain actors are encouraged to increase their ambition and strive for *additional,* net-positive environmental and socio-economic outcomes that align with social taxonomy requirements[cxxxvii] and deliver an ambitious just transition that "uplifts lives and livelihoods". Like environmental taxonomies, social taxonomies will guide ESG and investment decision-making by financiers in the future. Aligning to the requirements of social taxonomies will secure access to finance and reduce the cost of capital. However, unlike environmental taxonomies (which are based on a minimum requirement of "don no harm"), social taxonomies are likely to require additionality in the socio-economic benefits companies provide.

Just transition principles

Six just transition principles underpin governance for ambition and additionality (Table 9). They enshrine best practice from leading thinkers and expand on the principles from the International Labour Organisation, Grantham Research Institute on Climate Change and the Environment and Centre for Climate Change Economics, Just Transition Centre and The B Team, Shareholders for Change, and The Council for Inclusive Capitalism.

Table 9: Just transition principles[cxxxviii]

Just transition principle	Description
1. Governance for additionality	• Ambitious governance, striving for "additionality", is an essential enabler for a broad and impactful just transition to net zero mining value chains. Governance for additionality is more than just avoiding risks. It provides mining value chains and their stakeholders with additional, net-positive co-benefits and opportunities that improve livelihoods, human health, well-being, autonomy, and resilience, thereby enabling a just transition.
2. Ensure social dialogue & participation by all stakeholders	• Create opportunities for inclusive and participatory social dialog with stakeholders to better understand their vulnerabilities and needs for a just transition. • Ensure inclusive, participatory, and stakeholder-centered transition planning & decision-making, so that stakeholders are active participants in defining how net zero mining contributes positively to their livelihoods, well-being, resilience, and autonomy. • Promote multi-stakeholder collaboration & transparency. • Engage in national and international policy processes for fostering an enabling environment that is supportive of a just transition.
3. Uphold human rights & enable decent livelihoods	• Respect, protect and promote human rights, particularly the right to decent work and fair pay. • Support the participation and inclusion of communities and marginalized groups in economic activities. • Support sustainable livelihoods through local economic development, inclusion, and equal access to opportunities. • Avoid and remediate environmental degradation to support community livelihoods dependent on local ecosystem services.
4. Support workers' & communities' evolution and regional resilience	• Support worker and community evolution and resilience by providing necessary and accessible education, training, and reskilling opportunities. • Provide the necessary support to local suppliers so that the regional supplier ecosystem can evolve with the transition. • Provide climate change adaptation solutions for workers and communities, particularly for historically marginalized groups. • prioritize retention, retraining and redeployment of workers. Retrench as a last resort and provide necessary support to minimize its impacts. • Support small-scale and artisanal miners with their own just transition.
5. Champion sustainable development to address existing inequalities	• Contribute positively to sustainable development and the reduction of inequality, poverty, and unemployment challenges in host countries. • Decouple environmental and socio-economic risks from business growth and expansion. • Promote diversity, economic inclusion, and equal access to opportunities, particularly for marginalized groups (e.g., women, black and indigenous communities) • Identify existing inequalities at an asset level and adapt procurement policies and operational procedures to support the reduction of those inequalities through local procurement and supplier support (e.g., prioritizing the employment of or skills development for women). • Enable equitable access to basic services, such as food, energy and water security, access to healthcare, education, and cultural/recreational activities, through multi-stakeholder collaboration (informed by inclusive stakeholder engagement).
6. Avoid & clean up environmental damage	• Avoid and mitigate negative environmental impacts from the expansion of ETM mining and decarbonization of mining value chains • Ensure a healthy and sustainable environment contributes positively to stakeholders' livelihoods, health, well-being, and resilience. • Ensure effective and inclusive mine rehabilitation that restores environmental health, provides carbon and biodiversity offset opportunities, and enables sustainable livelihoods post-mine closure.

Just transition interventions

Various cross-cutting *interventions*[cxxxix] are available to the mining value chain to mitigate threats and *enable* the provision of net-positive, additional environmental and socio-economic outcomes for a just transition, these include:

- **Financing a just transition:** Mining value chain actors can access sustainable finance instruments that are designed to fund just transition interventions. These include social loans or bonds, and sustainability-linked loans or bonds, which are linked to social key performance indicators and targets (refer to *Chapter 5: Sustainable finance for a just transition to net zero mining* for more information on different sustainable finance instruments).

Box 15: Anglo American secures sustainability-linked loan for social development

Anglo American secured a US$100 million, 10-year sustainability-linked loan with the International Finance Corporation (IFC) for delivering their Sustainable Mining Plan. The loan is IFC's first in the mining sector and is understood to be the first in the mining sector, globally, that focuses exclusively on social development indicators. The specific KPIs and targets of the loan agreement are aimed at supporting community development, including the creation of jobs, and improving the quality of education for more than 73 000 students in Anglo's mining regions in South Africa. These are critical interventions for supporting a just transition in South Africa[cxl].

- **Inclusive stakeholder engagement:** Inclusive and participatory stakeholder engagement processes (e.g., grievance mechanisms; environmental and social impacts assessments; the right to prior and informed consent) magnifies the benefits of a just transition.[cxli] It informs mining value chain actors of stakeholder needs and requirements, helping companies to avoid threats and capitalize on opportunities (e.g., co-developing carbon offset projects that address specific community needs). Inclusive participatory processes empower stakeholders, providing them with autonomy and inclusion in planning and decision-making processes. The aim should be to encourage "active and inclusive participation" by stakeholders. Such participation encourages stakeholders to buy-in to the project, reducing the risk of community opposition.
- **Stronger ESG reporting:**[cxlii] Companies are encouraged to continuously monitor, report, and disclose ESG data at an assets level, rather than aggregate data at a company level (e.g., the RMF Responsible Mining Index has specific mine site ESG metrics and reports[cxliii]). Companies should also identify pre-existing environmental and socio-economic challenges in mining regions to develop a baseline against which reported ESG data, and progress against just transition principles, can be compared. This is important for appraising how different ESG risks translate into just transition threats for workers and communities in different countries, environments, and contexts. Integrating a strong, holistic, decentralized ESG framework, with an emphasis on negative impacts that might threaten a just transition for at-risk stakeholders, will enable best practice governance of just transition threats and opportunities.
- **Multi-stakeholder collaboration:** Delivering a just transition is beyond the capability of one company.[cxliv] It is a shared responsibility between all stakeholders. Multi-stakeholder collaboration between national and local governments; local communities; labor, civil society, and the private sector is needed. Addressing reskilling needs, for example, requires localized support from mining value chain actors under the umbrella of broader, supportive public policy is critical.
- **Public-private Partnerships:** [cxlv] Public-private partnerships (PPPs) will also be important for delivering net-positive benefits to stakeholders for a just transition (Box 16). For example,

miners are encouraged to collaborate with local governments through PPPs to deploy sufficient renewable energy capacity to provide their operations, their workers, and the local community with affordable clean energy. This enables net-positive environmental and socio-economic outcomes by improving energy access and security, increases livelihood opportunities, and improves human health, well-being, and resilience. Integrating renewable energy ownership opportunities for local communities in post-closure livelihood plans would further contribute to a just transition. Climate change adaptation infrastructure (e.g., rainwater tanks, ecological infrastructure such as wetlands) is another key opportunity for PPPs to enable a just transition by enhancing communities' resilience to climate change. This is where the concept of governance for additionality addresses environmental and socio-economic impacts and maximize co-benefits to ensure net-positive, additional outcomes, and enables a just transition to net zero mining and global economy.

Box 16: Anglo American's renewable regional ecosystem in southern Africa[cxlvi]

Anglo American have outlined plans to collaborate with partner governments, utility providers and communities in South Africa for the development of a regional renewable energy ecosystem. The initiative involves the construction of on-site PV plants and off-site wind farms to reduce Anglo's Scope 2 emissions and a foundation for producing green hydrogen. In addition, the initiative is expected to increase grid capacity and enhance grid stability (2.7–4.4 GW of green energy in South Africa alone), which support inclusive energy access as part of a just transition more broadly.

- **Skills and job gap assessments:** Skills and job gap assessments identify skills and jobs that are at risk from the transition to net zero emissions or the deployment of new technologies (e.g., automation and digitization). Skills gap assessments inform worker resilience plans, which should aim to support employees, contract workers and communities through the net zero transition. Support could include retaining, upskilling, and redeploying employees, and contract workers. Businesses and national governments should work together on such assessment (e.g., South Africa conducted employment vulnerability assessments and sector jobs resilience plans and is in the process of developing just transition-focused public policy, while the European Union have established a €17.5 billion Just Transition Fund to support members states[cxlvii]).
- **Education and training programs:** Prepare workers and local communities for post-mine closure life to strengthen their autonomy and resilience (e.g., collaborating with local governments to support soft skills; health awareness; technical skills and entrepreneurial skills for children and adults). This could also include support to enhance the national skills base in host countries to foster a diverse future skills pipeline (e.g., collaborating with national and local governments to strengthen Science, Technology, Engineering and Mathematics (STEM) education at school and college level, and providing scholarships, internships, vacation training and graduate training[cxlviii]).

Box 17: De Beers' Accelerating Women Owned Micro-Enterprises (AWOME)[cxlix]

In 2017, De Beers launched the Accelerating Women Owned Micro-Enterprises (AWOME) program - a partnership with UN Women and local governments that aims to support women micro-entrepreneurs build their businesses, create more jobs, and generate a more secure income. The program provides mentoring, network, business, and life skills training, which in turn, creates new jobs, regular wages, and a wider range of businesses to help local communities to thrive. A holistic model is employed, upskilling, and equipping local trainers to ensure the initiative will endure long into the future.

In the Limpopo province of South Africa – a region with significant transition risk – the program supported a small-scale, subsistence farmer grow her business. The thriving enterprise now supplies vegetable to several markets, contributing to food security for the local village.

- **Governance for a just transition:** Embed the six just transition principles into employment and procurement policies, and into carbon offset, mine rehabilitation and post-closure plans.

  Develop and implement fair and equitable employment policies for company employees and contractors that aim to address existing employment inequalities for women, youth, unskilled workers, and at-risk stakeholders. This includes avoiding an over-reliance on imported skilled labor or cheap migrant labor, while also providing the necessary benefits and support for vulnerable stakeholders (e.g., skills development; access to healthcare).

  Procurement policies are another key intervention for enabling a just transition across mining value chains and communities. Prioritizing local procurement can support economic development; re-industrialization; job creation; skills development and tax revenues in host countries. Identifying local community procurement opportunities at an asset level can support direct and indirect job creation; livelihoods, and gender and youth employment within local communities.

  Carbon offset, mine rehabilitation and post-closure plans also provide opportunities for contributing to a just transition. Clearly defining just transition requirements for site-specific contexts will help ensure carbon offset and mine closure plans address site-specific just transition threats and provide relevant opportunities for workers, local communities, and other stakeholders (Box 18). Just transition requirements for these different plans must be informed by inclusive and participatory stakeholder engagement and consider climate change adaptation requirements as well.

Box 18: Just transition opportunities in mine closure and carbon offsetting

Mine closure and purposeful carbon offsetting projects present a huge opportunity to address several environmental and socio-economic impacts from mining value chain activities and provide additional net-positive environmental and socio-economic outcomes for workers and communities. Using mine rehabilitation projects as nature-based carbon in-setting projects (e.g., using dry stack tailings from nickel production to neutralize soil acidity and sequester carbon, in addition to reforestation with indigenous species) can simultaneously address ecosystem degradation, biodiversity and GHG emissions impacts, while enabling successful post-closure livelihood plans and climate resilience (e.g., it improves environmental health to better support climate smart agriculture or eco-tourism opportunities). Any excess carbon credits from the in-setting project can be sold and revenues used to help finance post-closure livelihood opportunities. However, post-mining land-use must be informed by inclusive and participatory stakeholder engagement with workers and local communities.

- **Adhere to international best-practice:**[cl] Adopting and adhering to international best practice will support companies through this challenging transition to net zero emissions, and help them contribute to a just transition for workers and communities. While there is a significant amount of best practice guidelines, standards and frameworks, the following lists a selection that might best enable a just transition: the United Nations Guiding Principles on Business and Human Rights (UNGP); the 10 Principles of the UN Global Compact; the SDGs; the OECD Due Diligence Guidance for Responsible Supply Chains of Minerals frameworks; the ICMM's mining principles; the Copper Mark; the IFC's Performance Standards; RMF's Responsible Mining Index; the ILO's Guidelines for a just transition; and the Responsible Minerals Initiative's Risk Readiness Assessment, amongst others.

4.3. Skills and job gap assessment for supporting copper and nickel mining value chain workers

Future skills and job requirements for net zero mining value chains will cause employment risks and opportunities that need to be managed closely to ensure a just transition. An assessment of the skills and jobs gaps that arise through the future deployment of low-carbon technology interventions across net zero mining value chains was undertaken to inform future employment risks and opportunities.

The skills and job gap assessment highlighted:

- There will be changing employment dynamics between fossil fuel and low-carbon sectors (e.g., renewable energy and ETMs sectors). The introduction of low-carbon technology interventions will replace or reduce the use of traditional fossil fuels, such as diesel, coal, and coal-powered electricity. These changes will have negative employment impacts across fossil fuel value chains, but such impacts will likely be offset by employment opportunities in expanding renewable energy value chains. Although impacts on workers and communities may be unevenly distributed[cli]. Skills of the fossil fuel sector are often transferable to ETMs sector (e.g., coal miners or engineers often have the relevant skills and expertise to work at a copper or nickel mine).
- New occupations and skills requirements will arise from the adoption of low-carbon technology interventions. The workforce will require some form of training and upskilling to be able to operate or work in a net zero mine (e.g., training to operate new machinery, battery electric vehicles, remote-controlled drones). New opportunities will require more advanced skills and education. Some of the base skills that will be required already exist in the mining value chain, however, the wider workforce will require upskilling. Some specialist skills will have to be sourced from other sectors outside the mining value chain, such as big data specialists, programmers, and artificial intelligence technicians.
- Occupations with higher expertise and skill are at lower risk of job loss as they hold skills that are adaptable and transferable.[clii] Engineering and technical personnel have the most adaptable and transferable skills but will require upskilling and retraining to work on new technologies.
- Occupations with lower expertise and skills are at a higher risk of job loss from automation or being replaced by cleaner and more efficient processes.[cliii] Operating some low-carbon technologies will require skills that already exist in the workplace, while others will require new skills. Most low-carbon technology interventions will lead to changes in skills requirements for certain jobs associated with fossil fuel-based technologies along the mining value chain but are unlikely to cause major job losses with appropriate training and reskilling. For example, a diesel

truck driver might be replaced by an autonomous truck. There may be opportunities for drivers to monitor rather than drive autonomous trucks, but this will need to be assessed on a case-by-case basis.

- With careful planning and robust training and skills development programs, the adoption of low-carbon technology interventions can have a positive impact on jobs and skills in the mine value chain.

Figure 26 provides examples of potential skills impact for current job roles at a mine site and shows how these roles may evolve over time. The reality will be far more complex and will be different depending on specific contexts in different countries, regions, companies, and mines.

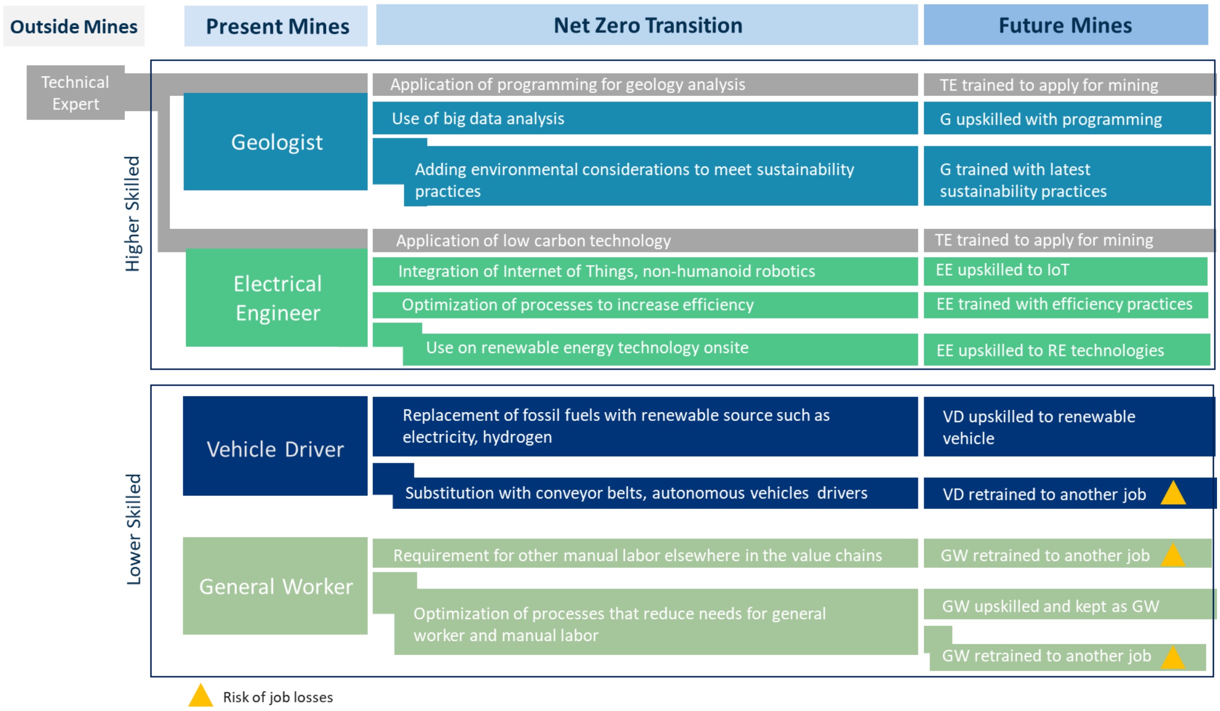


Figure 26: Examples of potential skills evolution in the Net zero transition of the mining sector

Deploying low-carbon technology interventions for minimizing GHG emissions at the mine value chain will require careful planning to manage negative impacts on the workforce. A just transition should minimize redundancies and maximize redeployment of workers.[cliv] Negative impacts on the workforce can be minimized by anticipating changes in jobs before they occur. This can be done through a skills and jobs gap assessments. Training and reskilling should be prioritized for affected workers. Where training and reskilling is not possible, employers should consider redeploying workers to other work areas where their skills can be utilized before considering retrenchment.

Training and upskilling should be about identifying skills, knowledge and experience that will be most valuable for the new and transformed occupations in future net zero mines. Skills development programs should be informed by skills gap assessments and inclusive dialog with workers, labor unions, community representatives and other employers across the mining value chain. Collaboration with local governments is also important for supporting and informing training and skill development programs[clv] (Box 19).

Box 19: The impact of automation and digitization in Pilbara, Australia[clvi]

Since 2019, Pilbara hosts 75% of the automated vehicle fleets in operation globally. While the deployment of Autonomous Haulage Systems (AHS) improved productivity and improved mine-site safety, it also led to a drastic reduction in the number of truck drivers. The AHS system only requires two field staff per shift (with an additional cross crews' role). The technology needs employees to give direction to the machines, and manage and oversee operations, which means that higher-skilled jobs are required. Although job opportunities are still available, the new skills requirements lead to the exclusion of Indigenous workers who did not have the necessary skill set to support the AHS. In addition, the lack of alternative employment and economic opportunities locked local community members into unsustainable careers and poor-quality jobs. To address the skills gap, mining value chain actors in the region are working with the government to invest in reskilling and retraining programs for their workers and local community. The technical and further education (TAFE) institutions in Pilbara are stepping up efforts to address the country's growing digital skills gap through new training programs focused on areas such as mechatronics, robotics and data analytics. However, the objective is not to only invest in skills needed for the mining sector but also high quality and transferable skills relevant for other industries. Launched in June 2019, collaborations led to the first nationally recognized course in automation in Australia.

To ensure that appropriate planning and skills development programs are implemented, mining value chain actors can follow the high-level skills and job gap assessment presented in Table 10. This will support a just transition of the workers across the value chain.

Table 10: Skills and job gap assessment framework

Criteria	Description
1. Anticipate changes in skills and jobs for a net zero mine	• Review your organization's climate change and net zero strategies for jobs and skills impacts. • Assess what skills, expertise and knowledge will be needed to implement the organization's climate change and net zero strategies at a corporate and mine site level, including understanding of local specificities. • Consider changes in operations, production processes and adoption of new technologies. • Map the future of your organization in terms of technology adoption and processes improvement.
2. Assess current and future skills requirements	• Conduct a net zero jobs and skills gap analysis based on the organization's prioritized low-carbon interventions. • The net zero jobs and skills gap analysis should: o Map out current job roles and existing skills in the organization o Investigate what potential future jobs and skills will be required for the implementation of the organization prioritized low-carbon interventions o Identify skills which will become redundant due to changes in technology and production processes o Identify skills that are transferrable o Identify roles that will need retraining and upskilling o Identify training needs
3. Develop a net zero jobs and skills strategy	• Develop a net zero jobs and skills strategy as part of the organization's existing jobs and skills strategy. • The net zero jobs and skills strategy should cover: o Consideration for decent work o Considerations for an inclusive and transparent process o Mechanism for engagement and consultation with workers and other stakeholders o Training and development plans including considerations for retraining and upskilling workforce that have higher risk of job loss o Sourcing and training of local workforce o Local skills and development programs

4.4. A just transition strategy toolkit

Copper and nickel mining value chain actors can use the just transition strategy toolkit (Table 11) to support the operationalization of a just transition at an organization level and guide the development of their own just transition strategy.

Table 11: A just transition toolkit for copper and nickel mining value chain actors

<table>
<tr><th colspan="3">A strategy toolkit for a just transition to net zero mining value chains</th></tr>
<tr><td rowspan="5">Ensure participation and inclusion of stakeholders at every step</td><td>1. Adopt just transition principles</td><td>Just transition principles should be integrated into company strategies:
1. Adopt governance for additionality principle
2. Promote social inclusion, dialogue & participation in planning & decision-making processes
3. Uphold human rights & decent livelihoods
4. Support workers, wider communities & regional resilience building
5. Champion sustainable development and address existing inequalities
6. Avoid & clean up environmental damage</td></tr>
<tr><td>2. Identify and engage with relevant stakeholders</td><td>• Identify relevant stakeholders, with specific attention to at-risk groups.
• Create opportunities for inclusive & participatory engagement with stakeholders in transition planning & decision-making processes. This will inform processes and ensure that stakeholders are active participants in defining the vision, threat, and opportunities of a just transition.</td></tr>
<tr><td>3. Conduct environment and social impacts assessments, and skills and job gap assessments to identify just transition threats and opportunities</td><td>• Identify and assess risks and opportunities from the Net zero transition for different stakeholder groups previously identified. Take account of the wide range of threats that might stem from existing ESG-related risks.
• Understand existing environmental and socio-economic contexts at different operating sites, regions, and host countries. This will provide a baseline against which progress can be assessed.</td></tr>
<tr><td>4. Define the just transition requirements for different stakeholders</td><td>• Define risk mitigations and ensure additional, net-positive outcomes for different stakeholders. This should be informed by inclusive and participatory stakeholder engagement.
• Monitor and evaluate progress against predefined just transition requirements.</td></tr>
<tr><td>5. Develop a just transition strategy and decentralized implementation plans</td><td>• Develop an overarching, company-level just transition strategy to guide and inform decentralized, site-level implementation, and regional impact.
• The just transition strategy is an integral part of the organization Net zero strategy. Decentralized just transition implementation plans should inform other site-level plans, such as ESG plans, decentralized carbon offset plans, mine rehabilitation and post-closure livelihood plans.
• Collaborate with local and regional government to facilitate stakeholder engagement and implement just transition strategies and plans.</td></tr>
</table>

5. SUSTAINABLE FINANCE FOR ENABLING A JUST TRANSITION TO NET ZERO COPPER AND NICKEL

Achieving a just transition to net zero mining will be costly but mining value chain actors can use sustainable finance to help kick-start their transition. An estimated US$3 trillion of investment will be required annually between 2020 and 2030 to transition the global economy.[clvii] Much of this investment will need to be channeled into energy efficiency and renewable energy technologies, electricity grid expansion, and electrifying heating and transport systems. The mining value chain is well positioned to take advantage of these sustainable investment opportunities. Research suggests that metals and mining value chain actors can generate a return on investment of 17%, which is above the weighted average expected return of 12% across other sectors (e.g., transport).[clviii]

To meet growing demand whilst delivering net zero emissions, value chain actors are encouraged to increase their investment in RD&D and target capital expenditure on the net zero transition. Sustainable finance can provide a useful source of funding for both. Research indicates that metals and mining value chain actors are investing less than 40% of their cash flows into RD&D and capital expenditure for the transition, which is below the weighted average of 50% found in other sectors (e.g., chemicals, communications, construction sectors). Yet value chain actors stand to earn 17% back on such investments. By allocating more cash flows and leveraging its balance sheets, the global metal and mining industry is estimated to have more than US$200 billion of capital annually that could be targeted at sustainable investments.[clix] Given this low investment rate and rising commodity prices, the metals and mining industry will face growing pressure to increase its investment in net zero mining value chains that also deliver a just transition.

The following provides a review of the rapidly expanding sustainable finance sector, including the drivers, benefits, and challenges of securing sustainable finance. It provides a deep dive into the most suitable sustainable finance instruments (e.g., green loans and bonds) for funding the deployment of low-carbon technology interventions, including the norms, standards, and requirements for accessing different instruments.

5.1. The sustainable finance opportunity for net zero mining

Sustainable finance is a useful investment tool that can support a just transition to net zero mining value chains, alleviate investment and capital expansion challenges, and provide rigorous independent assurance of climate actions taken. Sustainable finance is an alternative and potentially cheaper source of debt, asset, or project-linked financing (e.g., deployment of low-carbon technology, just transition interventions). Sustainable finance can support a more disciplined approach to capital and investment planning and reduce the weighted average cost of capital and project risks (e.g., projects funded through sustainable finance instruments ought to be more environmentally and socially sustainable reducing physical and transition risk). In the current market environment, where rising commodity prices are set to accelerate investments, sustainable finance can be used to steer a path to net zero mining, and signal delivery of sustainable, just transition.

5.1.1. What is sustainable finance?

Sustainable finance broadly refers to any investment or financial instrument that is used to fund sustainable development initiatives, be they environmental or social. In its most mainstreamed form, it refers to the funding of investments that integrate ESG criteria into risk management and investment decision-making. In other forms, it also integrates "impacts" with the aim of having net-positive environmental and socio-economic outcomes.

For the purposes of this document, the preferred definition is that provided by the South African National Treasury.[clx] It defines sustainable finance as encompassing *"financial models, services, products, markets, and ethical practices to deliver resilience and long-term value in each of the economic, environmental, and social aspects and thereby contributing to the delivery of the sustainable development goals and climate resilience. It is achieved when the financial sector:*

- *Evaluates portfolio as well as transaction-level environmental and social risk exposure and opportunities, using science-based methodologies and best practice norms;*
- *Links these to products, activities and capital allocations;*
- *Maximizes opportunities to mitigate risk and achieve benefits in each of the social and environmental and economic aspects; and*
- *Contributes to the delivery of the sustainable development goals."*

Sustainable finance can also be categorized into green, transition and just transition finance, depending on the scope and activities of investments:[clxi]

- **Green finance** has a narrower focus on environmental sustainability and includes climate finance (finance for climate change mitigation and adaptation), blue finance (finance for marine ecosystems) and conservation finance (finance for conservation and biodiversity, such as wildlife bonds).
- **Transition finance** is somewhat more ambiguous in that it provides funding to support unsustainable (e.g., carbon-intensive) companies implement changes to become relatively more sustainable (e.g., reduce GHG emissions). The activity being funded may not be considered green or sustainable in and of itself, but it is relatively more sustainable than the business-as-usual activity or scenario. Transition finance can, there, be understood to include all ESG aspects that *incrementally* reduce risk and improve sustainability performance, but which are not necessarily considered "fully" sustainable.
- **Just transition finance** focuses on social and governance aspects of sustainability to ensure cash flows for social benefit (e.g., education, skills development) but can also include environmental aspects (e.g., climate change adaptation) given the interlinkages between environmental and social sustainability within a just transition (for more information on a just transition, please refer to the Executive Summary: "*A just transition for mining value chains*".

For simplicity, these are collectively referred to as "sustainable finance" throughout the Chapter.

5.1.2. The growing sustainable finance ecosystem

The sustainable finance ecosystem is rapidly evolving, and mining value chain actors are encouraged to act quickly to secure access to sustainable finance opportunities, or risk being left behind. The evolution of the sustainable finance ecosystem has seen new: financing instruments, products, and arrangements (e.g., green bonds, loans, equity); investment and portfolio evaluation guidance, methodologies and tools (e.g., the Task Force on Climate-Related Financial Disclosures (TCFD), International Capital Market Association's (ICMA) Green Bond Principles); perspectives and expectations of the financial sector, including policies and regulations (e.g., sustainable finance taxonomies[29]). Except for a few examples, mining value chain actors have not taken advantage of opportunities that this evolving ecosystem presents. Those that are slow to respond to these changes in the finance market risk being left behind.

Sustainable finance has seen accelerated growth over the last decade, affecting all asset classes and sectors of the economy. While sustainable finance is on an upward trend, a lack of standardization and associated classification issues has led to different estimates of total investments[clxii]. One estimate indicates that sustainable investments increased from ~US$13.3 trillion in 2012 to ~US$35.3 trillion in 2020.[30] Another estimate indicates that sustainability-dedicated investment products (e.g., green, social and mixed bonds) increased by 80% from 2019 to a total value of ~US$3.2 trillion in 2020.[31] A third estimate, looking specifically at sustainable debt issuance (e.g., bonds, loans), indicates a growth from ~US$15 billion in 2013 to ~US$2.3 trillion in 2021 (Figure 27).[clxiii] Despite classification challenges, sustainable finance is and will continue to grow. What remains underdeveloped is explicit use of sustainable finance in mining and other hard-to-abate sectors.

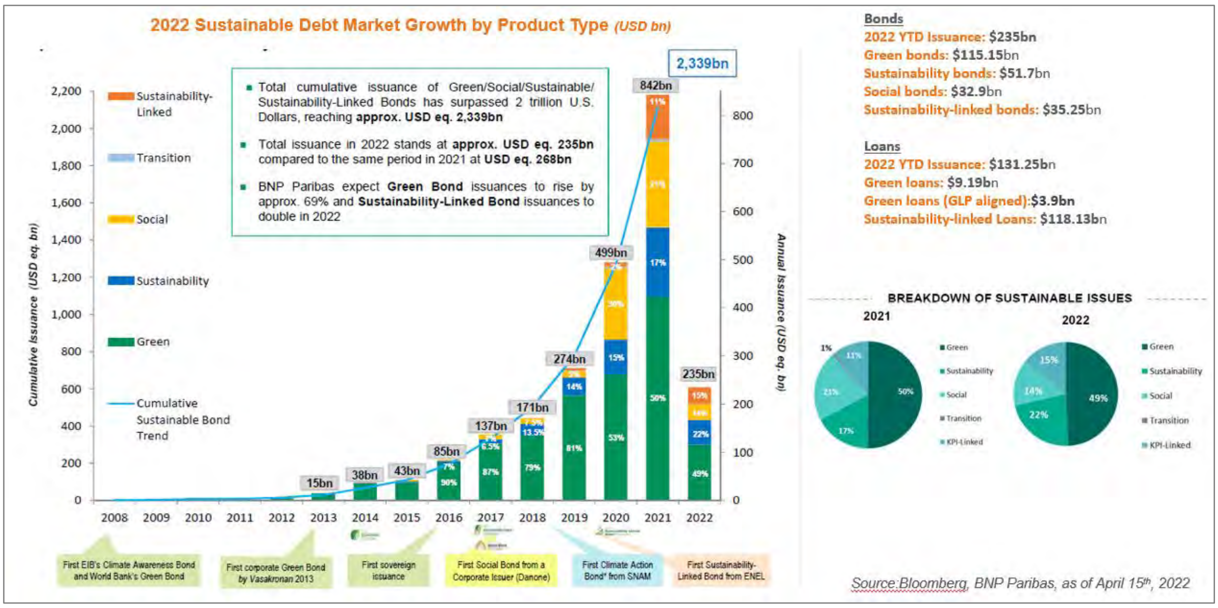


Figure 27: A growing trend in annual sustainable debt issuance[clxiv]

This growing trend has largely been market driven as investors look to mitigate investment portfolio risks.[clxv] There is a growing realization across the financial sector that climate change (and other environmental and social sustainability issues) present material risks to investors. These risks include: (i) physical risks (e.g., flooding, drought, fires); (ii) transition risks (e.g., carbon tax liability, changing consumer preferences), and (iii) liability risks. Better understanding the risks associated with their

---

[29] It is noted that sustainable finance taxonomies are not necessarily policies or regulations in and of themselves but have a direct influence on the enabling environment for sustainable finance.

[30] The Global Sustainable Investment Alliance's (GSIA) estimate is based on broad definition of sustainable finance and provides a snapshot of sustainable investments across "*Europe, the United States, Japan, Canada, Australia and New Zealand (Australasia) based on the regional and national reports from GSIA members or in the case of Europe, from secondary industry data*". They define sustainable finance as: *"Sustainable investment is an investment approach that considers environmental, social and governance (ESG) factors in portfolio selection and management"*.

[31] The United Nations Conference on Trade and Development (UNCTAD) estimate appears to be based on a narrower definition of sustainable finance, but the exact definition and methodology is unclear.

investments allows investors to better manage their own risk exposure and channel financial flows towards more sustainable activities with positive real-world outcomes.

An increasing number of investors and financiers have made sustainability a core criterion in their investment decisions.[clxvi] Financial institutions increasingly incorporating ESG-related risk and performance into their credit rating systems, cost structures and investment decision-making. This has led to growing demand for measuring and disclosing a company's (or investment's) risk exposure and sustainability performance to investors and financiers, although the level of scrutiny between sustainable finance instruments may differ (e.g., assessment of sustainability performance is more rigorous for sustainability-linked instruments compared to ESG or green equity funds/indexes).

Changing consumer preferences and a growing demand for investment opportunities that generate net-positive environmental and socio-economic impacts are drivers behind sustainable finance.[clxvii] Consumer preferences are evolving to favor more sustainable products and investment opportunities. This is increasing demand for sustainable investments that can generate net-positive environmental and socio-economic impacts "on the ground" (e.g., improved climate resilience, reduced poverty). These benefits are making sustainable finance opportunities increasingly more attractive for investors and financiers. Delivering net-positive outcomes at the grassroots is acknowledge by some as challenging. Investors and mining value chain actors will need to manage this carefully to avoid greenwashing and reputational risks that could threaten their social license to operate.

Policy, regulation, and international agreements are driving sustainable finance.[clxviii] There have been some 680 sustainable finance-related policy and regulatory measures across 100 countries[clxix]. For example, the European Green Deal, the Action Plan on Critical Raw Materials, and the European Green Deal Investment Plan, all commit to transition Europe to a low-carbon and sustainable economy, with a financial system that supports sustainable growth. COP26 saw the launch of the International Sustainability Standards Board (ISSB), an initiative backed by the International Financial Reporting Standards (IFRS) and the Sustainable Accounting Standards Board (SASB). Their aim is to develop a global baseline for sustainability disclosures for the capital markets, which will continue to drive the sustainable finance market.[clxx] The emergence of sustainable finance taxonomies around the world is also driving the sustainable finance market. These taxonomies help companies and investors make informed investment decisions and provide market clarity on what constitutes as a sustainable activity or investment (Box 20). Increasing pressure from policies, regulations and international agreements, and the financial sector more broadly, has also driven the development of responsible mining standards and labels (e.g., LME Aluminum 'green mark', Copper Mark).

Box 20: Sustainable Finance Taxonomies

A sustainable or green finance taxonomy is a classification tool designed to support investors and companies make more sustainable investment decisions. They provide a list of activities across different sectors that are considered green or sustainable. Various countries around the world have developed, or are in the process of developing, sustainable finance taxonomies (Figure 28). From a mining point of view, taxonomies include criteria on renewable energy use, but not for the activity of sustainable mining itself – this is still to be defined. This presents an opportunity for mature value chain actors, with sustainable operations, to inform the criteria for sustainable mining activities in such taxonomies. When these activities are defined, it will become increasingly important for mining value chain actors to meet the minimum requirements set out in these taxonomies to ensure future access to finance.

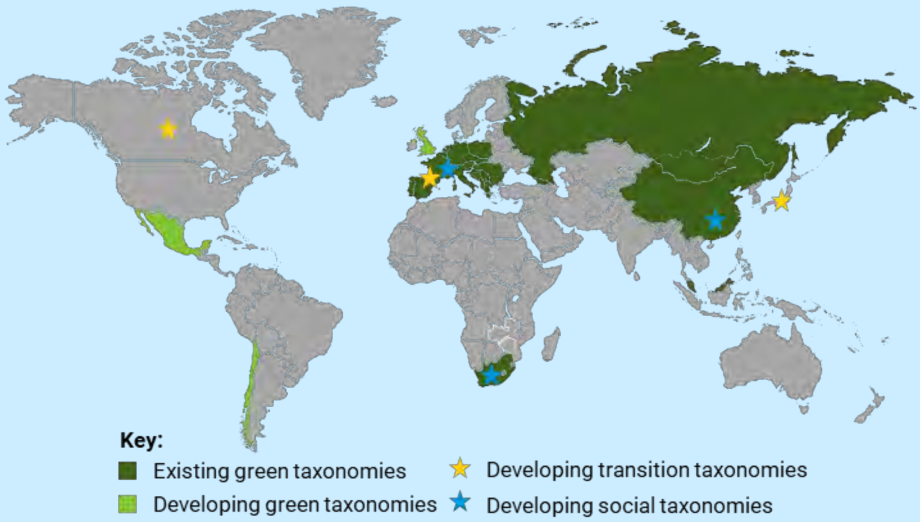


Figure 28: Sustainable finance taxonomies around the world

To date, most taxonomies have focused on environmentally sustainable actives, particular from a climate point of view. There are, however, plans to extend these taxonomies to include other environmental aspects, such as water and biodiversity, and develop sustainable social taxonomies and transition taxonomies. Sustainable finance taxonomies are important public policy tools and are expected to form the basis of future regulations around sustainable finance and the economic activities that taxonomies cover.

5.1.3. Mapping the sustainable finance ecosystem

The sustainable finance ecosystem consists of sources, intermediaries, instruments, and products to facilitate sustainable mining, including delivery of a just transition[clxxi] (Figure 29). Sources and intermediaries include Multilateral Development Banks (MDBs) and Development Finance Institutions (DFIs; e.g., the World Bank, IFC, GIZ, AFD); Corporate Finance Institutions (CFIs; e.g., commercial banks); institutional investors, asset managers and wealth managers; insurance companies and private investors (e.g., households, philanthropists, venture capitalists). There are a host of different sustainable finance instruments, including debt-based instruments (e.g., bonds, loans); equity products (e.g., public, private equity, venture capital); risk sharing instruments (e.g., concessional finance, insurance); grant funding; blended finance; alternative instruments (e.g., carbon offsets) and public finance / fiscal interventions[32] (e.g., carbon taxes, tax incentives). Figure 29 provides a snapshot of the sustainable finance ecosystem, mapping different sources, intermediaries, instruments, and end-uses for supporting a just transition to net zero mining value chains. While public sector instruments are not the focus of the

[32] While public finance / fiscal instruments are noted, they are not the focus of the Roadmap.

Roadmap, they are included in Figure 29 to provide broader context of the sustainable finance ecosystem.

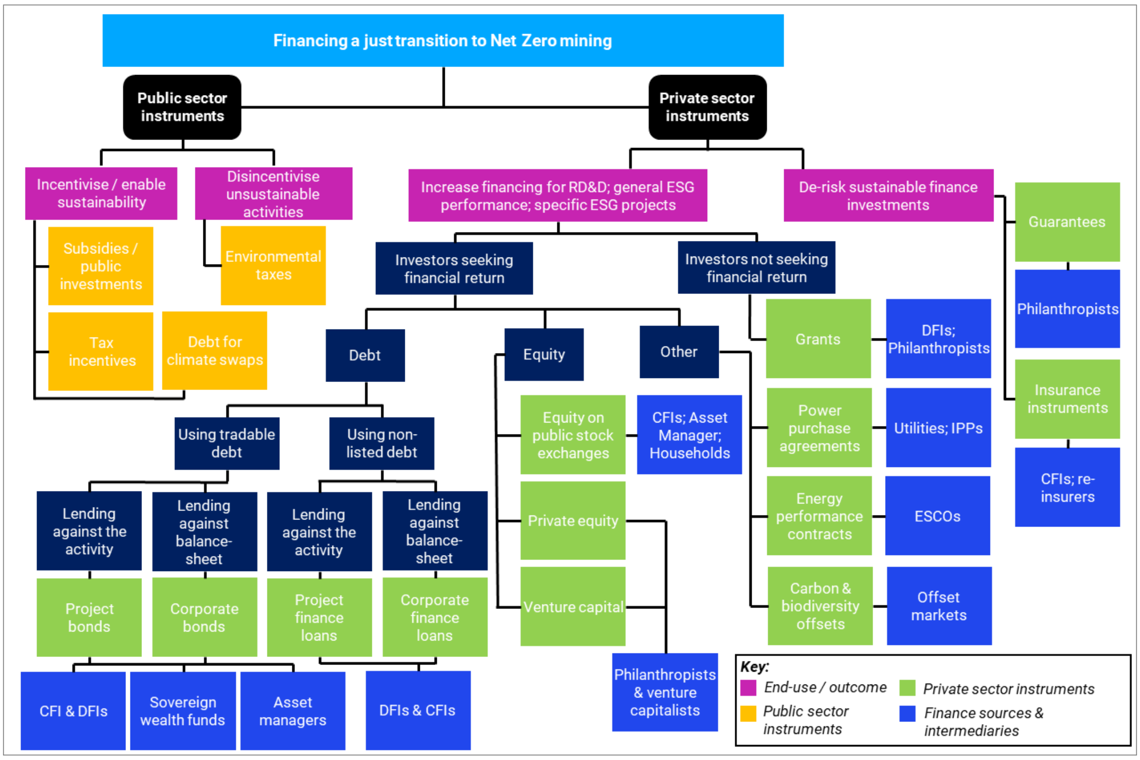


Figure 29: Mapping sustainable finance sources, intermediaries, instruments, and end-uses[clxxii]

Mining value chain actors should engage with sustainable finance providers and start identifying opportunities for using different instruments to support their transition to net zero emissions. Figure 30 identifies sustainable finance providers across different study regions that mining value chain actors can engaging. Table 12 provides additional detail on each of these financial institutions

Figure 30: Selection of financial institutions providing sustainable finance across study regions[clxxiii]

Table 12: Identifying financial institutions providing sustainable finance across study regions

Region	Country	Name of Entity	Type of Entity	Description
South America	Chile	Bank of Chile	Commercial Bank	Issued first green bond in Chile from Chilean financial institution only of US$48 mil for energy.
		ENGIE Chile	Commercial Bank	US$125 mil loan for wind farm development with a senior loan from IFC, blended finance, and Chinese fund allocation.
		IFC	Development Institution	Tracking system development for status on green finance indicators in Latin America, including Chile.
	Peru	BBVA / IFC	Commercial Bank / Development	IFC provides a US$60 mil loan to BBVA Peru to finance green buildings and climate change.
		IFC	Development Institution	Tracking system development for status on green finance indicators in Latin America, including Peru.
Asia	China	China Development Bank	Commercial Bank	One of the five principal green finance lenders in China.
		Industrial and Commercial Bank of China	Commercial Bank	One of the five principal green finance lenders in China.
		Construction Bank of China	Commercial Bank	One of the five principal green finance lenders in China.
		Bank of China	Commercial Bank	One of the five principal green finance lenders in China.
		IFC	Development Institution	Key Performance Indicator development for sustainability efforts in Chinese banks.
	Russia	Center-Invest Bank	Commercial Bank	First Russian Bank to issue Green ETF bonds that conform to local and international standards.
		VEB.RF	Russian State Development Institution	Launched the national green finance system in July 2021, allows Russian companies up to RUB50 bil for green projects.
		Societe Generale	Commercial Bank	First Green loan provider to Polymetal, Russia's second largest gold producing mining entity.
Southeast Asia	Indonesia	Bank OCBC NISP / IFC	Commercial Bank / Development	Joint IDR2.75 tril gender and green bond development, second green bond in 3 years.
		Bank OCBC NISP / IFC	Commercial Bank / Development	First Green bond in Indonesia (US$150 mil).
		Asian Development Bank (ADB)	Development Institution	Green financing loan for SDG Indonesia One-Green Finance Facility, the first of its kind program in Southeast Asia.
		IFC	Development Institution	Standardization of Sustainability reporting in the Indonesian banking sector.
	Philippines	BDO Unibank / IFC	Commercial Bank / Development	Issued first green bond in Philippines (US$150 mil) and first in East Asia and the Pacific.
		Bank of the Philippine Islands (BPI)	Commercial Bank	One of the key Philippine banks investing in green loans and financing in the region, including the SEF program, which provides capital and technical support for renewable energy project owners.
		Rizal Commercial Banking Corporation (RCBC)	Commercial Bank	One of four Filipino banks to issue green bonds (US$309 mil in 2019 for energy).
Africa	South Africa	Absa Bank Ltd.	Commercial Bank / Development	Green loan to commercial bank in South Africa to support climate-based financial services and business in the country (US$150 mil).
		Development Bank of Southern Africa (DBSA)	Development Institution	Responsible for Advisement of government-based Green Fund of R800 mil.
	Zambia	Kukula Capital	Commercial bank	ZMW 1 billion green outcomes fund provides general funding options for green finance improvements.
	Democratic Republic of Congo	Green Climate Fund	Development institution	USD 65.8 million in green finance funding for various projects in the DRC to date.

5.2. Benefits, requirements, and things to keep in mind when accessing sustainable finance

5.2.1. Benefits from pursuing sustainable finance opportunities

Mining value chain actors can take advantage of various financial and non-financial benefits from accessing and meeting the requirements for sustainable finance, including:[clxxiv]

- **Diversifying a company's investment pool and securing access to finance:** Value chain actors can attract a wider and more diverse pool of investors interested in impact and sustainable investing. Downstream actors (e.g., original equipment manufacturers (OEMs)) can also benefit from improved access to finance. Because emerging methodologies applied by investors and financiers consider value chain impacts[33], poor ESG performance in the mining value chain can effectively disqualify downstream actors from accessing sustainable finance.
- **Pricing advantages and cheaper cost of capital:** The cost structure of sustainable debt instruments can be cheaper relative to traditional debt instruments. For example, sustainability-linked bonds or loans are linked to the sustainability performance of a company or investment, with either a discount for good performance, a penalty for poor performance, or both. For mining value chain actors with poor ESG performance, the cost of capital can be between 20% and 25% higher. Good ESG performance can help value chain actors secure better terms of insurance and credit ratings. Reducing the cost of capital via sustainable finance can overcome capital investment hurdles associated with low-carbon technology interventions.
- **Communicating sustainability strategies to the market:** Sustainability-linked instruments provide an efficient means of communicating a company's sustainability strategy to the market. These instruments require clear articulation of a company's sustainability direction and targets for key performance areas (e.g., GHG emissions, water, biodiversity, health, safety) that the company will focus on. It also provides a useful means of communicating the company's sustainability actions with clients who are looking to responsibly source sustainably mined and processed metals.
- **Strengthening internal cooperation on sustainability:** meeting the requirements for sustainable finance connects ESG, operations and finance functions within a company. It also strengthens internal strategy execution and decision-making. For example, sustainability-linked instruments can support the integration of ESG considerations in an objective and measurable way into financial strategies, with similar decision-making benefits to establishing an internal carbon price (e.g., purchasing more sustainable goods and services rather than cheaper, "dirtier" goods and services).

5.2.2. Requirements for accessing sustainable finance

To secure access to sustainable finance instruments, mining value chain actors will need to meet the following general requirements (noting that different sustainable finance instruments have their own specific/unique requirements:

- Adhere to best practice principles, frameworks, and methodologies for supporting transparency and credibility of sustainability disclosures. These include the Copper Mark; the CDP; the TCFD; IFC

---

[33] Such as Partnership for Carbon Accounting Financials (PCAF) which relies on GHG Protocol and does not recognise 'unavoidable emissions' and finance classifications tools (taxonomies) that consider lifecycle emissions impacts.

Performance Standards; the UN SDGs; RMI's Risk Readiness Assessment and the Global Reporting Initiative Standards, amongst others.

- **Have ambitious sustainability and ESG-related strategy:** Mining value chain actors need to ensure minimum good governance elements are established, including a clear strategic intention to improve sustainability performance at a board level, with clear sustainability strategies, actions plans and targets to achieve this. Value chain actors should incorporate ESG into their core business strategies and transparently report their progress against targets.
- **Monitor and disclose ESG risks and performance:** Value chain actors need to provide information relating to their climate-related, environmental, and social risks (e.g., disclosing climate risks through the TCFD). Environmental metrics, particularly those monitoring climate change and GHG emissions, are the most common indicators of sustainability performance reported by companies and assessed by financiers. However, there is growing demand for more diverse metrics relating to water-use, biodiversity, waste reduction, social performance (e.g., gender equality, health and safety, human rights) and governance (e.g., governing purpose, public disclosures, risk management). Mining value chain actors need to remain up to date with upcoming best-practice for sustainability disclosures, such as the global baseline for sustainability disclosures for the capital markets currently under development by the ISSB.[clxxv]
- **Ensure net zero transition and broader sustainability plans incorporate distinctive just transition objectives.** Mining value chain actors will need to accommodate ESG methods that incorporate the evaluation of social sustainability opportunities and risks.

5.2.3. Challenges to keep in mind when accessing sustainable finance

Sustainable finance is not without its risks and challenges that mining value chain actors should keep in mind. These include:[clxxvi]

- **Greenwashing:** There is a risk that sustainability strategies, action plans and targets lack transparency, credibility, or ambition. This leads to sourcing sustainable finance to address immaterial environmental or social risks leading to greenwashing and reputational harm. Borrowers need to be careful of their use of sustainable finance instruments, particularly debt-based instruments, and ensure their sustainability strategies address all material ESG risks. For example, using green bond use of proceeds to address GHG emissions while ignoring and not disclosing water, biodiversity, and social risks - which could be of greater significance - could lead to greenwashing claims, reputational damage, and impede access to finance in the future. Similarly with sustainability-linked instruments, sustainability performance targets (SBTs) and key performance indicators (KPIs) might be marginal impact indicators (e.g., marginal GHG emissions) which cause the borrower to avoid big ticket impacts, resulting in greenwashing. In summary, defining ambition is a risk. To overcome this challenge, actors should set science-based targets.
- **Inconsistencies of data reporting:** Reporting inconsistencies can make it challenging for financial institutions to measure company sustainability performance. Companies are encouraged to adhere to best-practice methodologies for measuring and reporting sustainability performance data (e.g., TCFD, CDP, ICMM's Social and Economic Reporting Framework[clxxvii]).
- **Administrative burden:** Ensuring credible and transparent sustainability performance monitoring and reporting, and meeting the requirements of different sustainable finance instruments, has an administrative burden (e.g., monitoring and reporting SPTs and KPIs for sustainability-linked

instruments). This is particularly challenging for small companies that may not initially have the resources to ensure compliance requirements for sustainable finance. Obtaining second party verification for accessing sustainable finance instruments is another administrative burden.

- **Achieving and maintaining agreed sustainability performance:** A borrower needs to meet minimum sustainability requirements to access the benefits of sustainable finance, or be penalized (e.g., higher cost of capital) for not meeting specific targets (e.g., sustainability-link instrument KPIs). Achieving and maintaining agreed sustainability performance, while expanding copper and nickel production, will be a key challenge for mining value chain actors.
- **Commercial structures, size, risk, and timelines:** Mobilizing sustainable finance can face challenges associated with maturity mismatches between long-term sustainable investments and relatively short-term time horizons for investors. This is particularly challenging for low-carbon technology providers and in developing countries more broadly. Ticket size for different projects can also be a challenge, with investors favoring larger price projects, involving established technology with low-risk profiles and predictable financial returns. There is a gap for early stage, smaller-scale technology-based projects, if assets are not pooled (noting that pooling requires some diversification among assets).
- **Policy, regulatory and best practice gaps:** There are many sustainable finance policies, regulations, and voluntary standards/principles found across the world, but they are often incomplete, and gaps and misalignments exist between them due to the ongoing fast pace of development. For example, sustainable finance taxonomies do not yet provide criteria for sustainable mining activities. A common set of minimum policies, regulations, and voluntary standards/principles for sustainable finance is critical to address these gaps. In response, industry bodies and market forces have developed international standards, such as the ICMA's Green Bond Principles, the Climate Bond Initiative's (CBI) Climate Bond Standards and the launch of the ISSB at COP26.
- **Double counting sustainability performance and outcomes:** One such example is the reselling of green loans, the process by which bankers bundle green loans into a green bond which is sold to another financial institution. This type of arrangement allows both the banker and recipient of the bond to claim sustainable outcomes or benefits (e.g., a certain emissions reduction or avoidance) for their business, while these double counts the reality (i.e., double counting emissions reductions). Agreeing ownership of delivered sustainability outcomes between parties should be included in sustainable financing discussions.

These trends and drivers — the trend toward systematic ESG requirements in finance, and the emerging sustainable and transition finance activity and requirements — present an opportunity for proactive mining value chain actors to significantly benefit, while conservative actors that wait for the regulatory changes to act and transform corporate practices face increasing risks.

5.3. A closer look at sustainable finance instruments

Sustainable finance is not a funding path that mining value chain actors have traditionally engaged in, presenting a significant opportunity of untapped financial resources to accelerate a just transition towards net zero mining. That said, there are a few sustainable finance case studies across mining. Fortescue Metals Group raised an US$800 million green bond to funding renewable energy, energy efficiency, energy storage and transport projects, among others.[clxxviii] SQM in Chile and the Livent Corporation in Argentina, two lithium producers, each raised green bonds to finance energy efficiency projects and for facilitating the growth of electrification in the transport sector (US$700M and US$225M, respectively).[clxxix] Teck Resources executed a

US$40 billion sustainability-linked revolving credit facility, with KPI's linked to GHG emissions, health and safety and gender diversity.[clxxx] South32 secured a sustainability-linked loan, with KPIs linked to reducing GHG emissions and improving their energy- and water-use efficiency.[clxxxi] Outside of these few pockets of understanding and using sustainable finance, industry understanding of sustainable finance instrument is limited.

5.3.1. Sustainable finance for a just transition

Companies are encouraged to consider using sustainable finance instruments specifically designed to fund social interventions that support the goal of a just transition. For example, Anglo American secured a US$100 million, 10-year sustainability-linked loan with the IFC for delivering their Sustainable Mining Plan. The loan is IFC's first in the mining sector and is understood to also be a first in the mining sector globally because of its exclusive focus on social development indicators. The specific KPIs and targets of the loan agreement are aimed at supporting community development, including the creation of jobs, and improving the quality of education for more than 73,000 students in Anglo's mining regions in South Africa.[clxxxii] Using these kinds of sustainable finance instruments can provide critical funding for just transition interventions.

5.3.2. Recommendations on the use of sustainable finance instruments

External sustainable finance is an important tool that can provide corporate or project financing for the execution of a company's sustainability strategy so that it can deliver a just, net zero transition; and validate that transition. Some companies may also investment in sustainability projects from their own balance sheets (e.g., R&D, low-carbon technologies, social interventions).

The choice of sustainable finance instrument(s) used by a company to facilitate a just transition to net zero mining depends on: (i) whether the company can clearly identify specific use of proceeds that can be labelled green or social under a given sustainable finance taxonomy; (ii) whether the company has a clearly defined sustainability strategy with ambitious targets; (iii) the company's overall financing strategy (corporate or project financing, typical maturity profile, loan or bond financing); and (iv) the preferences of a company's lenders or investors. Below recommendations are provided on the use of different sustainable finance instruments to support deployment of low-carbon technology interventions and delivery of a just transition. *These recommendations are based on extensive research and stakeholder engagements on each of the instruments listed below.*

1. **Sustainable bonds and loans (use-of-proceeds):** useful when a specific use of proceeds can be identified for social or green purposes (e.g., for low-carbon technology interventions such as energy efficiency, renewable energy skills development). There is a requirement that borrowers monitor and report how the proceeds are used and what they are spent on, so these instruments are more suitable for project financing, rather than general corporate financing. Identifying specific sustainable projects can help align the borrower to the debt and sustainability principles required for accessing these instruments (e.g., an externally verified framework guaranteeing the use-of-proceeds for sustainability purposes). Given the cost and administrative burden associated with raising a bond, the size of the issuance needs to be upwards of ~US$50 million. Loans, however, can be smaller.
2. **Sustainability-linked bonds and loans (target driven):** useful for corporate financing of a range of mature low-carbon technology or other sustainable interventions. These instruments offer mining value chain actors more flexibility in how the proceeds can be used. Depending on the specific SPTs and KPIs, these instruments can fund a range of sustainable interventions, such as GHG mitigation, biodiversity, water and just transition interventions. In addition, the issuer can aggregate a greater

number of sustainable interventions, making it easier to reach the minimum size threshold for a sustainability-linked bond issuance. Since the issuer will incur financial penalties if the KPIs are not met, these instruments are only suitable for mature and proven technologies/interventions – the issuer needs to be confident the technology will work.

3. **Sustainable concessional/blended finance:** Suitable for smaller mining value chain actors in developing countries where they might not have access to capital, reasonably priced debt, or risk-friendly investors. The maturity of the technology or activity being funded will influence the specific instruments used to deliver concessional finance. For example, debt instruments are more suitable for mature technologies while grants are more suitable for less mature technologies and/or RD&D. Suitable for a range of low-carbon, sustainable and just transition interventions.
4. **Sustainable grant funding:** Suitable for funding early-stage technologies and/or RD&D into alternative technologies. These include alternative technologies for process optimization and energy efficiency (e.g., coarse particle flotation, in-situ recovery); alternative energy storage technologies; green hydrogen electrolyzers; alternative reductants; circular economy interventions and carbon removal technologies (e.g., carbon mineralization and enhanced weathering, bioenergy with carbon capture and storage (BECCS)).
5. **Listed green equity:** Best suited to large, listed mining value chain companies with mature sustainability strategies and good sustainability performance. Green equity offers companies flexibility in how they use the proceeds. Companies can finance a range sustainable technologies or interventions without the technology maturity restrictions applied to bonds and loans. Meeting stock exchange requirements to be listed as green equity can carry high administrative burden and cost. For example, companies will need to prove that business activities are sustainable or that a certain revenue percentage comes from proven sustainable activities (e.g., as stated in sustainable finance taxonomies, or sustainable equity tagging products like the London Stock Exchange Green Economy Mark).
6. **Sustainable private equity:** More suitable for established or "specialized" mining value chain actors and technology start-ups with a demonstrated track record of positive environmental and social impact. Private equity typically has less stringent sustainability requirements and more flexibility in terms of use-of-proceeds and can be used for a range of technologies or interventions. Although, this is dependent on the ambition of the financer. Adhering to best-practice sustainability standards, such as the ICMM Mining Principles or the Copper Mark, can support access to sustainable private equity.
7. **Sustainable venture capital:** Suitable for new and growing value chain actors without considerable track record, and for those driving innovative or less mature sustainability technologies or interventions. Value chain actors will need to demonstrate ambitious sustainability strategies, plans, targets, and performance to attract and secure venture capital. Adhering to best-practice sustainability standards, such as the ICMM Mining Principles or the Copper Mark, can support access to venture capital.
8. **Insurance and guarantee instruments:** Suitable for financing sustainable technologies or interventions as part of a blended finance facility in developing countries where project risks are high for commercial investors. Insurance products for biophysical climate risks are mature and common globally.

Box 21: Alternative sustainable finance instruments

Alongside vanilla debt, equity and risk-sharing instruments, instruments such as carbon or biodiversity offsets, Energy Performance Contracts (EPCs) and Power Purchase Agreements (PPAs) offer mining value chain actors alternative financing options to support their Net zero journey.

Self-developed carbon or biodiversity offsets: Mining value chain actors could self-develop carbon removal and biodiversity offset projects to offset their own residual/hard-to-abate GHG emissions and biodiversity impacts. They will have to raise the necessary capital to procure, implement, and manage the carbon removal project. Such self-developed offset projects can provide co-benefits for mine rehabilitation and post-closure livelihood plans. In the long-term (2040-2050) there is potential to sell excess offset credits to the offset market. Proceeds from the sale of self-developed credits could be used to finance future mine rehabilitation and post-closure livelihood plans or recover some of the investment for the self-developed offset project.

Energy performance contracts: Despite relatively low uptake, EPCs provide an interesting opportunity for mining value chain actors to finance energy efficiency projects. Under an EPC, an Energy Service Company (ESCO) develops, implements, and finances an energy efficiency project off the balance sheet. The customer uses the cost savings from the energy efficiency project (i.e., savings from reduced energy expenditure) to pay the ESCO for capital equipment and supporting technical services. Most suitable where large energy and cost efficiency can be achieved as these will typically deliver a shorter payback period. Such contracts can often delivery service improvements.

Power Purchase Agreements (PPAs): Suitable for mining value chain actors who cannot afford to self-develop their own renewable energy projects. Under a PPA, value chain actors can procure renewable energy from a third-party developer (who takes on the risks associated with the infrastructure and finance) in exchange for land on which the infrastructure is built. This can take place either directly through a utility grid (sleeved PPA) or notionally (a synthetic PPA where the project does not actually provide the buyer with electricity but via a financial transaction for the volume agreed).[clxxxiii] Companies can buy renewable energy (via renewable energy certificates) through a negotiated tariff from an independent energy developer who finances and operates the project optimally.

6. POLICY, LEGAL AND REGULATORY CONSIDERATIONS FOR THE NET ZERO TRANSITION

Prompted by the 2015 Paris Agreement, the regulatory framework surrounding energy-intensive industries has noticeably evolved over the past six years. While progression is not internationally uniform, the literature is now clear, at a general level, on what regulatory measures should be in place to favor strong mitigation measures and what should be removed to avoid promoting fossil fuels.[clxxxiv] International and domestic policies, laws and regulations are, therefore, important for creating a supportive enabling environment for the mining sector to transition to net zero emissions. However, policies, laws and regulations can also become a barrier to the net zero transition, particularly in circumstances where they are absent, incoherent, misaligned, or contradictory. To overcome these barriers, mining value chain actors will need to engage with governments and policy makers

The following builds on this wide general knowledge and applies it to copper and nickel mining and their value chains to provide a regulatory roadmap for their decarbonization. It identifies potential barriers related to energy policy, legal mining frameworks, climate change policy and the international trade and investment architecture. The Chapter concludes with recommendations for engaging with policy makers to overcome these barriers and accelerate the transition to net zero mining.

Box 22: Methodology summary

Each of the seven selected mining countries were graded according to whether it has enabling or dis-incentivizing regulatory factors. Grading was done on a scale of 1 to 5, with 1 being significantly discouraging and 5 being significantly enabling). Each of the grades for domestic policy and regulation are then totaled into a final score for each country in the range of 0 and 85, with 85 being the highest possible score. Countries below the score of 50 are highlighted in red, while score between 50 and 70 are yellow and above 70 is shown in green.

For smelting countries, indicators are scored on a scale 0 to 10, with 0 being significantly resistant to decarbonization and 10 being fully committed to decarbonization. Scoring indicators for smelting countries include a scale of 0 to 1 for all indicators except for total percent of waste recycled and climate policy scores, which are out of 2 and 4 points, respectively.

Each mining and smelting country, scored accordingly, was placed in a heat map to provide an overview of current policy status on copper and nickel mining and smelting operations. Smelting countries are colored according to their score between 0 and 10, while mining countries have call out boxes with their total score. *More information on the methodology is available in the Appendix "Methodology: Policy, legal and regulatory barriers assessment" – page 111.*

6.1. Considerations for copper mining value chains

Results for mining and smelting countries vary based on the principal metal of mining operations. Context for both mining and smelting countries is provided below. 67% of the six copper mining countries score less than ¾ of the 85 total score, accounting for 23% of the global copper production (Figure 31).

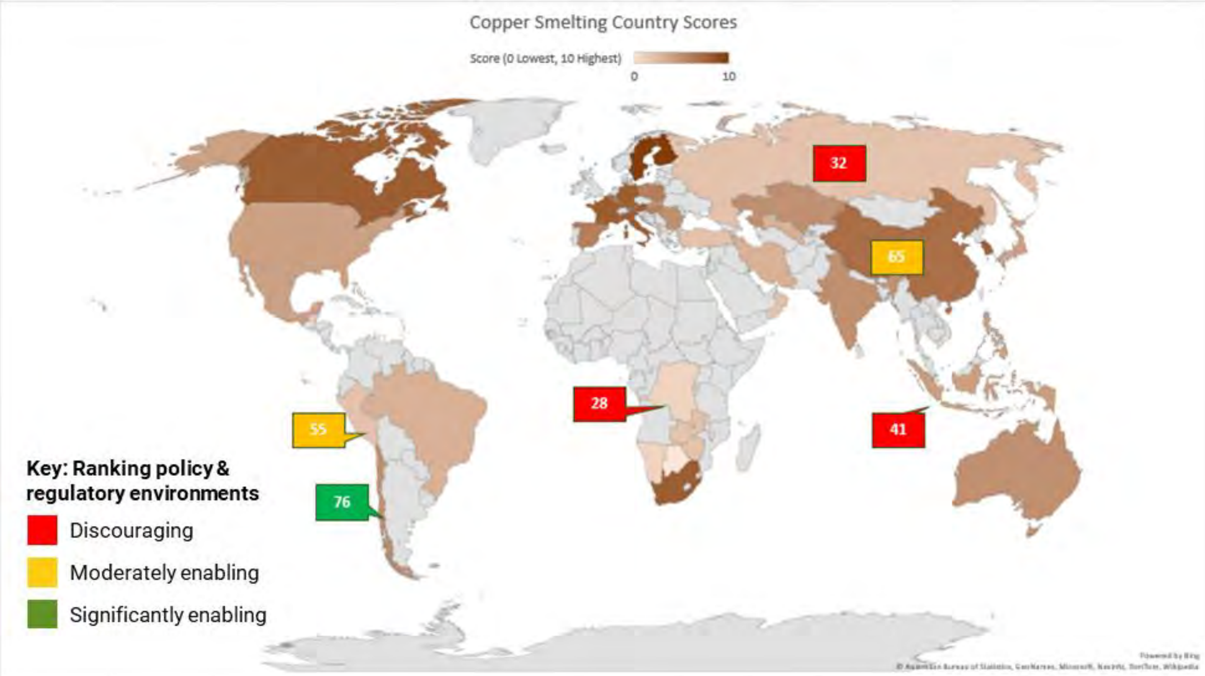


Figure 31: Copper mining and smelting country scores based on the quality of the policy and legal framework in enabling decarbonization of mining and smelting

6.1.1. Energy policy

Of the six countries analyzed, Chile, Peru, and China all scored higher than 20 out of a total of 25 in renewable energy legal framework indicators. The greatest indicator scores are for the enabling framework for independent power producer (IPP) operations and renewable energy policy framework. Most copper mining countries have well-established renewable energy goals, like minimum threshold targets in the electricity / energy mix and policies supporting private participation in electricity generation. However, not all countries authorize corporate power purchasing agreements (PPAs) whereby mining value chain actors buy directly from IPPs.

6.1.2. Legal Mining Framework

Mining legal framework scores for all countries are relatively lower than other thematic groups. All countries' mining code indicator only score a 1 or 2 out of 5 points. There is an industry-wide shortfall of mining codes that sufficiently promote emissions reductions. Without outright banning fossil fuel subsidies, with few mandates for mines to explicitly use renewable energy, and with stabilization clauses potentially exempting mines from carbon pricing, mining laws continue to inhibit sector decarbonization.

6.1.3. Climate change policy

Similarly, all copper mining countries score relatively low in the climate change policy for industrial decarbonization group. The lowest scoring sector in this group is the financial incentives score, where again all countries score a 1 or 2 out of 5 points. This indicator, which measures a country's fiscal incentives towards promoting the purchase and use of energy-efficient equipment in the industrial sectors, indicates that copper mining countries still have room to fully develop financial schemes and incentives to encourage efficiency in industrial processes and, in particular, in the mining sector. In addition, outside of Chile, green hydrogen policies are rare, and none of the countries have a full-fledged carbon pricing policy in place.

A robust national climate policy is missing in many copper smelting countries. While 57% of copper smelting countries have a net zero commitment by 2050, and 47% have a carbon pricing policy[34] in place, only 40% have both policies. Only 10% have a climate policy score of 3 or 4. Some 79% of global copper smelting capacity takes place outside of the highest scoring countries, including Canada, Western and Northern Europe, South Africa, and South Korea.

Waste management laws and agencies in copper smelting countries are associated with high recycling rate of metals. Some 74% of copper smelting countries contain both a national law for solid waste management and a national agency to enforce it. In 65% of smelting countries, recycled waste stream represents more than 20% of the total waste stream. However, for 26% of countries, national laws for solid waste management and national enforcement agencies are still missing. The latter countries are more likely to have recycled waste streams below the global average of approximately 20%. Very few countries with a law in place do not have a national agency. Overall, it appears that copper smelting is currently operating in an environment that does not encourage decarbonization.

Table 13: Policy and regulation scores for copper mining countries broken down by thematic group

Larger Goal	Low carbon intervention	Indicator[clxxxv]	Copper Mining Countries					
			Chile [clxxxvi]	Peru [clxxxvii]	Russia [clxxxviii]	China [clxxxix]	DRC[cxc]	Indo-nesia [cxci]
Energy policy: Renewable Energy	Renewable Energy and Energy Storage	RE Framework	5	5	4	5	1	3
		IPP Operations	5	5	5	5	3	3
		Net-Metering	5	1	1	5	1	1
		Short-term Target	5	5	1	5	1	4
		Corporate PPA Authorization	5	5	2	2	3	1
Legal Mining Framework	Renewable Energy, Operational and Process Energy Efficiency, Fuel Switching and Electrification, Tailings reprocessing	Mining Code	2	1	1	2	1	1
		Community Consultation	5	4	1	1	5	3
		Biodiversity Offset	5	5	1	3	1	3
		Water	5	5	2	5	2	5
		Best Available Techniques	5	1	3	5	1	1
Climate change policy: Industrial Decarbonization	Renewable Energy, Operational and Process Energy Efficiency,	NDC reduction targets	5	5	4	5	3	5
		Biofuel Blend	5	5	1	5	1	5
		Green Hydrogen Policy	5	1	1	2	1	1

34 For the carbon price assessment: Absence of carbon pricing scored 1; plans to implement carbon price scored 2. The level of the pricing was then considered and scored as follows: below $\text{US\$40}/tCO_2e$, the score was 3; between $\text{US\$41}/tCO_2e$ and $\text{US\$60}/tCO_2e$ the score was 4 and greater than $\text{US\$60}/tCO_2e$, the score was 5.

	Fuel Switching and Electrification	Research and Development	5	2	1	5	1	1
		Minimum Energy Performance Standards	5	2	1	5	1	1
		Financial Incentives	1	2	1	2	1	1
		Carbon Price	3	1	2	3	1	2
Total Score (out of 85)			**76**	**55**	**32**	**65**	**28**	**41**

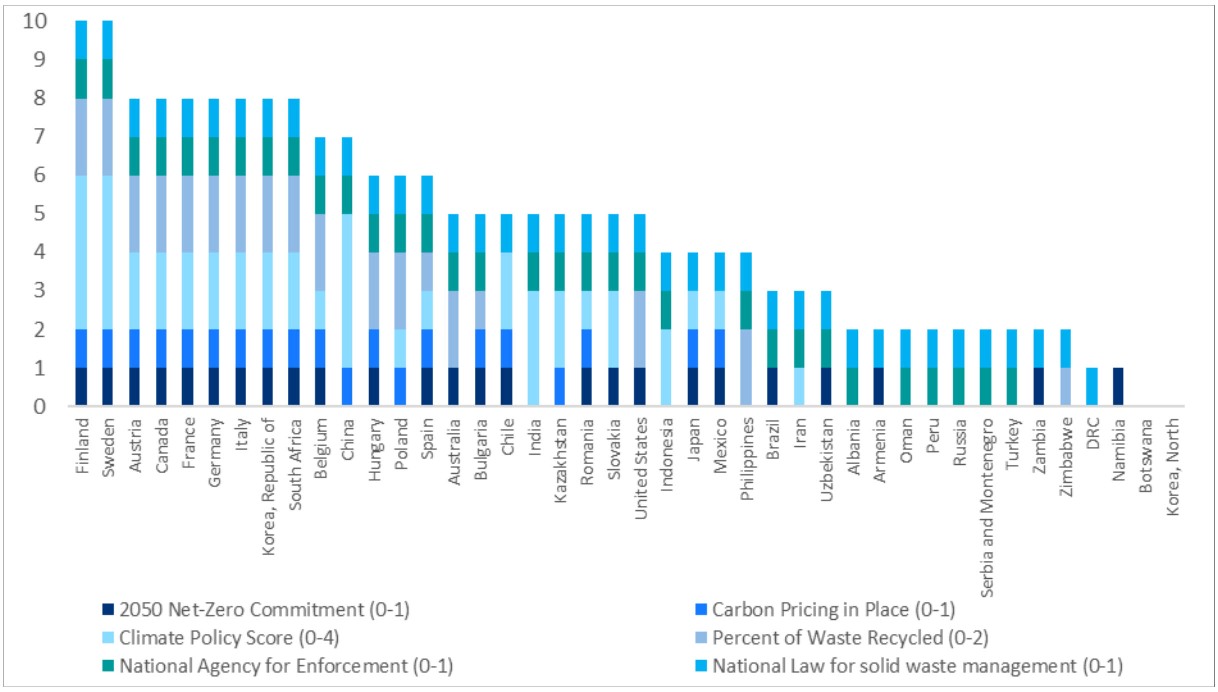


Figure 32: Scores of every major copper smelting country (scores range from 10 highest – 0 lowest)[cxcii]

6.2. Considerations for nickel mining value chains

All three nickel mining countries score less than ¾ of the 85 score, accounting for 55% of global nickel production (Figure 33).

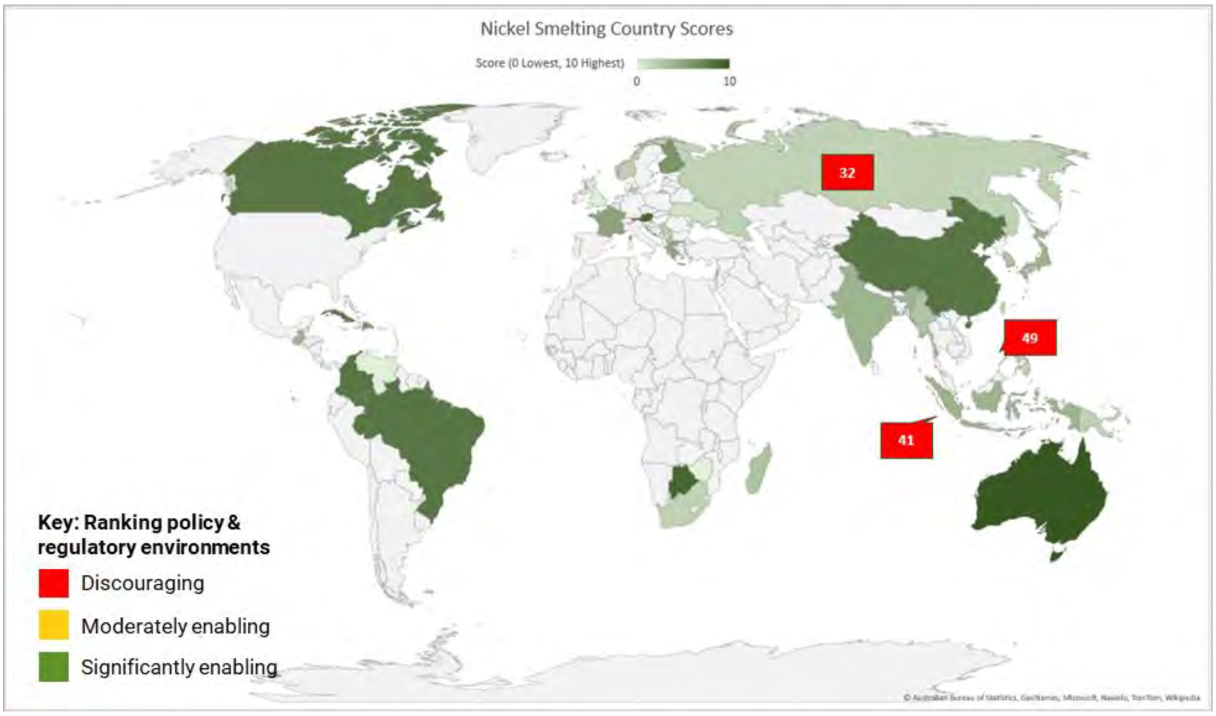


Figure 33: Nickel mining and smelting country scores based on the quality of the policy and legal framework in enabling decarbonization of mining and smelting

6.2.1. Energy policy

Nickel mining countries have relatively strong renewable energy policy frameworks, but they remain basic. Nickel mining countries score high on the renewable energy policy indicators, in particular when it comes to enabling IPPs to operate. The lowest scoring indicator in this category is net-metering, and although private electricity generation is strongly supported, enabling infrastructure for net-metering is not yet in place for Russia, Philippines, and Indonesia, while corporate PPAs are not yet authorized in Russia and Indonesia.

6.2.2. Legal Mining Framework

The newest industry best-practices for regulation have not gone into full effect in nickel mining countries. The modern standard for environmental impact assessments for mining operations include both a strong policy to regulate biodiversity offsets according to the mitigation hierarchy and the use of Best Available Techniques, which mandates mining operations to rely on best technologies for maximum environmental performance. These techniques are not fully implemented in nickel mining countries. Consequently, mining legal framework scores for nickel mining countries are low for both of these indicators, with only Indonesia and Russia scoring a 3 out of 5, respectively for biodiversity and Best Available Techniques. In addition, as with copper mining countries, the mining laws remain a hindrance to decarbonization in nickel mining countries.

6.2.3. Climate change policy

Similarly, all nickel mining countries score relatively low in the climate change policy for industrial decarbonization group. The lowest scoring sector in this group is the minimum energy performance standard score, which scores 1 out of 5 for Russia, Philippines, and Indonesia. This indicator measures a country's adoption of minimum performance standards for industrial uses of vehicles, buildings, machines, and overall operations. Low scores in these standards indicate that these countries must make significant effort to standardize the mining and industry sectors and set an energy efficiency threshold. Nickel countries also rarely have policies advancing green hydrogen, financial incentives for efficiency, carbon tax, or public support for RD&D programs.

Climate policies are weak in most nickel smelting countries. Only 55% of these countries have a Net zero commitment by 2050, 41% only have a carbon pricing scheme, and only 35% have both policies in place. Additionally, only 16% of nickel smelting countries in the sample have a climate policy score of 3 or 4. Just like for the copper smelting countries, most nickel smelting (60% for nickel smelting countries) takes place outside of the highest scoring countries of Northern and Western Europe, Canada, South Africa, and South Korea. Climate policies overall are not strong enough to incentivize decarbonization of nickel smelting.

Waste and recycling frameworks do not guarantee that materials are recycled. While most nickel smelting countries that have both national laws for solid waste management and a national agency to enforce them score full points for recycled waste, it is not always the case that recycling takes place meaningfully: In fact, 33% of nickel smelting countries that have both national laws for waste management and enforcement either do not report or have values of recycled waste that amount to less than 10% of their total waste stream. Additionally, 16% of countries do not have either of these policies in effect, all of which have recycled waste streams lower than the global average of approximately 20%. Ensuring that policy, once established, remains effective is a challenge particularly for middle- and low-income countries.

Table 14: Policy and regulation scores for nickel mining countries broken down by thematic group

Larger Goal	Low carbon interventions	Indicator[cxciii]	Nickel Mining Countries		
			Russia[cxciv]	Philippines[cxcv]	Indonesia[cxcvi]
Energy policy: Renewable Energy	Renewable Energy and Energy Storage	RE Framework	4	5	3
		IPP Operations	5	5	3
		Net-Metering	1	1	1
		Short-term Target	1	5	4
		Corporate PPA Authorization	2	5	1
Legal Mining Framework	Renewable Energy, Operational and Process Energy Efficiency, Fuel Switching and Electrification, Tailings reprocessing	Mining Code	1	2	1
		Community Consultation	1	5	3
		Biodiversity Offset	1	1	3
		Water	2	4	5
		Best Available Techniques	3	1	1
Climate change policy: Industrial Decarbonization	Renewable Energy, Operational and Process Energy Efficiency,	NDC reduction targets	4	2	5
		Biofuel Blend	1	5	5

Larger Goal	Low carbon interventions	Indicator[cxciii]	Nickel Mining Countries		
			Russia[cxciv]	Philippines[cxcv]	Indonesia[cxcvi]
	Fuel Switching and Electrification	Green Hydrogen Policy	1	2	1
		Research and Development	1	2	1
		Minimum Energy Performance Standards	1	1	1
		Financial Incentives	1	2	1
		Carbon price	2	1	2
Total Score (out of 85)			**32**	**49**	**41**

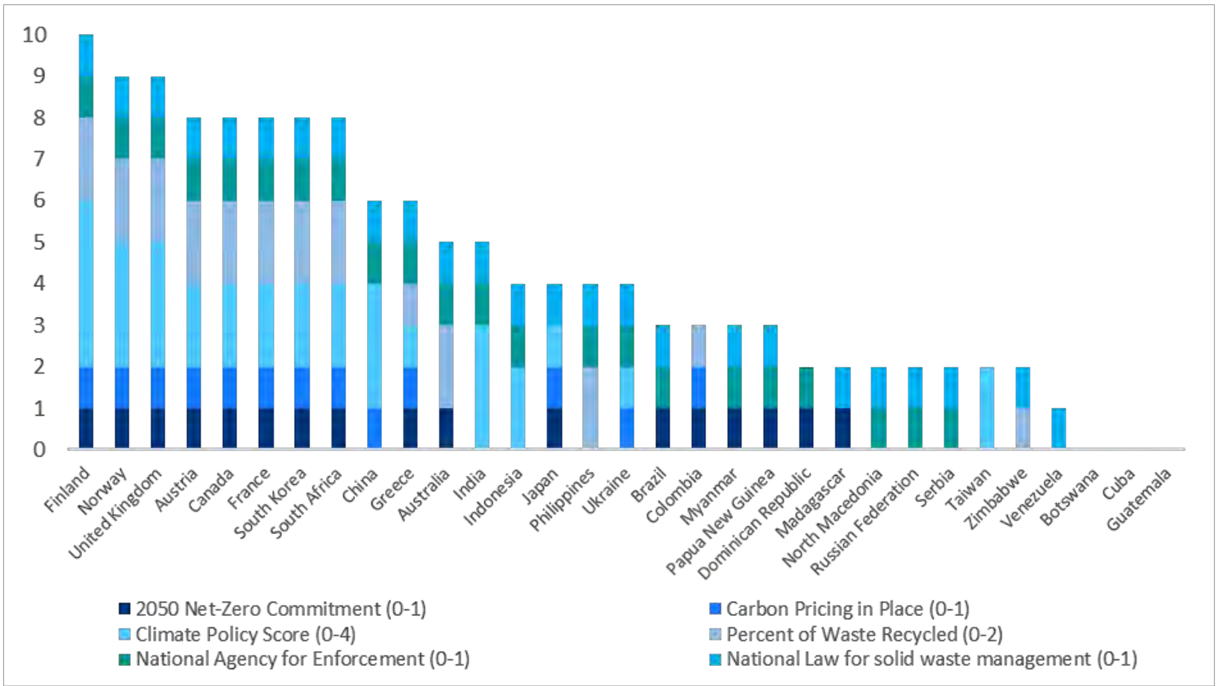


Figure 34: Scores of every major nickel smelting country (scores range from 10 highest – 0 lowest)[cxcvii]

6.3. International trade and investment architecture

Core elements of the international trade and investment architecture work as decarbonization barriers.[cxcviii] The World Trade Organization (WTO) is considered to be in a state of crisis and, as such, unable to serve countries' need for an effective multilateral forum to negotiate comprehensive rules to ensure that international trade supports decarbonization efforts. Lacking such a forum, national-level decarbonization policies and practices are not being coordinated, and international trade rules addressing decarbonization are not being developed and applied. Comprehensive reforms addressing the multifaceted reasons for the crisis of the WTO are needed, so that the WTO is reinvigorated as a multilateral forum and adopts climate-aligned international trade rules to support and accelerate decarbonization.

In turn, the existing network of more than 2500 investment treaties and chapters, coupled with their mechanisms of investor–state dispute settlement (ISDS) through international arbitration, offer extraordinary legal protections and remedies to carbon-intensive investments, making it difficult and costly for host countries to adopt decarbonization-oriented policies. At the same time, these instruments fail to integrate climate policy considerations and to offer countries strong mechanisms to enforce climate and broader environmental laws and regulations against foreign investors. To address these pervasive barriers to decarbonization, countries need to profoundly reform investment treaties or terminate or withdraw from them, and instead adopt investment governance frameworks that support decarbonization.

Opportunities exist to strengthen or enact decarbonization enablers in international legal frameworks. Going significantly beyond the existing aspirational provisions on dialogue and cooperation on environmental and climate-related issues, contained in a small number of trade and investment treaties, countries could negotiate international legal frameworks with *binding and enforceable commitments on decarbonization enablers* with specific actions and measurable targets.

Notably, countries can commit in international legal frameworks to *removing fossil fuel subsidies*, which would enable decarbonization, as they distort competition by artificially making carbon-intensive energy sources more attractive, thus discouraging renewable energy investment, besides perpetuating existing inequalities between developing and developed countries. Decarbonization could also be enabled by greater international cooperation and coordination on carbon pricing schemes (for example, through *border carbon adjustments* (BCAs)—charges levied on imported carbon-intensive goods and services), *harmonization of methods to measure the embedded carbon of goods and services, and tax incentives for decarbonization measures. Climate-oriented banking standards and guidelines* would lead the international financial system to prioritize zero-emissions investment.

6.4. Recommendations for overcoming policy, legal and regulatory barriers

Engaging in policy-making processes can help overcome barriers and foster a more supportive enabling environment for the net zero transition. To foster the development of a framework of international agreements and domestic policies, laws, and regulations conducive to decarbonization, mining value chain actors are encouraged to:

6.4.1. Proactively engage in policy-making processes:

Mining value chain actors need to be proactive, collaborative, and constructive in engaging in domestic and international policy-making processes and initiatives to foster a more favorable enabling legal environment for a just net zero mining transition (e.g., by participating in international multi-stakeholder initiatives to develop and propose model regulations).

6.4.2. Align positioning and public sector engagement strategies:

Align sector-wide and company-specific lobbying policies with ambitious climate action to show coherence across the mining value chain. Coherent internal positioning and aligned government relations concerning climate action is needed. Coherent collective action and multi-stakeholder engagement is likely to be more effective than piecemeal approaches

6.4.3. Agree on and communicate needs and barriers with governments:

Reach sector-wide agreement on ambitious climate change policies, existing legal barriers to ambitious climate action, growing transition risk of policy sluggishness, proposed solution to barriers and the sector’s readiness to anticipate urgent and ambitious climate policy measures. Communicate sector-wide agreements to government with support of industry associations (e.g., ICMM, IGF).

6.4.4. Prioritize action in regions with weak enabling environments:

Prioritize action in regions with high potential supply but poor enabling environments. Non-governmental actors and development finance may play an especially important role in these regions. Support from the IFC is crucial to build capacity in developing country governments to strengthen domestic and international legal and policy frameworks and bring them in line with climate change goals, ensuring that these frameworks support and encourage, and do not undermine, decarbonization efforts throughout global value chains, including those of nickel and copper.

7. COLLABORATIVE INITIATIVES TO SUPPORT THE NET ZERO TRANSITION

Transitioning to net zero copper and nickel mining value chains will require a coordinated effort by different actors, both within and outside the mining value chain. The magnitude of transitioning copper and nickel mining value chains to net zero emissions, in an inclusive and just manner, is beyond the resources and control of any single company or government. While a company can make substantial contributions to achieving net zero emissions (e.g., adapting internal procurement policies and switching to renewable energy sources), several barriers and challenges are outside its direct control (e.g., technology innovation, access to sustainable finance, market development, mitigation action by supply chain actors[35] and national policies and regulations that might hinder the deployment of low-carbon technologies). Such challenges can only be overcome through multi-stakeholder collaboration.[cxcix]

The following Chapter maps various global initiatives that could support individual value chain actors execute the net zero Roadmap and discusses the importance of collaboration for influencing the broader, external ecosystem and enabling environment. It concludes with recommendations for collaborating to address scope 3 emissions.

7.1. Collaboration to drive change in the external ecosystem

Industry collaboration and collective commitments to net zero emissions, and other sustainable development initiatives, provide important market signals that can influence the broader ecosystem and help overcome external barriers to the transition[cc]. Mining value chain actors can collectively influence the broader, external ecosystem and enabling environment by joining and working with various initiatives (e.g., the ICMM). This will help send important market signals to drive technology innovation, market development, sustainable finance flows, and public policy for addressing scope 1, 2 and 3 emissions.

Facilitated collaboration through an initiative can aggregate the pipeline of opportunity and demand for low-carbon interventions through non-competitive means. For example, becoming an ICMM member and collectively committing to net zero scope 1 and 2 emissions, or joining the EV100 and RE100 initiatives, informs technology providers, financiers, supply chain actors and governments that the sector is committed to taking action and driving change. Doing so can encourage these external actors to increase investments in low-carbon technologies, fast-track market development and create innovative finance instruments to support wider uptake and deployment of low-carbon technologies for minimizing scope 1, 2 and 3 emissions.

Collectively engaging with policymakers and governments through representative initiatives can help overcome potential regulatory barriers to the deployment of low-carbon technologies and a just transition to net zero emissions[cci]. By pooling resources to engage with policy makers and governments, mining value chain actors can develop more efficient public engagement strategies, stronger and more credible arguments, and demonstrate greater backing through collective commitments and actions.

[35] Mining supply chain actors are those upstream and downstream of the defined mining value chain (extraction and processing). They provide inputs into the extraction and processing stages of the mining value chain, as well as purchase copper and nickel to further process into finished goods (e.g., copper wire, solar panel etc.).

This can help address scope 2 emissions by encouraging governments to increase the deployment of grid-based renewable energy. It can also help address scope 1 and 3 emissions by fostering a more favorable enabling environment for the deployment of low-carbon interventions within copper and nickel mining operations and across their supply chains. Public-private partnerships are also critical for the deployment of low-carbon interventions and ensuring a just transition (e.g., shared ownership models for renewable energy deployment).

7.2. Collaboration to support mining value chain actors implement the net zero Roadmap

Engaging with sustainable and responsible mining, technology and collaborative initiatives[36] can support individual copper and nickel mining value chain actors implement the net zero Roadmap, by leveraging their networks, expertise, technical capacity and resources.[ccii] Figure 35 maps the various global initiatives available to the mining value chain actors and where on the mining value chain (extraction, processing and transportation) they can provide support for implementing elements of the Roadmap. It categorizes selected global initiatives according to their core focus areas:

- Responsible and sustainable mining initiatives
- Copper and nickel industry associations
- Low-carbon technology innovation and deployment initiatives
- Cross-cutting collaborative initiatives
- Voluntary carbon offset standards

It also maps each group of initiatives against the copper and nickel mining value chain (as indicated by the value chain icons) to identify where they could provide collaborative support to individual companies across the value chain.

Engaging with and joining these initiatives, can provide individual companies (and the broader sector) with the following support and co-benefits:

Aspirational ESG commitments: Joining responsible and sustainable mining initiatives, will help individual companies commit to best practice for inclusive, responsible, and sustainable mining value chains. For example:

- ICMM members are required to adhere to the ICMM's Principles for good ESG performance.
- The Copper Mark and Joint Due Diligence Standard for Copper, Lead, Nickel, and Zinc provide an assurance standard for responsibly and sustainable produced copper and nickel.
- IRMA's Standard for Responsible Mining defines good practices for what responsible mining should look like at the industrial scale and provides a third-party certification to further encourage improved ESG performance by value chain actors.[cciii]

[36] For the purpose of this document, "initiatives" are defined as global collaborative platforms, within and outside of the mining sector, that can support different elements of the Roadmap (e.g., from low-carbon technology deployment and responsible carbon offsetting, to improving social performance and supporting a just transition).

Figure 35: Mapping sustainable & responsible mining; technology and collaborative initiatives against the mining value chain

Increased climate ambition and action: Achieve net zero by 2050 through increased ambition and commit. For example:

- ICMM members have committed to net zero GHG emissions by 2050 or sooner.
- The TPI (Transition Pathways Initiative) is a global initiative which assesses companies' preparedness for the transition to a low carbon economy.[cciv]

Awareness and capacity building: Build in-house knowledge, expertise, and capacity for *monitoring*, *disclosing* and *reducing* GHG emissions and other ESG risks. For example:

- The ICMM provides various guidance documents and support for improving ESG performance.
- The ICA and NI provide a range of techno-economic, market, sustainable development, and ESG-related performance support.[ccv]

Low-carbon technology deployment: Reduce scope 1 and 2 emissions by supporting companies to access and deploy low-carbon technology interventions. This can be done either directly, by supporting market access and development, or indirectly through policy and regulatory advocacy. For example:

- WIPO Green provides an online platform for low-carbon technology exchange.
- The ICMM's Innovation for Cleaner, Safer Vehicles initiative brings member companies together with OEMs, in a non-competitive space, to accelerate the development of new generation mining vehicles and improve existing ones. This initiative supports the reduction of scope 1 emissions and improves the health and safety of workers.
- The Global Mining Guidelines (GMG) Group have an Electric Mine Working Group that "aims to accelerate the adoption of all-electric technologies in mining, address the challenges associated with them, and share information on how they can enable safer, more efficient, productive, and cost-effective mines".
- The United Nations Climate Technology Centre & Network provides companies with low-carbon technology solutions and capacity building. It also provides advice on policy, legal and regulatory frameworks to foster greater technology exchange and deployment.[ccvi]

Technology innovation: Fast-track research, development, and deployment (RD&D) and piloting of innovative low-carbon and sustainable technologies that enable the Net zero transition by 2050. For example:

- The Green Hydrogen Catapult aims to drive massive green hydrogen scale-up by 2026.
- The Ellen MacArthur Foundation provides evidence-based research on circular economy opportunities and how they can contribute to tackling climate change and biodiversity loss across various sectors.[ccvii]

Credible, Net zero-aligned carbon offsetting: Engaging with voluntary carbon offset standards can support the development of credible carbon offset strategies that use net zero-aligned carbon offsets to neutralize residual emissions for achieving Net zero. These standards also verify that carbon offset projects or credits adhere to best practice and can support individual companies connect with project developers and access offset markets. For example:

- The Gold Standard provides: (i) best practice standards and eligibility requirements for investing in credible carbon offsets; (ii) support for self-developing own offset projects, and (iii) access to offset markets, amongst a host of additional services.

- The Climate Action Reserve provides information about the Offset Market place in the USA, including a list of project developers; traders and brokers; retails and exchanges.[ccviii]

Sustainable finance: Access to sustainable finance through direct engagement, awareness raising and networking with financiers and investors, and indirect engagement through ESG-related disclosures and performance support. For example:

- The Third Derivative connects technology innovators with a network of financiers to accelerate innovation, market transformation and technology deployment.
- The Mission Possible Partnership works with financiers to facilitate networking, climate and transition finance, and sustainable finance policy.[ccix]

Stakeholder engagement: Bring actors and stakeholders together, by leveraging initiatives' convening power to close gaps in relationships and communication, particularly between mining value chain companies, governments, communities, civil society, and labor. Some initiatives also support engagement with governments and policy advocacy to strengthen the enabling environment for a net zero transition. For example:

- The ICA and CA connect upstream and downstream parts of the copper value chain and provide a common platform to advocate for shared interests with policy makers, governments, and other key stakeholders.[ccx]

Knowledge sharing and partnerships for a just transition: Contributing to a just transition is beyond the resources of any one company and will require collaboration between stakeholders within and outside the mining value chain. Engaging with collaborative, just transition initiatives can support knowledge sharing and capacity development to help mining value chain actors develop and implement robust just transition strategies. For example:

- The Just Transition Initiative engages with stakeholders to create policy recommendations and strategies for achieving a just transition. It also identifies and addresses knowledge gaps – in both the conceptual and practical understanding of a just transition – and facilitates knowledge sharing and partnerships among stakeholders and scholars.
- The ICMM's Skills for our Common Future initiative, will support member companies "achieve the ambition of building skills for host communities to fully participate in the economy of the future, delivered through partnerships between the mining sector, communities, government and civil society"[ccxi].

Roadmap users are encouraged to use Table 15 and Table 16 to identify initiatives that can provide them with the necessary support they need for their net zero journey, and then to engage with them. Table 15 provides a closer look at: (i) the type of support each initiative provides, and (ii) the stakeholders each initiative primarily engages with. Table 16 provides an overview of selected international Voluntary Carbon Offset Standards and gives an indication of the support each provides. Box 23 provides an overview of the evaluation criteria used in Table 15.

Box 23: Evaluation criteria for the comparative analysis of collaborative initiatives

Stakeholder scope provides an indication of the various stakeholders the initiative works, engages, or collaborates with. *Expertise and support services* provides an indication of the type of expertise and support services provided by each initiative. These are categorised into the following type of initiatives:

- Technology acceleration (targeted at specific technology readiness levels): R&D (TRL 1-3, Providing R&D expertise/support services to stimulate new technologies); Development and piloting (TRL 4-6, Supporting technology development or piloting); Deployment (TRL 7-9, Supporting deployment of technology).
- Sustainable finance: Providing sustainable finance thought-leadership or supporting access to sustainable finance.
- Policy advocacy: Providing policy and regulation support, and/or engaging in policy and regulation advocacy with governments or regulatory bodies.
- Stakeholder engagement and collaboration: Supporting stakeholder engagement and collaboration.
- Sustainable mining and ESG: Sharing expertise in implementing sustainable practices and principles for mining, and/or that can support with ESG reporting and assurance.
- Technical capacity and knowledge sharing: Developing and sharing technical research or supporting actors with technical goods and services (such as emissions reporting and accounting, energy audits and broader technical research for net zero mining).

Table 15: Comparative analysis of selected global initiatives that can support an inclusive net zero transition[ccxii]

INITIATIVE	STAKEHOLDER SCOPE								EXPERTISE AND SUPPORT SERVICES							
	Mining value chain actors	Industry associations	Financiers	Government / regulators	Supply chain actors	Local communities	Civil Society & labor	Researchers	R&D	Development and piloting	Deployment	Finance	Policy advocacy	Stakeholder engagement / collaboration	ESG / Assurance	Technical support / Capacity
SUSTAINABLE & RESPONSIBLE MINING INITIATIVES																
International Council Mining and Metals (ICMM)	✓	✓	✓	✓	✓	✓	✓	✓				✓	✓	✓	✓	✓
The World Bank's Climate-Smart & Forest-Smart Mining initiatives	✓		✓	✓				✓				✓	✓		✓	✓
Global Mining Guidelines Group (GMG)	✓	✓		✓	✓			✓	✓	✓	✓					✓
Initiative for Responsible Mining Assurance (IRMA)	✓		✓	✓		✓	✓					✓	✓	✓	✓	
Intergovernmental Forum on Mining, Minerals, Metals & Sustainable Development (IGF)	✓			✓									✓			✓
Executive Industries Transparency Initiative (EITI)	✓			✓	✓		✓						✓		✓	
World Economic Forum - Mining and Metals Industry Community	✓	✓					✓	✓						✓	✓	✓
Responsible Minerals Initiative (RMI)	✓	✓		✓	✓	✓	✓							✓	✓	✓
Responsible Mining Foundation (RMF)	✓				✓	✓									✓	✓
COPPER VALUE CHAIN INITIATIVES																
The International Copper Association, Ltd. (ICA) and the Copper Alliance (CA)	✓	✓		✓	✓			✓					✓	✓	✓	✓
The Copper Mark	✓		✓									✓			✓	
International Copper Study Group (ICSG)	✓	✓		✓				✓	✓	✓	✓			✓		✓
NICKEL VALUE CHAIN INITIAITVES																
The Nickel Institute (NI)	✓	✓		✓	✓			✓							✓	✓
NiPERA Inc.	✓	✓		✓				✓					✓		✓	✓
International Nickel Study Group (INSG)	✓	✓		✓	✓			✓					✓		✓	✓
LOW-CARBON TECHNOLOGY INITIAITVES																
WIPO Green	✓	✓	✓	✓	✓			✓			✓	✓				✓
Amira Global	✓	✓						✓	✓	✓	✓				✓	✓
World Economic Forum – Digital Transformation Initiative (WEF DTI)	✓	✓	✓		✓			✓	✓	✓	✓			✓		✓

INITIATIVE	STAKEHOLDER SCOPE								EXPERTISE AND SUPPORT SERVICES							
	Mining value chain actors	Industry associations	Financiers	Government / regulators	Supply chain actors	Local communities	Civil Society & labor	Researchers	R&D	Development and piloting	Deployment	Finance	Policy advocacy	Stakeholder engagement / collaboration	ESG / Assurance	Technical support / Capacity
Think and Act Differently (TAD)	✓	✓						✓	✓	✓	✓	✓		✓		✓
The UN Climate Technology Centre & Network (CTCN)	✓	✓		✓	✓			✓	✓	✓	✓		✓			✓
RE100 Initiative	✓	✓		✓									✓			✓
Energy Resource Governance Initiative (ERGI)	✓	✓		✓									✓		✓	✓
The Energy and Mining Collaboration (EMC)	✓	✓	✓	✓	✓	✓		✓	✓	✓						✓
EV100 Initiative	✓	✓		✓	✓						✓		✓	✓		
Smart Freight Centre (SFC)	✓	✓		✓	✓			✓					✓			✓
The World Economic Forum's Global Battery Alliance (WEF GBA)	✓	✓	✓	✓	✓		✓	✓			✓	✓	✓	✓		✓
Green Hydrogen Catapult	✓				✓			✓	✓	✓	✓	✓				✓
The Electric Mine Consortium (EMC)	✓							✓			✓					✓
The Green Hydrogen Coalition (GHC)	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓	✓		✓
Charge on Innovation Challenge	✓									✓			✓	✓		
The International Council on Clean Transportation (ICCT)		✓		✓							✓	✓			✓	✓
Third Derivative (D3)	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓	✓		✓
ReThink Mining	✓				✓			✓	✓	✓				✓		✓
Ellen MacArthur Foundation	✓			✓	✓		✓	✓	✓				✓	✓		✓
CROSS-CUTTING COLLABORATIVE INITIATIVES																
The Partnering Initiative (TPI)	✓	✓		✓	✓	✓	✓						✓	✓		✓
Leadership Group for Industrial Transition (LeadIT)	✓	✓	✓	✓	✓		✓	✓				✓	✓	✓		✓
The Transition Pathways Initiative (TPI)	✓		✓									✓			✓	✓
The Just Transition Initiative	✓	✓		✓		✓				✓			✓	✓	✓	
Just Transition Centre	✓	✓		✓		✓				✓			✓	✓	✓	
The B Team	✓	✓				✓	✓							✓		

INITIATIVE	STAKEHOLDER SCOPE								EXPERTISE AND SUPPORT SERVICES							
	Mining value chain actors	Industry associations	Financiers	Government / regulators	Supply chain actors	Local communities	Civil Society & labor	Researchers	R&D	Development and piloting	Deployment	Finance	Policy advocacy	Stakeholder engagement / collaboration	ESG / Assurance	Technical support / Capacity
Mission Possible Partnership (MPP)	✓	✓	✓	✓	✓			✓			✓	✓	✓	✓		✓

Copper and nickel mining value chain actors should engage with International Voluntary Carbon Offset Standards to ensure their use of carbon offsets aligns with best practice. Engaging with Offset Standards (Table 16) can help value chain actors in self-developing credible carbon offset projects, and in verifying registering and retiring them at the appropriate time to reach net zero emissions. They can improve awareness and understanding of the offset market ecosystem as well (e.g., the Climate Action Reserve provides information about the Offset Market place in the USA, including a (non-exhaustive) list of project developers; traders and brokers; retails and exchanges). These standards can also assist with GHG emissions accounting methodologies to avoid associated risks and help mitigate any E&S risks that might arise from the offset project. Some standards also provide access to offset markets, where credible offset credits can be purchased to neutralize any unforeseen increases in residual emissions.

Engaging with the International Carbon Reduction & Offset Alliance (ICROA) can strengthen the broader ecosystem and enabling environment for net zero aligned carbon offsets. ICROA is, to some extent, more of a “thought leadership organization” that aims to drive best practice, rather than a voluntary standard. Value chain actors should not only stay up to date with the latest research by ICROA but encourage other initiatives, like the ICMM, for example, to endorse their recommendations to drive a more credible voluntary offset market.

Responsible and sustainable mining initiatives should collaborate with Voluntary Carbon Offset Standards initiatives to develop and include specific net zero-aligned carbon removal offset criteria into voluntary sustainable mining standards. There appears to be a potential gap in voluntary sustainable mining standards for the credible use of carbon removal offsets to achieve Net zero emissions. In the absence of specific carbon removal criteria, individual companies have the added burden of engaging with and adhering to different initiatives and standards. This could potentially lead to misalignment in the use of offsets by copper and nickel mining value chains actors, threatening the validity of net zero targets and claims.

Table 16: Review of International Voluntary Carbon Offset Standards[ccxiii]

Standard	Best practice standard/ regulations	Independent assessment / verification	GHG accounting methodologies	Registry	Project development	Access to markets
Gold Standard	✓	✓		✓	✓	✓
Verra	✓	✓	✓	✓	✓	
Climate Action Reserve (CAR)	✓	✓	✓	✓	✓	
American Carbon Registry (ACR)	✓	✓	✓	✓		
International Carbon Reduction & Offset Alliance (ICROA)	✓					

7.3. Collaboration for addressing Scope 3 emissions

Collaborating with copper and nickel supply chain actors will be critical for minimizing scope 3 emissions – a significant source of emissions that threatens the achievement of net zero targets. A company’s supply chain typically accounts for the bulk of their GHG emissions (and other ESG impacts), with the CDP suggesting that scope 3 emissions are, on average, 11 times higher than a company’s scope 1 and 2 emissions[ccxiv]. The challenge with addressing scope 3 emissions is that they are largely outside of a company’s direct control, but are within its sphere of influence (e.g., mining value chain actors can encourage suppliers to produce and transport goods in a more sustainable way). Therefore, collaborating with supply chain actors to encourage and help them reach net zero is critical for minimizing copper and nickel mining value chain actors' scope 3 emissions.

A strategic focus should be to encourage supply chain actors to minimize their scope 1 and 2 emissions before endorsing their use of carbon removal offsets. Various "scope 3 interventions" exist that deliver business-to-business or initiative-to-business collaborations for minimizing scope 3 emissions. These interventions can be broadly categorized into the three groups depending on their desired outcomes: (i) stakeholder engagement to improve knowledge and awareness; (ii) incentives and penalties to encourage action by supply chain actors; and (iii) direct and indirect supply chain support.[ccxv]

i. **Stakeholder engagement to improve knowledge and awareness**: Awareness & information sharing can improve supply chain actors' understanding of: (i) climate change risks; (ii) best practice for measuring and disclosing GHG emissions (including global reporting and ambition standards); (iii) GHG emissions mitigation interventions and responsible use of Net zero-aligned carbon offsets, and (iv) how to access sustainable finance, amongst others. Improved stakeholder awareness encourages stronger ambition, commitment & action, and can be done directly by hosting webinars and workshops, or indirectly through sharing third-party reports, publications, webinars, etc. Knowledge sharing shouldn't be limited to climate change but include various ESG risks, such as water security; pollution; health and safety, a just transition and so on.

ii. **Incentives and penalties to encourage supply chain action**: Using incentives and penalties (e.g., discounts, minimum requirements, and/or benchmarking suppliers/customer performance) can encourage sustainable behavior change; reward first movers and healthy competition among suppliers and customers. Using an internal carbon price to inform procurement policies and decision-making, for example, can be used to encourage preferential procurement of low-carbon goods and services. Procurement policies can also be adapted to include minimum emissions content requirements by suppliers (e.g., including a minimum carbon content threshold for all capital goods purchased). These can later be adapted to include other ESG -related requirements, such as minimum water footprint or recycled content requirements. Similar mechanisms can be used to encourage behavior change by customers (e.g., including minimum requirements in contractual agreements).

iii. **Direct and indirect supply chain support**: Directly support mitigation by supply chain actors through joint ventures (e.g., collectively investing in renewable energy deployment); or by financing their monitoring and reporting, and mitigation efforts. Indirectly support supply chain mitigation through policy advocacy in host countries to strengthen the enabling environment (e.g., advocate for policy and regulatory changes that reduce potential barriers to the deployment of low-carbon technologies). Engage with finance institutions to inform them of supply chain actors mitigation needs and try foster increases sustainable finance flows to support supply chain mitigation.

7.4. Recommendations for fostering multi-stakeholder collaboration

Mining value chain actors are encouraged to strategically engage with a diverse range of initiatives that can best address their transition needs. Rather than engaging with as many initiatives as possible, or only certain types of initiatives (e.g., technology focused), value chain actors should strategically choose which initiatives to engage with. Companies should consider the following when choosing initiatives:

- Strategically engage with initiatives that align with a company's transition needs and strategic objectives, and that provide the relevant support services and access to relevant stakeholders. It is recommended that value chain actors identify their performance and transition needs before short-listing potential initiatives to engage.
- Engage with a broad range of initiatives to take advantage of a diverse pool of experts, stakeholders, partnerships, support services, technologies, and markets. Include technology-focused initiatives and collaborative initiatives that support policy advocacy. Without policy advocacy support, regulatory barriers to technology deployment will hinder a company's Net zero journey.

Responsible and sustainable mining initiatives should look to provide more guidance on net zero-aligned carbon offsetting and include carbon removal offset criteria into their voluntary standards. While there are numerous responsible and sustainable mining initiatives (ICMM; RMI; RMF; ICA; Copper Mark; NI etc.) that provide a tremendous amount of guidance and support for addressing various ESG risks, there appears to be a gap for responsible and net zero-aligned carbon offsetting. In the short-term (~2022 – 2030), these initiatives should aim to increase industry knowledge of best practice for Net zero-aligned carbon offsetting by through portion papers, publications, and stakeholder engagements. In the medium-term (~2030 – 2040), responsible and sustainable mining initiatives should look to include specific criteria for the responsible use of carbon removal offset into existing voluntary sustainability standards, guidelines, and frameworks.

Copper and nickel producers should align to the requirements of voluntary sustainable and responsible mining standards, such as the ICMM's Mining Principles, Copper Mark, Joint Due Diligence Standard, and IFC's Performance standards, amongst others. Aligning with and meeting the requirements of these voluntary standards will ensure collective towards achieving responsibly & sustainably produced copper and nickel. This will also support improved access to finance and markets in the future, improve individual competitiveness and provide important market and regulatory signals to strengthen the enabling environment for the net zero transition.

Collaborate with supply chain actors (upstream and downstream) to mitigate scope 3 emissions. This can be done through various mechanism, such as knowledge sharing and awareness building; incentives and penalties to encourage behavior change; and/or through direct and indirect support to supply chain actors for minimizing their emissions.

8. CONCLUSION

The GET threatens to perpetuate the climate change crisis if GHG emissions from primary production of ETMs (e.g., copper and nickel) do not reach net zero by 2050. Meeting the 1.5°C temperature target is expected to significantly increase demand for ETMs. Copper and nickel demand is projected to increase by 156% and 208% above 2020 levels respectively.

Under a BAU scenario, increasing demand for copper and nickel could increase GHG emissions from their primary production by 125% and 90% respectively (equivalent to 192 $MtCO_2e$ and 168 $MtCO_2e$ per year, respectively, by 2050). This presents a significant decarbonization challenge for both copper and nickel mining value chains and for the broader energy transition.

To reach net zero emissions and align with a 1.5°C temperature trajectory, mining value chain actors will need to reduce their absolute GHG emissions by ~50% by 2030 and by ~90% by 2050 (from 2020 levels). This equates to an average reduction rate of 4.2% per annum (from a 2020 baseline). Mining value chain actors are encouraged to follow the mitigation hierarchy for achieving net zero emissions: (i) monitor, report and set emissions reduction targets; (ii) avoid and minimize absolute emissions, (iii) invest in "beyond value chain mitigation" during the mitigation journey, and (iv) neutralize the remaining 10% of hard-to-abate emissions using credible carbon removal offsets.

A suite of cost-effective low-carbon technologies are already available for avoiding and reducing GHG emissions. These include energy efficiency interventions; autonomous and digital solutions; renewable energy (e.g., solar, wind, battery storage); fuel switching opportunities (e.g., sustainable biofuels, green hydrogen), and electrification solutions (e.g., battery electric vehicles (BEVs), trollies, conveyors) and circular economy interventions. Additional research and development is still required to scale up technologies such as larger electric haulage trucks, green hydrogen electrolyzers and fast charge technologies.

Carbon removal offsets are critical for achieving net zero emissions, but they must not be used as a substitution for absolute GHG emissions reductions. While implementing low-carbon technology interventions will minimize absolute GHG emissions, there will inevitably be some degree of unavoidable, hard-to-abate residual emissions (~10% or less of 2020 levels). To reach net zero emissions by 2050, any residual emissions will need to be "neutralized" using credible carbon removal offsets.

On their journey to net zero emissions, mining value chain actors are encouraged to mitigate additional environmental and socio-economic risks (beyond GHG emissions) that might stem from growing demand for ETMs and the transition to net zero mining value chains. Deploying low-carbon technologies can have unintended environmental and socio-economic consequences that need to be managed carefully. Unsustainable land-use change from increased mining can perpetuate the climate and biodiversity crises and threatens to exacerbate existing social challenges in mining regions and communities.

Therefore, to support an inclusive transition to net zero mining, one that benefits all stakeholders because of increased demand, it is critical that value chain actors play their part in enabling a just transition. A just transition for copper and nickel mining value chains should be broad and governed "for additionality" with net-positive environmental and socio-economic outcomes for all stakeholders. Mining value chain actors are encouraged to maximize and ensure equitable distribution of benefits and opportunities resulting from the expansion of ETM mining and broader net zero transition (e.g., providing a healthy and sustainable environment, decent work, social dialog, and inclusion, access to basic services for improving peoples' livelihoods, health, well-being, and autonomy and resilience). Collaboration is needed across mining value chain actors, governments, labor, and civil society to collectively, and inclusively, work towards delivery of a just transition.

Enabling a just transition to net zero mining value chains will not be without its challenges, least of which those associated with financing and policy and regulatory barriers. Mining value chain actors are encouraged to take advantage of sustainable finance opportunities and deploy sustainable finance instruments (like sustainability-linked bonds and loans) to kick-start their transition. Collaborating with governments to overcome policy and regulatory barriers is also critical.

The mining of ETMs is the foundation of the GET. The sustainability of mining practices will, therefore, influence the outcome of the GET. If mining continues on a carbon-intensive BAU trajectory, it could undermine the energy transition and lead to an overshoot of the 1.5°C temperature target. The Roadmap hopes to inspire and guide an accelerated transition towards net zero emissions whilst considering broader ecosystem actions, such as management of ESG impacts, dealing with policy challenges, and securing access to sustainable finance, that are essential to support the transition to net zero.

9. APPENDIX

9.1. Biodiversity impacts from mining activities

Table 17: Mining value chain impacts on biodiversity[ccxvi]

Potential impacts	Mining value chain activities									
	Plant site, materials handling, etc.	Extraction and waste rock storage	Rock blasting and ore removal	Mine dewatering	Placer and dredge mining	Ore stockpiling	Pyrometallurgical processing	Hydrometallurgical processing	Use and storage of process chemicals	Tailings containment/ disposals
Terrestrial biodiversity										
Loss of ecosystems and habitats	X	X			X					
Loss of rare and endangered species	X	X			X					
Effects on sensitive or migratory species	X	X	X				X	X		
Aquatic biodiversity										
Altered hydrologic regimes	X	X	X	X	X			X		X
Altered hydrogeological regimes		X	X	X				X		X
Increased heavy metals, acidity, or pollution	X	X	X	X	X	X		X	X	X
Increased turbidity (suspended solids)	X	X	X		X	X		X		X
Risk of groundwater contamination	X	X	X	X		X		X	X	X
Air quality impacts on biodiversity										
Increased ambient particulates (TSP)	X	X	X			X	X			X
Increased ambient sulfur dioxide (SO_2)							X			
Increased ambient oxides of nitrogen (NO_x)							X			
Increased ambient heavy metals	X	X	X			X	X			X
Social interfaces with biodiversity										
Loss of access to fisheries	X	X								X
Loss of access to fruit trees, medicinal plants	X	X								X
Loss of access to forage crops or grazing		X		X		X		X		X
Restricted access to biodiversity resources		X								X
Increased hunting pressures	X									

9.2. Baseline ESG risk assessment for copper and nickel mining

The Roadmap developed an ESG Risk Assessment Framework that aligns with existing ESG risk assessment methodologies and standards (Table 18). This framework was used to for the baseline ESG risk assessment of copper and nickel mining and for identifying potential ESG risks, trade-offs or co-benefits associated with the deployment of low-carbon technology interventions.

Table 18: ESG Risk Assessment Framework

Metric	Description	Alignment to ESG frameworks
Environmental metrics		
GHG emissions & Air quality	GHG emissions, or the avoidance thereof, that contribute to climate change risks. Also includes impacts on air quality via air pollution. i.e., the GHG emissions and air quality performance of a low-carbon intervention.	GRI, CDP, CDSB, ASAB, TCFD, IFC, ICMM, RMI, SDG13
Water management	Impacts on water quantity and quality, and, therefore, local water security. Also refers to the sustainable management of potential water-related risks.	GRI, CDP, SASB, WEF, IFC, ICMM, RMI, SDG 6 and 14
Energy management	Energy-use management, including clean energy sources but with a focus on energy efficiency/energy intensity.	GRI, IFC, CDP, ICMM, RMI, SDG 7 and 13
Waste and hazardous materials	The production and leakage of waste and hazardous materials into the environment that can cause environmental degradation and impact on human health, including tailings management.	GRI, IFC, ICMM, RMI, SDG 12
Ecosystems & Biodiversity	Impacts to ecosystem health, the provision of ecosystem services and biodiversity that might result from land-use change and the leakage of waste and hazardous materials into the environment. This also includes issues related to mining in protected areas, mine-rehabilitation, and mine-closure plans.	GRI, CDP, WEF, IFC, ICMM, RMI, SDG 14 and 15
Biophysical risks from Climate Change	The biophysical risks to mining value chains that result from climate change (such as extreme temperatures, drought, wildfires, floods, and extreme weather) and, therefore, includes climate adaptation and resilience.	CDP, TCFD, ICMM
Social metrics		
Health & Safety	Impacts on health and safety of employees and communities who participate in mining, processing and transportation activities, and low-carbon interventions.	GRI, SASB, WEF, IFC, ICMM, RMI, SDG 3
Employment, decent work & livelihoods	A broader metric that includes mine-level issues related to employment availability, decent work, skills development and training, worker redundancy management, and labor relations. It also includes broader employment and livelihood support for local communities and host-countries, such as local procurement and employment, socio-economic development plans, education contributions, and displacement/resettlement and post-closure livelihood planning.	GRI, SASB, WEF, ICMM, RMI, SDG 8
Security	Refers to the physical security of workers and communities in high-conflict areas (such as crime and violence), in addition to and resource security for employees and communities (such as food, water and energy security)	GRI, IFC, ICMM, RMI, SDG 2, 6, 7 and 16
Human rights	The protection of all fundamental human rights, without distinction, including the right to life and liberty, not to be subjected to slavery or torture, trafficked and child labor, freedom of opinion, movement and speech, the right to education, work, and a safe environment.	GRI, ICMM, RMI, SDG 2, 3, 4, 5, 6, 7, 8 and 16
Equality, diversity, and inclusion	Non-discrimination, inclusion and participation of all races, cultures and ethnic backgrounds, women, youth, and persons with disabilities in direct mine value chain activities or indirect activities within communities. It also includes the advancement of previous social metrics (such as health and safety, security, and human rights etc.) to all races, cultures and ethnic backgrounds, women, youth and persons with disabilities, such as local employment of women or supporting women entrepreneurship, for example.	GRI, IFC, SASB, WEF, ICMM, RMI, SDG 1, 5 and 10
Indigenous & local community relations	Relationships and inclusive engagements with indigenous and local communities, including conflict/grievance management, stakeholder mapping, participatory social dialogue, collaboration, the protection of Free Prior and Informed Consent, and the preservation of social, economic, cultural, and political institutions.	GRI, IFC, ICMM, RMI, SDG 16 and 17

Governance metrics		
Governing purpose	The acknowledgement of a company's social and environment impacts within the company's stated purpose.	GRI, WEF, ICMM, RMI
Quality & accountability of governing bodies	The composition and accountability of a company's governing body, executive and non-executive bodies, including their expertise and demographic composition.	GRI, WEF, RMI
Business ethics & integrity	Includes the development and enforcement of polices and mechanisms related to: anti-bribery and corruption, reporting unethical or unlawful behavior, lobbying practices, labor and community relationships and grievance mechanisms.	GRI, WEF, RMI, ICMM
Public disclosures	Public disclosures related to contracts and grants for the right to extract minerals, tax and financial disclosures, payment to producing countries, beneficial ownership, and responsible contracting and sourcing related to human rights, labor and environmental impacts of suppliers and contractors. This includes public disclosures related to environmental and social performance, such as environmental commitments and annual sustainability reports.	GRI, WEF, ICMM
Risk & opportunity oversight	Identification, management of and response plans for material market, regulatory, environmental, and social risks facing a company.	EPIC, WEF, SASB, ICMM, RMI
Mine-closure & post-closure viability	Includes both environmental mine-rehabilitation and post-closure livelihood viability issues. In other words, the management of post-closure transitions for affected ecosystems and communities, to ensure continued viability of the environment and their livelihoods.	GRI, RMI

Figure 36 and Figure 37 provide a summary of the baseline ESG risk assessment for copper and nickel respectively. In addition to an extensive literature review, the assessment utilized the 2020 Responsible Mining Index[ccxvii] results as a proxy for establishing the ESG risk baseline. It was based on copper and nickel mining companies with operations across the study regions (South America, central and southern Africa, Asia, Southeast Asia, and Asia Pacific regions). Those with copper and/or nickel operations outside of these locations were omitted from the assessment.

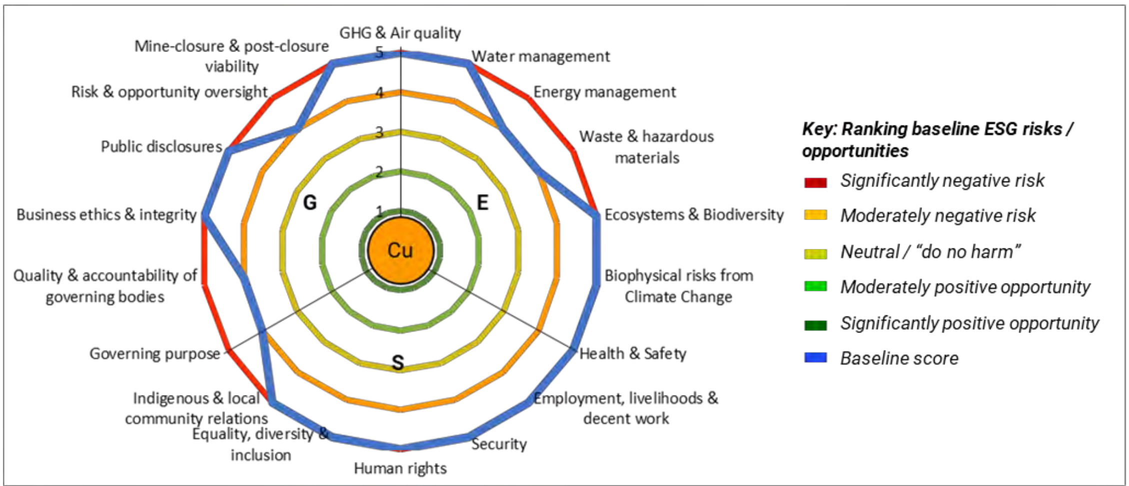


Figure 36: Copper baseline ESG assessment

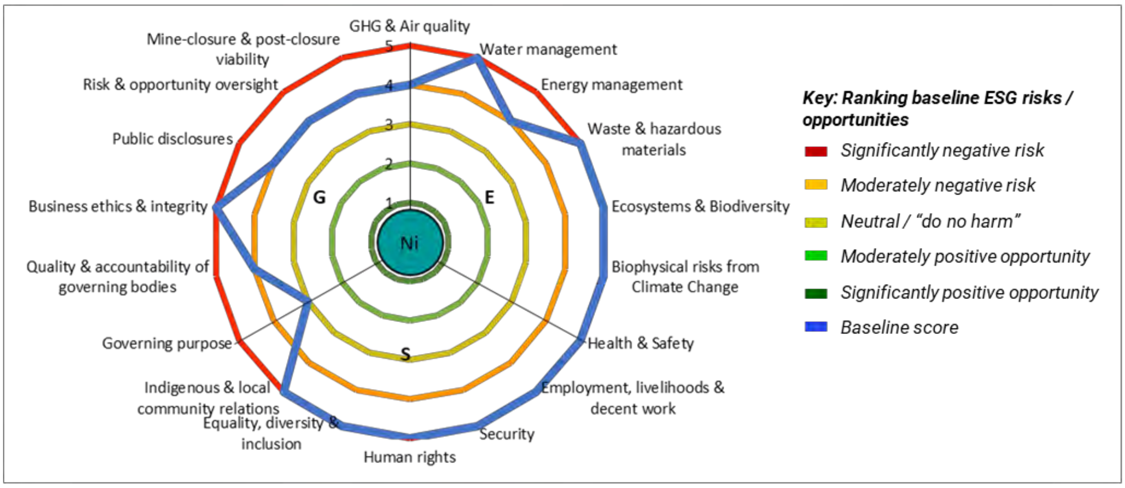


Figure 37: Nickel baseline ESG assessment

The baseline results suggest that the negative risks associated with copper and nickel mining value chains outweigh any positive opportunities or benefits provided by each value chain, particularly with regards to social metrics. This is often the case where socio-economic benefits are experienced at a national level, through contributions to GDP, income, and mining rents. However, negative socio-economic impacts are often felt at local level, through disruptions to livelihoods, increased water scarcity, forced resettlement and health impacts, with little access to health care.[ccxviii]

While this assessment provides a generalized overview of the risks facing each value chain more broadly, it is not to say that individual companies are not performing better against some of these metrics. Further, this analysis is not intended to expose poor performance against ESG metrics but rather highlight those ESG risks that need to be addressed whilst transitioning to a net zero emissions, and those that might be reduced or exacerbated when implementing low-carbon technology interventions.

9.3. Methodology: Policy, legal and regulatory barriers assessment

9.3.1. Regulatory and implementation environment along the value chain

After a sound literature review of the regulatory factors surrounding mitigation technologies, this Chapter created a matrix of the regulatory barriers and enablers for each type of mitigation strategy for the seven mining countries with the largest deposits in copper, nickel, or both (Chile, Peru, Russia, Philippines, Indonesia, DRC, and China). For these countries, 16 indicators are measured, grouped in three general categories (Table 19).

Table 19: Policy, law, and regulatory assessment indicators

Category	Indicators
Renewable energy enabling framework	Regulatory framework favorable for renewables development
	Enabling legal framework for private participation in generation (IPPs)
	Net-metering for industrial companies owning renewable energy
	Short-term target for the percentage of renewable energy in the electricity matrix
	Authorization of corporate Power Purchase Agreements (companies signing with third parties)
Legal framework for mining and spill-overs for decarbonization interventions	Mining code and contracts that promote emissions reductions and mitigation (no stabilization clauses preventing carbon taxes, no fossil fuel subsidies, and a specific mandate to use renewable energy to power operations)
	Community consultation processes
	Existence of biodiversity offset policy for industry based on mitigation hierarchy in environmental impact assessment (EIA) processes
	Best Available Techniques requirement in EIA processes
	Water policies applicable to mining that encourage recycling and zero wastewater
Industry decarbonization policies	Nationally Determined Contribution (NDC) with unconditional emission reduction commitments (by 2030)
	Biofuel blending standards applicable to industry vehicles
	Green hydrogen policy
	Public support to R&D in clean processes
	Minimum energy performance standards (MEPS) for industry (vehicles, buildings, machines)
	Financial or fiscal incentives for energy-efficient equipment
	Carbon price

The analysis selected six indicators to track: (1) commitment to net zero by 2050, (2) carbon pricing regulations, (3) percent of waste recycled, (4) existence of a national law for waste management, (5) existence of a national agency to enforce waste management laws, and (6) a climate policy score. These data come from known net zero commitments, World Bank climate pricing information, the Climate Change Performance Index, and the World Bank data catalogue. We also characterize the state of recycling in these countries given its importance for decarbonization in these stages.

The analysis also accounted for international legal instruments on investment and trade— notably agreements at the World Trade Organization (WTO), bilateral investment treaties (BITs), and free trade agreements (FTAs)— which can or do work as decarbonization barriers or enablers. While some international instruments have a global, cross-cutting nature (WTO law, soft-law norms), others vary depending on the country or countries analyzed (BITs and FTAs). These international legal factors can or do affect multiples steps of the value chain from mining to finished products and, depending on the low-carbon interventions being assessed, pertain to all relevant aspects (social, environmental, economic, trade, etc.).

9.3.2. Analysis of regulatory and implementation challenges and opportunities

Each of the seven selected copper and nickel mining countries were graded according to whether they had enabling or discouraging regulatory factors. Grading was based on a scale of 1 to 5, with 1 being significantly discouraging and 5 being significantly enabling.

Summary of scoring:

1. There is no current action toward or existence of the indicator
2. There is no current action toward or existence of the indicator
3. There is current action and existence of the indicator. However, there is minimal progress towards achieving the indicator within the given country,
4. There is current action and existence of the indicator. Additionally, there is major progress towards achieving the indicator with only minor problems and concerns,
5. There is current action and existence of the indicator. Additionally, the indicator has been fully achieved within the given country.

Each of the grades for domestic policy and regulation are then totaled into a final score for each country in the range of 0 and 85, with 85 being the highest possible score. Countries below the score of 50 are highlighted in red, while score between 50 and 70 are yellow and above 70 is shown in green. The scoring was

For smelting countries, indicators are scored on a scale from 0 to 10, with 0 being significantly resistant to decarbonization and 10 being fully committed to decarbonization. Scoring indicators for smelting countries include a scale of 0 to 1 for all indicators except for total percent of waste recycled and climate policy scores, which are out of 2 and 4 points, respectively.

Each mining and smelting country, scored accordingly, was placed in a heat map to provide an overview of current policy status on copper and nickel mining and smelting operations. Smelting countries are colored according to their score between 0 and 10 while mining countries have call out boxes with their total score.

9.3.3. International trade and investment architecture

Where the international legal framework works as a significant discouraging factor for decarbonization, or where it represents opportunities to enable decarbonization that are either partially or entirely missed, it is strongly recommended that countries come together and redesign applicable international rules. Considerations on barriers and enablers resulting from the international legal framework cannot be put on a heat map, given the application of that framework across various countries. Accordingly, the analysis is summarized in two synthesis tables. The first characterizes how the international legal framework on trade and investment may work as decarbonization barriers, as well as identifies how countries may remove those barriers. The second synthesis table identifies enablers that are or could be present in international legal instruments, presents reasons why each enabling measure identified does or could enable decarbonization, and outlines how countries can strengthen the measure, when it is in place, or to enact it, when it is absent.

10. REFERENCES

[i] Krishnan, M., Nauclér, T., Pacthod, D., Pinner, D., Samandari, H., Smit, S., and Tai. H. 2021. Solving the net-zero equation: Nine requirements for a more orderly transition. McKinsey & Company. https://www.mckinsey.com/business-functions/sustainability/our-insights/solving-the-net-zero-equation-nine-requirements-for-a-more-orderly-transition#.

[ii] IPCC, 2018: Summary for Policymakers. In: *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty* [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)]. *World Meteorological Organization, Geneva, Switzerland, 32 pp.*

[iii] UN. 2015. Paris Agreement to the United Nations Framework Convention on Climate Change, Dec. 12, 2015. https://unfccc.int/sites/default/files/english_paris_agreement.pdf.

[iv] IPCC, 2022: Summary for Policymakers. In: Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [P.R. Shukla, J. Skea, R. Slade, A. Al Khourdajie, R. van Diemen, D. McCollum, M. Pathak, S. Some, P. Vyas, R. Fradera, M. Belkacemi, A. Hasija, G. Lisboa, S. Luz, J. Malley, (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA. doi: 10.1017/9781009157926.001.

SBTi. 2021. SBTi corporate net-zero standard. Version 1.0. Science-based Targets initiative (SBTi). https://sciencebasedtargets.org/resources/files/Net-Zero-Standard.pdf.

[v] C. Xu, Q. Dai, L. Gaines, M. Hu, A. Tukker, and B. Steubing. 2020. Future Material Demand for Automotive Lithium-Based Batteries. Communications Materials, vol. 1, no. 1, p. 99. doi: 10.1038/s43246-020-00095-x.

[vi] Ribeiro, H. 2021. Volkswagen's Plan on LFP Use Shifts Hydroxide Dominance Narrative in EV Sector. *S&P Global*. https://www.spglobal.com/platts/en/market-insights/latest-news/metals/031721-volkswagens-plan-on-lfp-use-shifts-hydroxide-dominance-narrative-in-ev-sector.

Alamalhodaei, A. 2021. What Tesla's Bet on Iron-Based Batteries Means for Manufacturers. *TechCrunch*. https://techcrunch.com/2021/07/28/what-teslas-bet-on-iron-based-batteries-means-for-manufacturers/.

[vii] Nilsson, A.E. et al. 2017. A Review of the Carbon Footprint of Cu and Zn Production from Primary and Secondary Sources. *Minerals*, vol. 7, no. 9, p. 168.

[viii] S. Glöser, M. Soulier, and L. A. Tercero Espinoza. 2013. Dynamic Analysis of Global Copper Flows. Global Stocks, Postconsumer Material Flows, Recycling Indicators, and Uncertainty Evaluation. *Environmental Science & Technology*, vol. 47, no. 12, pp. 6564–6572. doi: 10.1021/es400069b.

B. K. Reck, D. B. Müller, K. Rostkowski, and T. E. Graedel. 2008. Anthropogenic Nickel Cycle: Insights into Use, Trade, and Recycling. *Environmental Science & Technology*, vol. 42, no. 9, pp. 3394–3400. doi: 10.1021/es072108l.

[ix] According to Bloomberg New Energy Finance.

[x] Maisch, M. 2019. Lithium-Ion Recycling Rates Far Higher Than Some Statistics Suggest. *PV Magazine*. https://www.pv-magazine.com/2019/07/12/lithium-ion-recycling-rates-far-higher-than-some-statistics-suggest/.

[xi] USGS. 2021. Iron and Steel Scrap. USGS. https://pubs.usgs.gov/periodicals/mcs2021/mcs2021-iron-steel-scrap.pdf.

[xii] US EPA. 2016. *Advancing Sustainable Materials Management: 2014 Fact Sheet*. https://www.epa.gov/sites/default/files/2016-11/documents/2014_smmfactsheet_508.pdf.

[xiii] Melin, H. 2019. *State-of-the-Art in Reuse and Recycling of Lithium-Ion Batteries—A Research Review*, Swedish Energy Agency. http://www.energimyndigheten.se/globalassets/forskning--innovation/overgripande/state-of-the-art-in-reuse-and-recycling-of-lithium-ion-batteries-2019.pdf.

[xiv] Kumagai, J. 2021. Lithium-Ion Battery Recycling Finally Takes off in North America and Europe. *IEEE Spectrum*. https://spectrum.ieee.org/lithiumion-battery-recycling-finally-takes-off-in-north-america-and-europe.

[xv] A. Elshkaki, T. E. Graedel, L. Ciacci, and B. K. Reck. 2016. Copper Demand, Supply, and Associated Energy Use to 2050. *Global Environmental Change*, vol. 39, pp. 305–315. doi: 10.1016/j.gloenvcha.2016.06.006.

[xvi] Emissions estimates are based on: W. Wei, P.B. Samuelsson, A. Tilliander, R. Gyllenram, and P.G. Jönsson. 2020. Energy Consumption and Greenhouse Gas Emissions of Nickel Products. *Energies*, vol. 13, no. 21. doi: 10.3390/en13215664.

[xvii] Lèbre, É., Stringer, M., Svobodova, K., Owen, J.R., Kemp, D., Cote, C., Arratia-Solar, A., and Valenta, R.k. 2020. The social and environmental complexities of extracting energy transition metals. Nature Communications 11, 4823. https://www.nature.com/articles/s41467-020-18661-9.

RMF. 2021. Harmful impacts of mining. Responsible Mining Foundation (RMF). https://www.responsibleminingfoundation.org/harmful-impacts-mining/.

[xviii] Paul, B.K. and Rashid, H. 2017. Chapter six: Land-use change and coastal management. In: Climate Hazards in Coastal Bangladesh. Paul, B.K. and Rashid, H. (eds). Butterworth-Heinemann.

[xix] Kivinen, S. 2017. Sustainable post-mining land use: Are closed metal mines abandoned or re-used space? Sustainability, 9. doi:10.3390/su9101705.

[xx] Sleeter, B.M., Loveland, T., Domke, G., Herold, N., Wickham, J. and Wood, N. 2018. Land Cover and Land-Use Change. In: Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II. Reidmiller, D.R., Avery, C.W. Easterling, D.R. Kunkel, K.E. Lewis, K.L.M. Maycock, T.K. and Stewart B.C. (eds). U.S. Global Change Research Program, Washington, DC, USA. https://nca2018.globalchange.gov/chapter/5/.

IPCC. 2019: Summary for Policymakers. In: Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems. P.R. Shukla, J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.-O. Pörtner, D. C. Roberts, P. Zhai, R. Slade, S. Connors, R. van Diemen, M. Ferrat, E. Haughey, S. Luz, S. Neogi, M. Pathak, J. Petzold, J. Portugal Pereira, P. Vyas, E. Huntley, K. Kissick, M. Belkacemi, and J. Malley (eds). In press. https://www.ipcc.ch/site/assets/uploads/2019/08/4.-SPM_Approved_Microsite_FINAL.pdf.

[xxi] SANBI. 2022. Ecosystem Services. South African National Biodiversity Institute (SANBI). https://www.sanbi.org/ecosystem-services/.

[xxii] WEF. 2022. The Global Risks Report 2022. 17th edition. World Economic Forum. https://www3.weforum.org/docs/WEF_The_Global_Risks_Report_2022.pdf.

WWF. 2020. Living Planet Report 2020. Bending the curve of biodiversity loss. Almond, R.E.A., Grooten M. and Petersen, T. (Eds). WWF, Gland, Switzerland. https://livingplanet.panda.org/en-za/.

Quinney, M. 2020. 5 reasons why biodiversity matters – to human health, the economy and your wellbeing. World Economic Forum. https://www.weforum.org/agenda/2020/05/5-reasons-why-biodiversity-matters-human-health-economies-business-wellbeing-coronavirus-covid19-animals-nature-ecosystems/.

[xxiii] Murguia, D. 2015. Global Area Disturbed and Pressures on Biodiversity by Large-Scale Metal Mining. Kassel University Press. http://www.uni-kassel.de/upress/online/OpenAccess/978-3-7376-0040-8.OpenAccess.pdf

Sonter, L.J., Ali, S.H., Watson, J.E.M. 2018. Mining and biodiversity: key issues and research needs in conservation science. Proceedings Royal Society Publishing B. 285: 20181926. https://royalsocietypublishing.org/doi/pdf/10.1098/rspb.2018.1926.

[xxiv] Leotaud, V.R. 2021. Nickel: the mined commodity most exposed to biodiversity risks – report. Mining Dot Com. https://www.mining.com/nickel-the-mined-commodity-most-exposed-to-biodiversity-risks-report/.

Nichols, W. 2021. Mining operations face growing biodiversity risks. Verisk Maplecroft. https://www.maplecroft.com/insights/analysis/mining-operations-face-growing-biodiversity-risks/.

Smith, N. 2018. Nickel: A green energy necessity with grave environmental risks. Verisk Maplecroft. https://www.maplecroft.com/insights/analysis/nickel-a-green-energy-necessity-with-grave-environmental-risks/.

[xxv] The biodiversity map (indicating species number of vascular plants) and distribution of copper deposits (Murguia, 2015).

Distribution of Nickel laterite deposits were sourced from: Berger, V.I., Singer, D.A., Bliss, J.D., and Moring, B.C. 2011. Ni-Co laterite deposits of the world: U.S. Geological Survey Open-File Report 2011-1058, U.S. Geological Survey, Menlo Park, California. https://mrdata.usgs.gov/catalog/cite-view.php?cite=880.

[xxvi] *Species richness* is the number of different species in a given area. *Species abundance* goes one step further and measures the number of individuals of each species in an area. *Species diversity* is the relative abundance of different species in a given area – a combination of species richness and abundance. Hillebrand, H., Blasius, B., Borer, E.T., Chase, J.M., Downing, J.A., Eriksson, B.K., Filstrup, C.T., Harpole, S.W., Hodapp, et al. 2017. Biodiversity change is uncoupled from species richness trends: Consequences for conservation and monitoring. Journal of Applied Ecology, 55(1): 169-184.

[xxvii] IUCN. 2021. *The IUCN Red List of Threatened Species. Version 2021-3*. https://www.iucnredlist.org.

[xxviii] Sonter, L.J., Ali, S.H. and Watson, J.E. 2018. Mining and biodiversity: key issues and research needs in conservation science. Proceedings of the Royal Society B. 285: 20181926. https://royalsocietypublishing.org/doi/full/10.1098/rspb.2018.1926#d1e392.

Hillebrand et al. 2017.

[xxix] UNEP-WCMC, Conservational International and Fauna & Flora International (2020). Biodiversity Indicators for Site- based Impacts. Cambridge, UK.

ICMM. N.d. Good practice guidance for mining and biodiversity. https://guidance.miningwithprinciples.com/good-practice-guide-mining-biodiversity/#:~:text=The%20Good%20Practice%20Guidance%20For,by%20promoting%20enhanced%20mutual%20understanding.

UNEP-WCMC. 2017. Biodiversity Indicators for Extractive Companies. https://www.unep-wcmc.org/resources-and-data/biodiversity-indicators-for-extractive-companies.

LandScale. N.d. Generate and Communicate Trusted Landscape-level Sustainability Insights. https://www.landscale.org/.

CSBI. 2015. A cross-sector guide for implementing the mitigation hierarchy. The Cross Sector Biodiversity Initiative. https://www.icmm.com/en-gb/guidance/environmental-stewardship/implementing-mitigation-hierarchy.

Gullison, T., Harder, J., Anstee, S., and Meyer, M. 2015. Good Practices for the Collection of Biodiversity Baseline Data. Prepared for: Multilateral Financing Institutions Biodiversity Working Group and Cross Sector Biodiversity Initiative. https://publications.iadb.org/en/good-practices-collection-biodiversity-baseline-data.

[xxx] Adapted from: UNEP-WCMC, Conservational International and Fauna & Flora International (2020). Biodiversity Indicators for Site- based Impacts. Cambridge, UK.

[xxxi] World Bank. 2022. Climate-Smart Mining: Minerals for climate action. The World Bank. https://www.worldbank.org/en/topic/extractiveindustries/brief/climate-smart-mining-minerals-for-climate-action.

World Bank. 2019. Forest-Smart Mining: Large scale mining on forests. The World Bank. https://www.profor.info/sites/profor.info/files/Forest%20Smart%20Mining_LSM%20REPORT_0.pdf.

ICMM. 2020. Tracking performance on closure management: ICMM's KPI Tool for Closure. https://www.icmm.com/en-gb/news/2020/tracking-performance-on-closure-management.

ICMM. 2022. Mining Principles: Performance Expectations. International Council on Mining and Metals (ICMM). https://www.icmm.com/website/publications/pdfs/mining-principles/mining-principles.pdf.

RMI. 2019. 2019 Risk Readiness Assessment Issue Areas and Industry Norms. Responsible Minerals Initiative (RMI). http://www.responsiblemineralsinitiative.org/media/docs/RRA/2019%20RRA%20Issue%20Areas%20and%20Industry%20Norms_FINAL.pdf.

IRMA. 2018. IRMA Standard for Responsible Mining. Initiative for Responsible Mining Assurance (IRMA). https://responsiblemining.net/wp-content/uploads/2018/07/IRMA_STANDARD_v.1.0_FINAL_2018-1.pdf.

IFC. 2022. Performance Standards. International Finance Corporation (IFC). https://www.ifc.org/wps/wcm/connect/Topics_Ext_Content/IFC_External_Corporate_Site/Sustainability-At-IFC/Policies-Standards/Performance-Standards/.

[xxxii] Hurlimann, A. and March, A. 2012. The role of spatial planning in adapting to climate change. Wiley Interdisciplinary Reviews: Climate Change, 3. 10.1002/wcc.183.

Busayo, E.T., Kalumba, A.M., and Orimoloye, I.R. 2019. Saptial planning and climate change adaptation assessment: Perspectives from Mdantsane Township dwellers in South Africa. Habitat International, 90. https://www.sciencedirect.com/science/article/pii/S0197397519301249.

[xxxiii] RMF. 2020. Responsible Mining Index Framework. Responsible Mining Foundation (RMF). https://www.responsibleminingfoundation.org/app/uploads/2019/09/RMI_Framework2020_EN_web.pdf.

[xxxiv] IUCN. 2021. Biodiversity offsets. International Union for Conservation of Nature (IUCN). https://www.iucn.org/resources/issues-briefs/biodiversity-offsets.

[xxxv] Aitken, S.E. and Burr, J.P. 2019. Why mines should look at total life to achieve tailings facility closure. In: Fourie, A.B. and Tibbett, M. (eds), Mine Closure 2019: Proceedings of the 13th International Conference on Mine Closure, Australian Centre for Geomechanics, Perth. https://papers.acg.uwa.edu.au/p/1915_83_Aitken/.

Bullock, L.A., James, R.H., Matter, J., Renforth, P. and Teagle, D.A.H. 2021. Global Carbon Dioxide Removal Potential of Waste Materials from Metal and Diamond Mining. Front. Clim. https://doi.org/10.3389/fclim.2021.694175.

Dipple, G.M., Power, I., Caroll, K. and De Baere, B. 2017. Pathways to accelerate carbon mineralisation in mine tailings. In: CO2 Summit III: Pathways to carbon capture, utilisation and storage deployment. May 22-26, 2017. https://dc.engconfintl.org/co2_summit3/16/.

[xxxvi] SBTi. 2021. SBTi corporate net-zero standard. Version 1.0. Science-based Targets initiative (SBTi). https://sciencebasedtargets.org/resources/files/Net-Zero-Standard.pdf.

[xxxvii] SBTi. 2021. Beyond value chain mitigation FAQ. https://sciencebasedtargets.org/resources/files/Beyond-Value-Chain-Mitigation-FAQ.pdf.

[xxxviii] SBTi. 2021. SBTi Corporate Net-Zero Standard. Version 1.0. Science-based Target initiative (SBTi). https://sciencebasedtargets.org/resources/files/Net-Zero-Standard.pdf.

[xxxix] Norgate, T. and Haque. N. 2010. Energy and Greenhouse Gas Impacts of Mining and Mineral Processing Operations. Journal of Cleaner Production, 18 (3): 266–74.

Chochilco. 2017. Yearbook: Copper and other Mineral Statistics. https://www.cochilco.cl/Lists/Anuario/Attachments/17/Anuario-%20avance7-10-7-17.pdf.

[xl] Norgate, T. and Haque. N. 2010. Energy and Greenhouse Gas Impacts of Mining and Mineral Processing Operations. Journal of Cleaner Production, 18 (3): 266–74.

Chochilco. 2017. Yearbook: Copper and other Mineral Statistics. https://www.cochilco.cl/Lists/Anuario/Attachments/17/Anuario-%20avance7-10-7-17.pdf.

[xli] International Energy Agency's Net Zero Energy scenario calls for all industrial electric motor sales to be best-in-class by 2035 to achieve industrial emissions reductions in line with a 1.5°C warming scenario.

[xlii] Esen, S., La Rosa, D., Dance, A., Valery, W. and Jankovic, A. 2007. Integration and optimisation of blasting and comminution processes. In: EXPLO conference, pp. 1–10.

Carrasco, C., Keeney, L., Scott, M. and Napier-Munn, T.J. 2016. Value driven methodology to assess risk and operating robustness for grade engineering strategies by means of stochastic optimisation. Minerals Engineering, 99: 76–88.

Kohmuench, J., Mankosa, M., Thanasekaran, H. and Hobert, A. 2018. Improving coarse particle flotation using the HydroFloat™(raising the trunk of the elephant curve). Minerals Engineering, 121: 137–145.

Valery, W., Duffy, K., Holtham, P., Reple, A., Walker, P. and Rosario, P. 2016. Techno-economic evaluation of bulk ore sorting for copper ore at the panaust phu kham operation. In: IMPC 2016-28th International Mineral Processing Congress, vol. 2016.

Duffy, K., Valery, W., Jankovic, A. and Holtham, P. 2015. Resource efficient mining processes of tomorrow. Conference: VIII Meeting of the Southern Hemisphere on Mineral TechnologyAt: Goiania, Brazil. https://www.researchgate.net/publication/309722403_Resource_Efficient_Mining_Processes_of_Tomorrow

[xliii] BloombergNEF. 2020. Scale-up of solar and wind puts existing coal, gas at risk. https://about.bnef.com/blog/scale-up-of-solar-and-wind-puts-existing-coal-gas-at-risk/

[xliv] Kirk, T. and Cannon, C. 2020. Sunshine for mines: A brighter vision for sustainable resources. RMI. https://rmi.org/sunshine-for-mines-a-brighter-vision-for-sustainable-resources.

[xlv] Genex Power. 2021. 250MW Kidston Pumped Storage Hydro Project. https://genexpower.com.au/250mw-kidston-pumped-storage-hydro-project/

[xlvi] GoC. 2021. Glencore RAGLAN mine renewable electricity smart-grid pilot demonstration. Government of Canada (GoC). https://www.nrcan.gc.ca/science-and-data/funding-partnerships/funding-opportunities/current-investments/glencore-raglan-mine-renewable-electricity-smart-grid-pilot-demonstration/16662.

[xlvii] PNNL. 2019. Compressed air energy storage. Pacific Northwest National Laboratory (PNNL). U.S. Department of Energy. https://caes.pnnl.gov/.

[xlviii] Vecchi, A., liang Li, Y., Ding, Y., Mancarella, P. and Sciacovelli A. 2021. Liquid air energy storage (LAES): a review on technology state-of-the-art, integration pathways and future perspectives. Advances in Applied Energy, 3: 100047.

[xlix] ARENA Wire. 2017. Time to ditch the generator? The town where renewables took over. https://arena.gov.au/blog/coober-pedy/.

[l] EDF. 2015. Study: Will switch from diesel trucks to natural gas reduce greenhouse impact? Environmental Defence Fund (EDF).https://www.edf.org/media/study-will-switch-diesel-trucks-natural-gas-reduce-greenhouse-impact.

Guglielmi, G. 2018. Methane leaks from US gas fields dwarf government estimates. *Nature*. https://www.nature.com/articles/d41586-018-05517-y.

Rodriguez, F. 2020. LNG trucks: A bridge to nowhere. The International Council on Clean Transportation (ICCT). https://theicct.org/blog/staff/lng-trucks-bridge-nowhere.

[li] Niño Vega, C.A. 2020. Study of hydrogen global market and technical and economic prefeasibility of using the proton exchange membrane fuel cell (PEM) fuelled with hydrogen in Chilean mining mobility. Universidad de Chile. https://repositorio.uchile.cl/handle/2250/178550.

[lii] Schmidt, O., Gambhir, A., Staffell, I., Hawkes, A., Nelson, J, and Few, S. 2017. Future cost and performance of water electrolysis: An expert elicitation study. *International Journal of Hydrogen Energy*, 42(52): 30470–30492.

RMI. 2021. The Green Hydrogen Catapult announces expansion of world-leading green hydrogen deployment. RMI. https://rmi.org/press-release/the-green-hydrogen-catapult-announces-expansion-of-world-leading-green-hydrogen-deployment/.

[liii] Ruffo, G.H. 2019. eDumper fact check reveals its battery pack weighs 8 tons. InsideEVs. https://insideevs.com/news/362547/edumper-8-ton-battery-pack/.

[liv] Glencore. 2019. Onaping Depth: Collaborating with the EV industry to prepare for mining at depth. https://www.glencore.com/media-and-insights/insights/Onaping-Depth-Collaborating-with-the-electric-vehicle-industry

[lv] Mining[dot]com. 2017. In-pit crushing and conveying systems changing the way ore is moved. https://www.mining.com/in-pit-crushing-systems-changing-the-way-ore-is-moved/

[lvi] Komatsu. 2010. Latest 254 tonne capacity 860E-IK truck. https://www.komatsu.com.au/company/news-media/news/latest-254-tonne-capacity-860e-ik-truck

[lvii] Ziegler, M.S., and Trancik, J.E. 2021. Re-examining rates of lithium-ion battery technology improvement and cost decline. Energy and Environmental Science,14 (4): 1635–1651. doi: 10.1039/D0EE02681F.

[lviii] Charge On Innovation Challenge. 2021. Electrifying Mining. https://chargeoninnovation.com/.

[lix] Toyota. 2018. Toyota develops World's first general-purpose hydrogen burner for industrial use. https://global.toyota/en/newsroom/corporate/25260001.html.

[lx] Mission Possible Partnership and RMI. 2021. Net Zero steel sector transition strategy. https://missionpossiblepartnership.org/wp-content/uploads/2021/10/MPP-Steel-Transition-Strategy-Oct-2021.pdf.

[lxi] SBTi. 2018. Value change in the value chain: Best practices in Scope 3 greenhouse gas management. Science-Based Targets initiatives (SBTi). https://sciencebasedtargets.org/resources/files/SBT_Value_Chain_Report-1.pdf.

Sturla-Zerene, G., Figueroa, E.B. and Sturla, M. 2020. Reducing GHG global emissions from copper refining and sea shipping of Chile's mining exports: A world win-win policy. Resources Policy, 65: 101565. doi: https://doi.org/10.1016/j.resourpol.2019.101565.

[lxii] SFC. N.d. What is the GLEC Framework?. Smart Freight Center (SFC). https://www.smartfreightcentre.org/en/how-to-implement-items/what-is-glec-framework/58/.

UNEP. 2020. Low-carbon Technology Partnership initiative. United Nations Environmental Programme (UNEP). https://climateinitiativesplatform.org/index.php/LCTPI_Low_Carbon_Technology_Partnership_initiative_(Main)#:~:text=The%20Low%20Carbon%20Technology%20Partnerships%20initiative%20(LCTPi)%20aims%20to%20accelerate,the%202%C2%B0C%20ceiling.

[lxiii] Nilsson, A.E., Aragonés, M.M., Torralvo, F.A., Dunon, V., Angel, H., Komnitsas, K., and Willquist, K. 2017. A Review of the Carbon Footprint of Cu and Zn Production from Primary and Secondary Sources. Minerals, 7(9): 168. https://www.mdpi.com/2075-163X/7/9/168.

[lxiv] Anglo American. 2021. The Circular Economy and Anglo American. https://www.angloamerican.com/about-us/our-stories/circular-economy.

[lxv] European Commission. 2020. Green Deal: Sustainable batteries for a circular and climate neutral economy. https://ec.europa.eu/commission/presscorner/detail/en/ip_20_2312.

[lxvi] ENVASS. 2017. Waste management hierarchy. Environmental Assurance (ENVASS). https://www.envass.co.za/the-waste-management-hierarchy-concept/.

[lxvii] Sinclair, L. and J. Thompson, J. 2015. In situ leaching of copper: Challenges and future prospects. Hydrometallurgy, 157: 306–324. doi: https://doi.org/10.1016/j.hydromet.2015.08.022.

[lxviii] Wang, E., Shi, F. and Manlapig, E. 2012. Mineral liberation by high voltage pulses and conventional comminution with same specific energy levels. Minerals Engineering, 27–28: 28–36. doi: https://doi.org/10.1016/j.mineng.2011.12.005.

[lxix] S&P Global. 2020. What is the "G" in ESG? S&P Global. https://www.spglobal.com/en/research-insights/articles/what-is-the-g-in-esg.

[lxx] Fidelity International. 2021. What is ESG investing? https://www.fidelity.com.sg/beginners/esg-investing/what-is-esg.

Walker, D. 2021. ESG insights: What does ESG mean for the mining industry? SLR. https://www.slrconsulting.com/news-and-insights/insights/esg-insights-what-does-esg-mean-mining-industry

Stobart, B. 2021. ESG insights: Four reasons why the mining industry should act on ESG. SLR. https://www.slrconsulting.com/news-and-insights/insights/esg-insights-four-reasons-why-mining-industry-should-act-esg

[lxxi] NT. 2021. Draft Green Finance Taxonomy. Working Draft. National Treasury (NT), Republic of South Africa, IFC, Carbon Trust and the NBI. http://www.treasury.gov.za/public%20comments/GreenFinance2021/Draft%20Green%20Finance%20Taxonomy.pdf.

European Commission. N.d. EU Taxonomy for sustainable activities. European Commission. https://ec.europa.eu/info/business-economy-euro/banking-and-finance/sustainable-finance/eu-taxonomy-sustainable-activities_en#what.

[lxxii] EU. 2021. Draft Report by Subgroup 4: Social Taxonomy. European Union: Platform on Sustainable Finance. https://ec.europa.eu/info/sites/default/files/business_economy_euro/banking_and_finance/documents/sf-draft-report-social-taxonomy-july2021_en.pdf.

[lxxiii] SBTi. 2018. Value change in the value chain: Best practices in scope 3 greenhouse gas management. Science Based Targets initiaitve (SBTi). https://sciencebasedtargets.org/resources/files/SBT_Value_Chain_Report-1.pdf.

Cherel-Bonnemaison, C., Erlandsson, G., Ibach, B., and Spiller, P. 2021. Buying into a more sustainable value chain. McKinsey and Company. https://www.mckinsey.com/business-functions/operations/our-insights/buying-into-a-more-sustainable-value-chain.

[lxxiv] Dehghani-Sanij, A.R., Tharumalingam, E., Dusseault, M.B., and Fraser, R. 2019. Study of energy storage systems and environmental challenges of batteries. Renewable and Sustainable Energy Reviews, 104: 192-208. https://www.sciencedirect.com/science/article/abs/pii/S1364032119300334.

Florin, N. and Dominish, E. 2017. Sustainability evaluation of energy storage technologies. Report prepared by the Institute of Sustainable Futures for the Australian Council of Learned Academies. https://acola.org/wp-content/uploads/2018/08/wp3-sustainability-evaluation-energy-storage-full-report.pdf.

Aichberger, C., and Jungmeier, G. 2020. Environmental life cycle impacts of automative batteries based on a literature review. Energies, 13: 6345. https://www.researchgate.net/publication/347303742_Environmental_Life_Cycle_Impacts_of_Automotive_Batteries_Based_on_a_Literature_Review.

[lxxv] Lèbre, É., Stringer, M., Svobodova, K. Owen, J.R., Kemp, D., Cote, C., Arratia-Solar, A., Velenta, R.K. 2020. The social and environmental complexities of extracting energy transition metals. Nature Communications, 11, 4823. https://www.nature.com/articles/s41467-020-18661-9.

El-Shaht, S. and Almulla, M. 2021. The energy transition needs metals. But it needs social awareness too. World Economic Forum. https://www.weforum.org/agenda/2021/10/decarbonization-energy-transition-metals-esg/.

[lxxvi] SBTi. 2021. SBTi corporate net-zero standard. Version 1.0. https://sciencebasedtargets.org/resources/files/Net-Zero-Standard.pdf.

[lxxvii] Smith School of Enterprise and the Environment. 2020. The Oxford Principles for Net Zero aligned carbon offsetting. University of Oxford. https://www.smithschool.ox.ac.uk/publications/reports/Oxford-Offsetting-Principles-2020.pdf.

IPCC. 2018. Summary for policy makers. Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways. In Press.

SBTi. 2020. Foundations for science-based net-zero target setting in the corporate sector. Version 1. Developed by the CDP on behalf of the Science-Based Targets initiative. https://sciencebasedtargets.org/resources/files/foundations-for-net-zero-full-paper.pdf.

[lxxviii] Antoci, A., Russu, P., and Ticci, E. 2020. Modeling maladaptation in the inequality–environment nexus. Journal of Economic Interaction and Coordination, 388.

Seddon, N., Chausson, A., Berry, P., Girardin, C.A., Smith, A. and Turner, B. 2020. Understanding the value and limits of nature-based solutions to climate change and other global challenges. Philosophical Transactions of the Royal Society B. Biological Sciences. https://doi.org/10.1098/rstb.2019.0120.

[lxxix] Smith School of Enterprise and the Environment (2020); IPCC (2018); SBTi (2020) and Vivid Economics. 2020. An investor guide to negative emission technologies and the importance of land-use. https://www.vivideconomics.com/casestudy/an-investor-guide-to-negative-emission-technologies-and-the-importance-of-land-use/

[lxxx] "Beyond value chain mitigation" refers to mitigation action or investments that fall outside of a company's value chain. This includes activities that avoid or reduce greenhouse gas emissions, and those that remove and

store greenhouse gases from the atmosphere. See: SBTi. 2021. Beyond value chain mitigation FAQ. https://sciencebasedtargets.org/resources/files/Beyond-Value-Chain-Mitigation-FAQ.pdf.

[lxxxi] SBTi. 2021. Beyond value chain mitigation FAQ. https://sciencebasedtargets.org/resources/files/Beyond-Value-Chain-Mitigation-FAQ.pdf.

[lxxxii] Carbon Offset Guide. N.d. What is a Carbon Offset? GHG Management Institute and Stockholm Environment Institute (SEI). https://www.offsetguide.org/understanding-carbon-offsets/what-is-a-carbon-offset/.

[lxxxiii] Antoci, A., Russu, P., and Ticci, E. 2020. Modeling maladaptation in the inequality–environment nexus. Journal of Economic Interaction and Coordination, 388.

Seddon, N., Chausson, A., Berry, P., Girardin, C.A., Smith, A. and Turner, B. 2020. Understanding the value and limits of nature-based solutions to climate change and other global challenges. Philosophical Transactions of the Royal Society B. Biological Sciences. https://doi.org/10.1098/rstb.2019.0120.

[lxxxiv] Smith School of Enterprise and the Environment (2020) and Vivid Economics (2020).

[lxxxv] Smith School of Enterprise and the Environment (2020) and Vivid Economics (2020).

[lxxxvi] Polonsky, M.J., Grau, S.L., and Garma, R. 2010. The New Greenwash? Potential Marketing Problems with Carbon Offsets. International Journal of Business Studies: A Publication of the Faculty of Business Administration, Edith Cowan University.

Phillips, T. 2021. Carbon offset is greenwashing, critics say. Mail and Guardian. https://mg.co.za/environment/2021-11-07-carbon-offset-is-greenwashing-critics-say/.

Rathi, A. and Williams, R. 2020. Why 'carbon offsets' don't do all that they promise. Bloomberg**.** https://www.bloomberg.com/news/articles/2020-08-15/why-carbon-offsets-don-t-do-all-that-they-promise-quicktake.

Carbon offset Guide. N.d. Concerns about how offset credits are used. http://www.offsetguide.org/concerns-about-how-offset-credits-are-used/.

[lxxxvii] Cames, M., Harthan, R.O., Fussler, J., Lazarus, M., Lee, C.M., Erickson, P., and Spalding-Fecher, R. 2016. How additional is the Clean Development Mechanism? Oko-Instiut e.V. https://www.verifavia.com/uploads/files/clean_dev_mechanism_en.pdf.

Irfan, U. 2020. Can you really negate your carbon emissions? Carbon offsets, explained. Vox. https://www.vox.com/2020/2/27/20994118/carbon-offset-climate-change-net-zero-neutral-emissions.

Hultman, N., Lou, J. and Hutton, S. 2020. A review of community co-benefits of the clean development mechanism (CDM). Environmental Research Letters. https://iopscience.iop.org/article/10.1088/1748-9326/ab6396/pdf.

Seddon *et al* (2020).

[lxxxviii] Gold Standard. 2019. Eligibility requirements for grid-connected renewable energy generation projects (VER and CER). Gold Standard. https://www.goldstandard.org/sites/default/files/documents/re_eligibility_-_for_second_consultation_-_june_2019_.pdf.

[lxxxix] Henze, V. 2022. Carbon Offset Prices Could Increase Fifty-Fold by 2050. BloombergNEF. https://about.bnef.com/blog/carbon-offset-prices-could-increase-fifty-fold-by-2050/.

[xc] Herr, O., Blum, J., Himes-Cornell, A., and Sutton-Grier, A. 2019. An analysis of the potential positive and negative livelihood impacts of coastal carbon offset projects. Journal of Environmental Management, 235: 463-479.

[xci] Hultman, N., Lou, J. and Hutton, S. 2020. A review of community co-benefits of the clean development mechanism (CDM). Environmental Research Letters. https://iopscience.iop.org/article/10.1088/1748-9326/ab6396/pdf.

Nature-based solutions initiative. 2021. On the misuse of nature-based carbon offsets. University of Oxford, Nature-based Solutions Initiative. https://www.naturebasedsolutionsinitiative.org/news/on-the-misuse-of-nature-based-carbon-offsets/.

Second Nature. 2020. Co-benefits of carbon offset projects: Information for carbon offset procurement. https://secondnature.org/wp-content/uploads/Co-Benefits-Document-Rev5.pdf.

Favretto, N., Afionis, S., Stringer, L.C., Dougill, A.J., Quinn, C.H. and Ranarijaona, H.L.T. 2020. Delivering Climate-Development Co-Benefits through Multi-Stakeholder Forestry Projects in Madagascar: Opportunities and Challenges. Land, 9(157).

[xcii] WEF. 2022. Explainer: Carbon insetting vs offsetting. World Economic Forum. https://www.weforum.org/agenda/2022/03/carbon-insetting-vs-offsetting-an-explainer/#:~:text=Carbon%20insetting%20is%20the%20implementation,direct%20emissions%20reductions%20by%20corporates.

International Platform for Insetting. N.d. What is insetting. https://www.insettingplatform.com/insetting-explained/#why-insetting.

[xciii] Carbon Trust Assessment.

[xciv] University of Arizona. 2022. Copper mining and processing: Lifecycle of a mine. https://superfund.arizona.edu/resources/modules/copper-mining-and-processing/life-cycle-mine.

[xcv] SBTi. 2021. Beyond value chain mitigation FAQ. https://sciencebasedtargets.org/resources/files/Beyond-Value-Chain-Mitigation-FAQ.pdf.

[xcvi] Smith, P., J. Nkem, K. Calvin, D. Campbell, F. Cherubini, G. Grassi, V. Korotkov, A.L. Hoang, S. Lwasa, P. McElwee, E. Nkonya, N. Saigusa, J.-F. Soussana, M.A. Taboada. 2019. Interlinkages Between Desertification, Land Degradation, Food Security and Greenhouse Gas Fluxes: Synergies, Trade-offs and Integrated Response Options. In: Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems [P.R. Shukla, J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.- O. Portner, D. C. Roberts, P. Zhai, R. Slade, S. Connors, R. van Diemen, M. Ferrat, E. Haughey, S. Luz, S. Neogi, M. Pathak, J. Petzold, J. Portugal Pereira, P. Vyas, E. Huntley, K. Kissick, M. Belkacemi, J. Malley, (eds.)]. In press.

SBTi. 2021.

[xcvii] Smith School of Enterprise and the Environment. 2020.

[xcviii] *Adapted from: Smith School of Enterprise and the Environment (2020) and Vivid Economics (2020). Average prices based on Carbon Trust Analysis.*

[xcix] *Adapted from: Carbon Offset Guide. N.d. What makes a high-quality carbon offset?. https://www.offsetguide.org/high-quality-offsets/.*

[c] CIEL. 2021. Carbon Capture and Storage. Centre for International Environmental Law (CIEL). https://www.ciel.org/issue/carbon-capture-and-storage/.

[ci] Smith, P., J. Nkem, K. Calvin, D. Campbell, F. Cherubini, G. Grassi, V. Korotkov, A.L. Hoang, S. Lwasa, P. McElwee, E. Nkonya, N. Saigusa, J.-F. Soussana, M.A. Taboada, 2019: Interlinkages Between Desertification, Land Degradation, Food Security and Greenhouse Gas Fluxes: Synergies, Trade-offs and Integrated Response Options. In: Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems [P.R. Shukla, J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.- O. Portner, D. C. Roberts, P. Zhai, R. Slade, S. Connors, R. van Diemen, M. Ferrat, E. Haughey, S. Luz, S. Neogi, M. Pathak, J. Petzold, J. Portugal Pereira, P. Vyas, E. Huntley, K. Kissick, M. Belkacemi, J. Malley, (eds.)]. In press.

[cii] Baik, E., Sanches, D.L., Turner, P.A., Mach, K.J., Field, C.B., and Benson, S.M. 2018. Geospatial analysis of near-term potential for carbon-negative bioenergy in the United States. Proceedings of the National Academy of Sciences, 115 (13): 3290–3295. https://www.pnas.org/content/115/13/3290.

Bas, A., Jacob, C., Hay, J., Pioch, S., and Thorin, S. 2016. Improving marine biodiversity offsetting: A proposed methodology for better assessing losses and gains. Journal of Environmental Management, 175: 46-59. https://doi.org/10.1016/j.jenvman.2016.03.027.

Broekhoff, D., Gillenwater, M., Colbert-Sangree, T., Cage, P. 2019. Securing climate benefit: a guide to using carbon offsets. Stockholm Environment Institute & Greenhouse Gas Management Institute. http://www.offsetguide.org/wp-content/uploads/2020/03/Carbon-Offset-Guide_3122020.pdf.

Ecosystem Marketplace. 2019. EM Carbon Offset Dashboard. https://www.ecosystemmarketplace.com/carbon-markets/em-data-dashboard/.

Fajardy, M. and MacDowell, N. 2017. Can BECCS Deliver Sustainable and Resource Efficient Negative Emissions?. Energy & Environnemental Science, 10 (6): 1389–1426. https://pubs.rsc.org/en/content/articlelanding/2017/EE/C7EE00465F.

Fasihi, M., Efimova, O., and Breyer, C. 2019. Techno-economic assessment of CO_2 direct air capture plants. Journal of Cleaner Production, 224: 957-980. https://www.sciencedirect.com/science/article/pii/S0959652619307772.

Fu, A., Li, W., Chen, Y., Wang, Y., Hao, H., Li. Y., Sun, F., Zhou, H., Zhu, C., and Hao, X. 2021. The effects of ecological rehabilitation projects on the resilience of an extremely drought-prone desert riparian forest ecosystem in the Tarim River Basin, Xinjiang, China. Scientific Reports, 11(18485). https://doi.org/10.1038/s41598-021-96742-5.

Fuss, S., Lamb, W.F., Callaghan, M.W., Hilaire, J., Creutzig, F., Amann, T., Beringer, T., Garcia, W.O., and Hartmann, J. 2018. Negative emissions-Part 2: Costs, Potentials and Side Effects. Environmental Research Letters, 13: 063002, https://iopscience.iop.org/article/10.1088/1748-9326/aabf9f.

Global CCS Institute. 2021. Technology readiness and costs of CCS. https://www.globalccsinstitute.com/wp-content/uploads/2021/03/Technology-Readiness-and-Costs-for-CCS-2021-1.pdf.

Gough, C., Garcia-Freites, S., Jones, C., Mander, S., Moore, B., Pereira, C., Order, M., Vaughan, N and Welfle, A. 2018. Challenges to the use of BECCS as a Keystone Technology in pursuit of 1.5°C. Cambridge University Press. https://www.cambridge.org/core/journals/global-sustainability/article/challenges-to-the-use-of-beccs-as-a-keystone-technology-in-pursuit-of-15c/5E8AE2ECC9DCACB5DFE4B97BBE70476D.

Han, Z., Lin, H., Xu, P., Li, Z., Wang, J., and Zou, J. 2022. Impact of organic fertilizer substitution and biochar amendment on net greenhouse gas budget in a tea plantation. Agriculture, Ecosystems & Environment, 326: 107779. https://www.sciencedirect.com/science/article/pii/S0167880921004837.

Hartmann, J.A., West, J., Renforth, P., Köhler, P., De La Rocha, CL., Wolf-Gladrow, D.A., Dürr, H.H., and Scheffran, J. 2013. Enhanced chemical weathering as a geoengineering strategy to reduce atmospheric carbon dioxide. Supply Nutrients, and Mitigate Ocean Acidification. Reviews of Geophysics, 51: 113–49. https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/rog.20004.

Haszeldine, S., Cavanagh, A., Scott, V., Sohi, S., Mašek, O. and Renforth, P. 2019. Greenhouse Gas Removal Technologies – approaches and implementation pathways in Scotland. ClimateXChange. https://www.climatexchange.org.uk/media/3749/greenhouse-gas-removal-technologies.pdf.

Heintzman, P. 2021. The potential for voluntary carbon offset programs in the Canadian snow-based outdoor recreation industry. Journal of Outdoor Recreation and Tourism. 36: 100422, https://doi.org/10.1016/j.jort.2021.100422.

IEA. 2020. Going carbon negative: What are the technology options?. International Energy Agency (IEA), Paris https://www.iea.org/commentaries/going-carbon-negative-what-are-the-technology-options.

Kantola, I.B., Masters, M.D., Beerling, D.J., Long, S.P. and DeLucia, E.H. 2017. Potential of global croplands and bioenergy crops for climate change mitigation through deployment for enhanced weathering. Biology Letters, 13. https://royalsocietypublishing.org/doi/10.1098/rsbl.2016.0714.

Khalidy, R. and Santos, M.R. 2021. The fate of atmospheric carbon sequestrated through weathering in mine tailings. Minerals Engineering, 163: 106767. https://doi.org/10.1016/j.mineng.2020.106767.

Laffoley, D. 2020. Protecting and effectively managing blue carbon ecosystems to realise the full value to society- a sea of opportunities. WWF UK. https://www.wwf.org.uk/sites/default/files/2020-11/WWF_blue_carbon020.pdf.

Larsen, J. Herndon, W., Grant, M., Marsters, P. 2019. Capturing Leadership: Policies for the US to advance direct air capture. New York: Rhodium Group. https://rhg.com/research/capturing-leadership-policies-for-the-us-to-advance-direct-air-capture-technology/.

Mentis, M. 2020. Environmental rehabilitation of damaged land. Forest Ecosystems, 7(19). https://doi.org/10.1186/s40663-020-00233-4.

Napp, T., Hills, T., Soltani, S.M., Bosch, J., and Mazur. C. N.d. A survey of key technological innovations for the low-carbon economy. Imperial College London, Grantham Institute, Climate Change and the Environment. https://www.oecd.org/environment/cc/g20-climate/collapsecontents/Imperial-College-London-innovation-for-the-low-carbon-economy.pdf.

NASEM. 2019. Negative Emissions Technologies and Reliable Sequestration: A Research Agenda. National Academies of Sciences, Engineering, and Medicine (NASEM) Washington, DC: The National Academies Press. https://www.nap.edu/catalog/25259/negative-emissions-technologies-and-reliable-sequestration-a-research-agenda.

National Research Council. 2019. Negative Emissions Technologies and Reliable Sequestration: A Research Agenda. Washington, DC: National Academies Press. https://www.nap.edu/catalog/25259/negative-emissions-technologies-and-reliable-sequestration-a-research-agenda.

Power, I.M., McCutcheon, J., Harrison, A.L., Wilson, S.A., Dipple, G.M., Kelly, S., Southam, C., Southam, G. 2014. Strategizing Carbon-Neutral Mines: A Case for Pilot Projects. Minerals, 4: 399-436. https://doi.org/10.3390/min4020399.

SBTi. 2021.

Smith School of Enterprise and the Environment (2020).

Strefler, J., Amann, T., Bauer, N., Kriegler, E., and Hartmann, J. 2018. Potential and Costs of Carbon Dioxide Removal by Enhanced Weathering of Rocks. Environmental Research Letters, 13:3. https://iopscience.iop.org/article/10.1088/1748-9326/aaa9c4.

Tisserant, A., Morales, M., Cavalett, O., O'Toole, A., Weldon, S., Rasse, D.P., and Cherubini, F. 2021. Life-cycle assessment to unravel co-benefits and trade-offs of large-scale biochar deployment in Norwegian agriculture. Resources, Conservation and Recycling, 106030. https://www.sciencedirect.com/science/article/pii/S0921344921006388.

UNFCCC. 2013. Afforestation and Reforestation Projects under the Clean Development Mechanism. United Nations Framework Convention on Climate Change. (UNFCCC). https://unfccc.int/resource/docs/publications/cdm_afforestation_bro_web.pdf.

Virah-Sawmy, M., Ebeling, J., and Taplin, R. 2014. Mining and biodiversity offsets: A transparent and science-based approach to measure "no-net-loss". Journal of Environmental Management, 143: 61-70. https://doi.org/10.1016/j.jenvman.2014.03.027.

Vivid Economics (2020).

Vivid Economics. 2019. Greenhouse Gas Removal (GGR) policy options – Final Report. https://www.vivideconomics.com/wp-content/uploads/2019/09/Greenhouse_Report_Gas_Removal_policy_options.pdf.

ciii Stern and Stiglitz. 2017. Report of the High Commission on Carbon Prices. https://static1.squarespace.com/static/54ff9c5ce4b0a53decccfb4c/t/59b7f2409f8dce5316811916/1505227332748/CarbonPricing_FullReport.pdf.

Dietz et al. 2018. The economics of 1.5°C climate change. London School of Economics and Imperial University Grantham's Institute. http://eprints.lse.ac.uk/90459/3/Dietz__economics-of-15-climate-change.pdf.

UNEP. 2021. Discussion paper on Governmental Carbon Pricing. https://www.unepfi.org/publications/discussion-paper-on-governmental-carbon-pricing/.

civ UNFCCC. 2015. The Paris agreement. UN. https://unfccc.int/sites/default/files/english_paris_agreement.pdf.

cv JTI. 2020. Just Transition Concepts and Relevance for Climate Action. Just Transition Initiative (JTI), Centre for Strategic and International Studies and the Climate Investment Funds. https://justtransitioninitiative.org/just-transition-concepts-and-relevance-for-climate-action/.

Montmasson-Clair, G. 2021. A policy toolbox for just transitions. Trade & Industrial Policy Strategies (TIPS). https://www.tips.org.za/research-archive/sustainable-growth/green-economy-2/item/4152-a-policy-toolbox-for-just-transitions.

Montmasson-Clair, G. 2020. Metals value chains in a climate-compatible world: A just transition approach. Trade and Industrial Policy Strategies (TIPS). https://www.tips.org.za/policy-briefs/item/3907-metals-value-chains-in-a-climate-compatible-world-a-just-transition-approach.

cvi ILO. 2015. Guidelines for a just transition towards environmentally sustainable economies and societies for all. International Labour Organization. https://www.ilo.org/wcmsp5/groups/public/---ed_emp/---emp_ent/documents/publication/wcms_432859.pdf.

cvii JTI. 2020. Just Transition Concepts and Relevance for Climate Action. Just Transition Initiative (JTI), Centre for Strategic and International Studies and the Climate Investment Funds. https://justtransitioninitiative.org/just-transition-concepts-and-relevance-for-climate-action/.

Robins, N., Brunsting, V., and Wood, D. 2018. Climate Change and the Just Transition: A Guide for Investor Action. UNPRI, Grantham Institute, Initiative for Responsible Investment. https://www.unpri.org/download?ac=9452.

Robins, N., Muller, S., and Szwarc, K. 2021. From grand to granular: translating just transition ambitions into investor action. Grantham Institute on Climate Change and the Environment and the Centre for Climate Change Economics and Policy. https://www.lse.ac.uk/granthaminstitute/wp-content/uploads/2021/07/From-the-Grand-to-the-Granular_translating-just-transition-ambitions-into-investor-action.pdf.

cviii Gambhir, A., Green, F., Pearson, J. 2018. Towards a just and equitable low-carbon energy transition. Grantham Institute. https://www.imperial.ac.uk/media/imperial-college/grantham-institute/public/publications/briefing-papers/26.-Towards-a-just-and-equitable-low-carbon-energy-transition.pdf.

Robins, N., Muller, S., and Szwarc, K. 2021. From grand to granular: translating just transition ambitions into investor action. Grantham Institute on Climate Change and the Environment and the Centre for Climate Change Economics and Policy. https://www.lse.ac.uk/granthaminstitute/wp-content/uploads/2021/07/From-the-Grand-to-the-Granular_translating-just-transition-ambitions-into-investor-action.pdf.

Velicu, R., Barca, S. 2020. The Just Transition and its work of inequality, Sustainability: Science, Practice and Policy. https://www.tandfonline.com/doi/full/10.1080/15487733.2020.1814585.

Atteridge, A., Strambo, C. 2020. Seven principles to realize a just transition to a low-carbon economy. Stockholm Environment Institute. https://cdn.sei.org/wp-content/uploads/2020/06/seven-principles-for-a-just-transition.pdf

[cix] Montmasson-Clair, G. 2021. A policy toolbox for just transitions. Trade & Industrial Policy Strategies (TIPS). https://www.tips.org.za/research-archive/sustainable-growth/green-economy-2/item/4152-a-policy-toolbox-for-just-transitions.

JTI. 2021. A framework for just transitions. Just Transition Initiative, Centre for Strategic and International Studies and the Climate Investment Funds. https://justtransitioninitiative.org/wp-content/uploads/2021/01/Framework-for-Just-Transitions_Download.pdf.

RMF. 2021a. Responsible Mining Index Framework, Version 22. Responsible Mining Foundation. https://www.responsibleminingfoundation.org/rmi-framework-2022/.

[cx] Montmasson-Clair, G. 2021. A policy toolbox for just transitions. Trade & Industrial Policy Strategies (TIPS). https://www.tips.org.za/research-archive/sustainable-growth/green-economy-2/item/4152-a-policy-toolbox-for-just-transitions.

JTI. 2021. A framework for just transitions. Just Transition Initiative, Centre for Strategic and International Studies and the Climate Investment Funds. https://justtransitioninitiative.org/wp-content/uploads/2021/01/Framework-for-Just-Transitions_Download.pdf.

JTI. 2020. Just Transition Concepts and Relevance for Climate Action. Just Transition Initiative (JTI), Centre for Strategic and International Studies and the Climate Investment Funds. https://justtransitioninitiative.org/just-transition-concepts-and-relevance-for-climate-action/.

[cxi] Montmasson-Clair, G. 2021. A policy toolbox for just transitions. Trade & Industrial Policy Strategies (TIPS). https://www.tips.org.za/research-archive/sustainable-growth/green-economy-2/item/4152-a-policy-toolbox-for-just-transitions.

Montmasson-Clair, G. 2020. Metals value chains in a climate-compatible world: A just transition approach. Trade and Industrial Policy Strategies (TIPS). https://www.tips.org.za/policy-briefs/item/3907-metals-value-chains-in-a-climate-compatible-world-a-just-transition-approach.

JTI. 2021. A framework for just transitions. Just Transition Initiative, Centre for Strategic and International Studies and the Climate Investment Funds. https://justtransitioninitiative.org/wp-content/uploads/2021/01/Framework-for-Just-Transitions_Download.pdf.

JTI. 2020. Just Transition Concepts and Relevance for Climate Action. Just Transition Initiative (JTI), Centre for Strategic and International Studies and the Climate Investment Funds. https://justtransitioninitiative.org/just-transition-concepts-and-relevance-for-climate-action/.

[cxii] Montmasson-Clair, G. 2021. A policy toolbox for just transitions. Trade & Industrial Policy Strategies (TIPS). https://www.tips.org.za/research-archive/sustainable-growth/green-economy-2/item/4152-a-policy-toolbox-for-just-transitions.

Montmasson-Clair, G. 2020. Metals value chains in a climate-compatible world: A just transition approach. Trade and Industrial Policy Strategies (TIPS). https://www.tips.org.za/policy-briefs/item/3907-metals-value-chains-in-a-climate-compatible-world-a-just-transition-approach.

JTI. 2020. Just Transition Concepts and Relevance for Climate Action. Just Transition Initiative (JTI), Centre for Strategic and International Studies and the Climate Investment Funds. https://justtransitioninitiative.org/just-transition-concepts-and-relevance-for-climate-action/.

[cxiii] Montmasson-Clair, G. 2021. A policy toolbox for just transitions. Trade & Industrial Policy Strategies (TIPS). https://www.tips.org.za/research-archive/sustainable-growth/green-economy-2/item/4152-a-policy-toolbox-for-just-transitions.

Montmasson-Clair, G. 2020. Metals value chains in a climate-compatible world: A just transition approach. Trade and Industrial Policy Strategies (TIPS). https://www.tips.org.za/policy-briefs/item/3907-metals-value-chains-in-a-climate-compatible-world-a-just-transition-approach.

JTI. 2021. A framework for just transitions. Just Transition Initiative, Centre for Strategic and International Studies and the Climate Investment Funds. https://justtransitioninitiative.org/wp-content/uploads/2021/01/Framework-for-Just-Transitions_Download.pdf.

JTI. 2020. Just Transition Concepts and Relevance for Climate Action. Just Transition Initiative (JTI), Centre for Strategic and International Studies and the Climate Investment Funds. https://justtransitioninitiative.org/just-transition-concepts-and-relevance-for-climate-action/.

[cxiv] Lèbre, É., Stringer, M., Svobodova, K. Owen, J.R., Kemp, D., Cote, C., Arratia-Solar, A., Velenta, R.K. 2020. The social and environmental complexities of extracting energy transition metals. Nature Communications, 11, 4823. https://www.nature.com/articles/s41467-020-18661-9.

[cxv] Two key assumptions were made for contextualizing and identifying just transition threats and opportunities: (i) copper and nickel production will increase to meet projected demand increases for each mineral; and (ii) copper and nickel value chains will transition to Net Zero emissions.

[cxvi] Lèbre, É., Stringer, M., Svobodova, K. Owen, J.R., Kemp, D., Cote, C., Arratia-Solar, A., Velenta, R.K. 2020. The social and environmental complexities of extracting energy transition metals. Nature Communications, 11, 4823. https://www.nature.com/articles/s41467-020-18661-9.

El-Shaht, S. and Almulla, M. 2021. The energy transition needs metals. But it needs social awareness too. World Economic Forum. https://www.weforum.org/agenda/2021/10/decarbonization-energy-transition-metals-esg/.

[cxvii] Increasing demand for copper and nickel could lead to an increase in the likelihood and severity of existing ESG risks and impacts. Transitioning to Net Zero emissions can also have unintended negative ESG impacts (as highlighted in the Chapter 2 executive summary: "Prioritizing low-carbon technology interventions and their ESG considerations").

[cxviii] S&P Global. 2020. What is the "G" in ESG? S&P Global. https://www.spglobal.com/en/research-insights/articles/what-is-the-g-in-esg.

Fidelity International. 2021. What is ESG investing? https://www.fidelity.com.sg/beginners/esg-investing/what-is-esg.

Walker, D. 2021. ESG insights: What does ESG mean for the mining industry? SLR. https://www.slrconsulting.com/news-and-insights/insights/esg-insights-what-does-esg-mean-mining-industry

Stobart, B. 2021. ESG insights: Four reasons why the mining industry should act on ESG. SLR. https://www.slrconsulting.com/news-and-insights/insights/esg-insights-four-reasons-why-mining-industry-should-act-esg

[cxix] Negative impacts, or externalities (environmental or social) are negative side-effects imposed onto a third party or broader society by the production and/or consumption of goods or services (Vivid Economics. 2016. Energy System Externalities in South Africa. Report prepared for the Department of Energy and Shell. http://www.energy.gov.za/files/IEP/2016/IEP-AnnexureC1-Energy-Systems-Externalities-in-SA.pdf.).

[cxx] Lèbre, É., Stringer, M., Svobodova, K. Owen, J.R., Kemp, D., Cote, C., Arratia-Solar, A., Velenta, R.K. 2020. The social and environmental complexities of extracting energy transition metals. Nature Communications, 11, 4823. https://www.nature.com/articles/s41467-020-18661-9.

El-Shaht, S. and Almulla, M. 2021. The energy transition needs metals. But it needs social awareness too. World Economic Forum. https://www.weforum.org/agenda/2021/10/decarbonization-energy-transition-metals-esg/.

Delevingne, L., Glazener, W., Grégoir, L., and Henderson, K. 2020. Climate risk and decarbonization: What every mining CEO needs to know. McKinsey & Company. https://www.mckinsey.com/business-functions/sustainability/our-insights/climate-risk-and-decarbonization-what-every-mining-ceo-needs-to-know.

JTC and The B Team. 2018. Just transition: A business guide. Just Transition Centre (JTC) and The B Team. http://bteam.niceandserious.com/assets/reports/Just-Transition-A-Business-Guide.pdf.

UNDP and UN Environment. 2018. Managing mining for sustainable development: A sourcebook. Bangkok: United Nations Development Programme. https://www.undp.org/publications/managing-mining-sustainable-development.

Haddaway, N. R., Cooke, S. J., Lesser, P., Macura, B., Nilsson, A. E., Taylor, J. J., Raito, K. 2019. Evidence of the impacts of metal mining and the effectiveness of mining mitigation measures on social-ecological systems in the Arctic and boreal regions: a systematic map protocol. Environmental Evidence 8:9. https://doi.org/10.1186/s13750-019-0152-8.

RMF and CCSI. 2020. Mining and the SDG: a 2020 status update. The Responsible Mining Foundation (RMF) and Columbia Center on Sustainable Investment (CCSI). https://www.responsibleminingfoundation.org/mining-and-the-sdgs/.

RMF. 2021a. Responsible Mining Index Framework, Version 22. Responsible Mining Foundation. https://www.responsibleminingfoundation.org/rmi-framework-2022/.

RMF. 2021b. The harmful impacts of mining: When extraction harms people, environments and economies. Responsible Mining Foundation (RMF). https://www.responsibleminingfoundation.org/app/uploads/RMF_Harmful_Impacts_Report_EN.pdf.

[cxxi] SANBI. 2022. Ecosystem Services. South African National Biodiversity Institute (SANBI). https://www.sanbi.org/ecosystem-services/.

[cxxii] Scheel, F., de Haan, E., and Keizebrink, V. 2016. Cobalt blues Environmental pollution and human rights violations in Katanga's copper and cobalt mines. file:///C:/Users/Reinhardt.Arp/Downloads/Cobalt-blues.pdf.

Jakobsson, L.S. 2019. Copper with a cost. Human rights and environmental risks in the mineral supply chains of ICT: A case study from Zambia. SWEDWATCH. https://swedwatch.org/wp-content/uploads/2019/05/94_Zambia_uppslag.pdf.

[cxxiii] JTC and The B Team. 2018. Just transition: A business guide. Just Transition Centre (JTC) and The B Team. http://bteam.niceandserious.com/assets/reports/Just-Transition-A-Business-Guide.pdf.

Lèbre et al. (2020); el-shaht and Almulla (2021); UNDP and UN Environment. (2018); Haddaway, et al. (2019); RMF and CCSI. (2020). RMF. (2021a). RMF. (2021b).

[cxxiv] Mancini L., Sala, S. 2018. Social impact assessment in the mining sector: Review and comparison of indicators frameworks. Resources Policy. 57: 98-111. https://doi.org/10.1016/j.resourpol.2018.02.002

OECD. 2019. Reducing the health risks of the copper, rare earth and cobalt industries. The transition to a low-carbon economy. https://www.oecd.org/greengrowth/Reducing%20the%20health%20risks%20of%20the%20copper,%20rare%20earth%20and%20cobalt%20industries.pdf

RMF and CCSI. 2020. Mining and the SDG: a 2020 status update. The Responsible Mining Foundation (RMF) and Columbia Center on Sustainable Investment (CCSI).

RMF. 2021. Responsible Mining Index Framework, Version 22. Responsible Mining Foundation. https://www.responsibleminingfoundation.org/rmi-framework-2022/.

RMF. 2021. The harmful impacts of mining: When extraction harms people, environments, and economies. Responsible Mining Foundation (RMF). https://www.responsibleminingfoundation.org/app/uploads/RMF_Harmful_Impacts_Report_EN.pdf.

Stewart. A.G. 2020. Mining is bad for health: a voyage of discovery. Environmental Geochemistry and Health. 42: 1153-1165. https://link.springer.com/article/10.1007/s10653-019-00367-7.

ICA. 2017. The impacts of copper mining in Chile. Economic and Social Implications for the country. International Copper Association (ICA). https://sustainablecopper.org/wp-content/uploads/2018/05/ICA-Summary-Document-The-Impacts-of-Copper-Mining-in-Chile-FV-04.04.2018.pdf 2017.

Kibria, G., 2014. Mining: Friend or foe? Economic, environmental, and social impacts- an overview. https://www.researchgate.net/publication/265379518_Mining_Friend_or_Foe_Economic_Environmental_Social_Impacts-_An_Overview.

Dominish, E., Florin, N. and Teske, S. 2019. Responsible Minerals Sourcing for Renewable Energy. Report prepared for Earthworks by the Institute for Sustainable Futures, University of Technology Sydney https://earthworks.org/assets/uploads/2019/04/MCEC_UTS_Report_lowres-1.pdf.

Ellix, H., Farmer, K., Kowalik, L., Little, R., Moonsamy, T., Mussacaleca, M., Ruban, P. and Zapata, G. 2021. Why women are leaving the mining industry and what mining companies can do about it. McKinsey & Company. Metals and Mining Practice. https://www.mckinsey.com/industries/metals-and-mining/our-insights/why-women-are-leaving-the-mining-industry-and-what-mining-companies-can-do-about-it.

EQUINET. 2018. Mining and health: A health literacy module. https://www.equinetafrica.org/sites/default/files/uploads/documents/HL%20module%20Mining%20and%20Health%202018.pdf.

[cxxv] Mancini L., Sala, S. 2018. Social impact assessment in the mining sector: Review and comparison of indicators frameworks. Resources Policy. 57: 98-111. https://doi.org/10.1016/j.resourpol.2018.02.002.

[cxxvi] Scheel, F., de Haan, E., and Keizebrink, V. 2016. Cobalt blues Environmental pollution and human rights violations in Katanga's copper and cobalt mines. file:///C:/Users/Reinhardt.Arp/Downloads/Cobalt-blues.pdf.

Styve, M.D. 2013. Norwegian investments in the Zambian mining industry. Caritas Norway. file:///C:/Users/Reinhardt.Arp/Downloads/Who_Benefits_Norwegian_Investments_in_th.pdf.

[cxxvii] For more information on environmental and socio-economic considerations for the deployment of low-caron technology interventions and carbon offsets, please refer to the Chapter 2 Executive Summary: “Prioritising low-carbon interventions and ESG considerations” and Chapter 3 Executive Summary: “Land-use change and carbon offsets”, respectively.

Ravillard, P., Ortega, B., Paramo, A., Chueca, E., Weiss, M., and Hallack, M. 2021. Implications of the energy transition on employment. Today’s results, tomorrow’s needs. Inter-American Development Bank (IDB). https://publications.iadb.org/publications/english/document/Implications-of-the-Energy-Transition-on-Employment-Todays-Results-Tomorrows-Needs.pdf.

Kemp, J. 2020. Energy transitions, job losses and political reactions. Reuters. https://www.reuters.com/article/us-global-energy-kemp-idUSKBN2662JJ.

IRENA. 2017. Renewable energy benefits: Understanding the socio-economics. International Renewable Energy Agency (IRENA). https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2017/Nov/IRENA_Understanding_Socio_Economics_2017.pdf?la=en&hash=C430B7EF772BA0E631190A75F7243B992211F102.

[cxxviii] Mining technology. 2017. Robots and Recruitment: The Impact Of Automation On Mining Jobs. https://www.mining-technology.com/features/featurerobots-and-recruitment-the-impact-of-automation-on-mining-jobs-5864897/.

Holcombea, S. and Kemp, D. 2019. Indigenous peoples and mine automation: An issues paper. Responsible Policy, 63: 101420.

[cxxix] Maladaptation is defined as action taken to avoid or reduce climate vulnerability that perversely impacts on other systems, sectors or social groups, thereby increasing climate vulnerability. For example, reforesting an area as part of a carbon offset project, using a single, non-native species (referred to monocultures), resulting in negative biodiversity and water impacts, and land grabs from local communities. *See:*

Antoci, A., Russu, P., and Ticci, E. 2020. Modeling maladaptation in the inequality–environment nexus. Journal of Economic Interaction and Coordination, 388.

Seddon, N., Chausson, A., Berry, P., Girardin, C.A., Smith, A. and Turner, B. 2020. Understanding the value and limits of nature-based solutions to climate change and other global challenges. Philosophical Transactions of the Royal Society B. Biological Sciences. https://doi.org/10.1098/rstb.2019.0120.

Herr, O., Blum, J., Himes-Cornell, A., and Sutton-Grier, A. 2019. An analysis of the potential positive and negative livelihood impacts of coastal carbon offset projects. Journal of Environmental Management, 235: 463-479.

[cxxx] JTC and The B Team. 2018. Just transition: A business guide. Just Transition Centre (JTC) and The B Team. http://bteam.niceandserious.com/assets/reports/Just-Transition-A-Business-Guide.pdf.

Willis Towers Watson. 2020. Managing the transition. Mining risk review 2020. https://www.wtwco.com/assets/pdf/WTW481050_REPORT_TURTL_Mining-Risk-Review_Aug-2020-v10.1.pdf.

Dowling, C. 2022. Mining companies face an evolving array of climate change risk and opportunities. Canadian Mining Journal. https://www.canadianminingjournal.com/featured-article/mining-companies-face-an-evolving-array-of-climate-change-risk-and-opportunities/.

[cxxxi] OECD. 2019. Reducing the health risks of the copper, rare earth and cobalt industries. The transition to a low-carbon ecnomy. https://www.oecd.org/greengrowth/Reducing%20the%20health%20risks%20of%20the%20copper,%20rare%20earth%20and%20cobalt%20industries.pdf.

[cxxxii] UN. 2020. World Social Report 2020: Inequality in a rapidly changing world. United Nations Department of Economic and Social Affairs. https://www.un.org/development/desa/dspd/wp-content/uploads/sites/22/2020/01/World-Social-Report-2020-FullReport.pdf.

[cxxxiii] A baseline ESG assessment suggests significant effort is still required to improve ESG performance across mining value chains. For more information, please refer to the Chapter 2 executive summary: "Prioritizing interventions and ESG considerations".

[cxxxiv] El-Shaht, S. and Almulla, M. 2021. The energy transition needs metals. But it needs social awareness too. World Economic Forum. https://www.weforum.org/agenda/2021/10/decarbonization-energy-transition-metals-esg/.

[cxxxv] The *governance for additionality* principle is a requirement in emerging sustainable social taxonomies and carbon offsets. It requires net-positive outcomes that would not have occurred in the absence of an intervention or project that goes beyond business-as-usual. Please refer to the European Union Platform on Sustainable Finance, Social Taxonomy for more information.

[cxxxvi] NT. 2021. Draft Green Finance Taxonomy. Working Draft. National Treasury (NT), Republic of South Africa, IFC, Carbon Trust and the NBI. http://www.treasury.gov.za/public%20comments/GreenFinance2021/Draft%20Green%20Finance%20Taxonomy.pdf.

European Commission. N.d. EU Taxonomy for sustainable activities. European Commission. https://ec.europa.eu/info/business-economy-euro/banking-and-finance/sustainable-finance/eu-taxonomy-sustainable-activities_en#what.

[cxxxvii] EU. 2021. Draft Report by Subgroup 4: Social Taxonomy. European Union: Platform on Sustainable Finance. https://ec.europa.eu/info/sites/default/files/business_economy_euro/banking_and_finance/documents/sf-draft-report-social-taxonomy-july2021_en.pdf.

[cxxxviii] Robins, N., Muller, S. and Szwarc, K. 2021. From the grand to the granular: translating just transition ambitions into investor action. London: Grantham Research Institute on Climate Change and the Environment and

Centre for Climate Change Economics and Policy, London School of Economics and Political Science. https://www.lse.ac.uk/granthaminstitute/wp-content/uploads/2021/07/From-the-Grand-to-the-Granular_translating-just-transition-ambitions-into-investor-action.pdf.

JTC and The B Team. 2018. Just transition: A business guide. Just Transition Centre (JTC) and The B Team. http://bteam.niceandserious.com/assets/reports/Just-Transition-A-Business-Guide.pdf.

ILO. 2015. Guidelines for a just transition towards environmentally sustainable economies and societies for all. International Labour Organisation. https://www.ilo.org/wcmsp5/groups/public/---ed_emp/---emp_ent/documents/publication/wcms_432859.pdf.

SFC. 2021. Just transition strategy. Shareholders for Change (SFC). https://www.shareholdersforchange.eu/just-transition-strategy/.

[cxxxix] Just transition “interventions” are governance mechanisms that *enable* a just transition. Just transition “opportunities” are present across mining value chain activities but require pro-active leadership and just transition interventions to ensure co-benefits and net-positive outcomes materialize (i.e. they rely on governance for additionality to deliver net-positive, additional environmental and socio-economic outcomes).

[cxl] Anglo American. 2022. Anglo American agrees sustainability-linked loan with International Finance Corporation. https://www.angloamerican.com/media/press-releases/2022/09-06-2022#:~:text=Anglo%20American%20has%20signed%20a,Anglo%20American's%20Sustainable%20Mining%20Plan.

[cxli] JTC and The B Team. 2018. Just transition: A business guide. Just Transition Centre (JTC) and The B Team. http://bteam.niceandserious.com/assets/reports/Just-Transition-A-Business-Guide.pdf.

RMF. 2021. Responsible Mining Index Framework, Version 22. Responsible Mining Foundation. https://www.responsibleminingfoundation.org/rmi-framework-2022/.

JTI. 2020. Just Transition Concepts and Relevance for Climate Action. Just Transition Initiative (JTI), Center for Strategic and International Studies and the Climate Investment Funds. https://justtransitioninitiative.org/just-transition-concepts-and-relevance-for-climate-action/.

JTI. 2021. A framework for just transitions. Just Transition Initiative, Center for Strategic and International Studies and the Climate Investment Funds. https://justtransitioninitiative.org/wp-content/uploads/2021/01/Framework-for-Just-Transitions_Download.pdf.

[cxlii] El-Shaht, S. and Almulla, M. 2021. The energy transition needs metals. But it needs social awareness too. World Economic Forum. https://www.weforum.org/agenda/2021/10/decarbonization-energy-transition-metals-esg/.

[cxliii] RMF. 2022. Mine Sites. Responsible Mining Foundation (RMF). https://2022.responsibleminingindex.org/en/mine-sites.

[cxliv] The Warren Centre. 2020. Zero Emission Copper Mine of the Future, Sydney: The University of Sydney. https://ses.library.usyd.edu.au/handle/2123/24317.

RMF and CCSI. 2020. Mining and the SDG: a 2020 status update. The Responsible Mining Foundation (RMF) and Columbia Center on Sustainable Investment (CCSI). https://www.responsibleminingfoundation.org/app/uploads/RMF_CCSI_Mining_and_SDGs_EN_Sept2020.pdf.

UNFCCC. 2021. Climate Action Pathway: Industry Action Table. United Nations Framework Convention on Climate Change (UNFCCC), Global Climate Action (GCA) and Marrakech Partnership. https://unfccc.int/climate-action/marrakech-partnership/reporting-tracking/pathways/industry-climate-action-pathway.

[cxlv] Igogo, T., Lowder, T., Engel-Cox, J., Newman, A., and Awuah-Offei, K. 2020. Integrating clean energy in mining operations: opportunities, challenges and enabling approaches. Joint Institute for Strategic Energy Analysis. https://www.nrel.gov/docs/fy20osti/76156.pdf.

[cxlvi] Anglo American. 2022. Sustainability Report 2021 (pg 28). https://www.angloamerican.com/~/media/Files/A/Anglo-American-Group/PLC/investors/annual-reporting/2022/aa-sustainability-report-full-2021.pdf.

[cxlvii] TIPS. 2019. National Employment Vulnerability Assessment. https://www.tips.org.za/images/National_Employment_Vulnerability_Assessment_Analysis_of_potential_climate-change_related_impacts_and_vulnerable_groups.pdf.

TIPS. 2020. Sector Jobs Resilience Plans. https://www.tips.org.za/projects/current-projects/item/3936-sector-jobs-resilience-plans.

EU. N.d. Just Transition Fund. https://www.europarl.europa.eu/factsheets/en/sheet/214/just-transition-fund.

[cxlviii] RMF. 2021. Responsible Mining Index Framework, Version 22. Responsible Mining Foundation. https://www.responsibleminingfoundation.org/rmi-framework-2022/.

[cxlix] DBG. N.d. AWOME (Accelerating Women Owned Micro-Enterprises). De Beers Group (DBG). https://www.debeersgroup.com/sustainability-and-ethics/accelerating-equal-opportunity/awome.

[cl] El-Shaht, S. and Almulla, M. 2021. The energy transition needs metals. But it needs social awareness too. World Economic Forum. https://www.weforum.org/agenda/2021/10/decarbonization-energy-transition-metals-esg/.

UNGC. N.d. The power of principles. The ten principles of the UN Global Compact. https://www.unglobalcompact.org/what-is-gc/mission/principles.

UN. 2011. Guiding Principles on Business and Human Rights : Implementing the United Nations "Protect, Respect and Remedy" Framework. https://digitallibrary.un.org/record/720245?ln=en. https://digitallibrary.un.org/record/720245?ln=en

The CopperMark. 2021. About the Copper Mark. https://coppermark.org/about/

ICMM. 2022. Mining Principles. International Council on Mining and Metals (ICMM). https://www.icmm.com/en-gb/about-us/member-requirements/mining-principles.

RMF. 2022. Responsible Mining Index. https://2022.responsibleminingindex.org/en.

ILO. 2015. Guidelines for a just transition toward environmentally sustainable economies and societies for all. International Labour Organisation (ILO). https://www.ilo.org/wcmsp5/groups/public/@ed_emp/@emp_ent/documents/publication/wcms_432859.pdf.

IFC. 2022. Performance Standards. International Finance Corporation (IFC). https://www.ifc.org/wps/wcm/connect/Topics_Ext_Content/IFC_External_Corporate_Site/Sustainability-At-IFC/Policies-Standards/Performance-Standards.

RMI. 2022. Risk Readiness Assessment (RRA). Responsible Minerals Initiative (RMI). https://www.responsiblemineralsinitiative.org/minerals-due-diligence/risk-management/risk-readiness-assessment-(rra)/.

OECD. 2016. OECD Due Diligence Guidance for Responsible Supply Chains of Minerals from Conflict-Affected and High-Risk Areas. Third Edition. https://www.oecd.org/corporate/mne/mining.htm#:~:text=for%20multinational%20enterprises-,OECD%20Due%20Diligence%20Guidance%20for%20Responsible%20Supply%20Chains%20of%20Minerals,Affected%20and%20High%2DRisk%20Areas&text=The%20OECD%20Due%20Diligence%20Guidance,mineral%20purchasing%20decisions%20and%20practices.

[cli] Cozzi, L. and Motherway, B. 2021. The importance of focusing on jobs and fairness in clean energy transitions. International Energy Agency (IEA). https://www.iea.org/commentaries/the-importance-of-focusing-on-jobs-and-fairness-in-clean-energy-transitions.

[clii] Ramdoo, I., Cosbey, A., Geipel, J. and Toledano, P. 2021. New tech, new deal: Mining policy options in the face of new technology. The International Institute for Sustainable Development (IISD). New Tech, New Deal: Mining policy options in the face of new technology (iisd.org).

[cliii] Ramdoo, I., Cosbey, A., Geipel, J. and Toledano, P. 2021. New tech, new deal: Mining policy options in the face of new technology. The International Institute for Sustainable Development (IISD). New Tech, New Deal: Mining policy options in the face of new technology (iisd.org).

[cliv] UNFCCC. 2016.United Nations Framework Convention on Climate Change. Just transition of the workforce, and the creation of decent work and quality jobs. https://unfccc.int/sites/default/files/resource/docs/2016/tp/07.pdf.

[clv] JTC and The B Team. 2018. Just transition: A business guide. Just Transition Centre (JTC) and The B Team. http://bteam.niceandserious.com/assets/reports/Just-Transition-A-Business-Guide.pdf.

[clvi] IISD. 2022. International Institute for Sustainable Development. IGF Case Studies: Automation and Water-Saving Technologies. https://www.jstor.org/stable/pdf/resrep21937.pdf?refreqid=excelsior%3A089f537dfc71e2502204a97e27b0fbc2&ab_segments=&origin=.

[clvii] Singer, B., Bingham, D., Tylenda, E., Meyer, M., Kim, K., Alabaster, S., Corbett, B., Jones, E. and Phillips, A. 2021. Green Capex: Making infrastructure happen. Goldman Sachs Equity Research. https://www.goldmansachs.com/insights/pages/gs-research/green-capex/green-capex-making-infrastructure-happen.pdf.

[clviii] Singer, B., Bingham, D., Tylenda, E., Meyer, M., Kim, K., Alabaster, S., Corbett, B., Jones, E. and Phillips, A. 2021. Green Capex: Making infrastructure happen. Goldman Sachs Equity Research.

https://www.goldmansachs.com/insights/pages/gs-research/green-capex/green-capex-making-infrastructure-happen.pdf.

[clix] Singer, B., Bingham, D., Tylenda, E., Meyer, M., Kim, K., Alabaster, S., Corbett, B., Jones, E. and Phillips, A. 2021. Green Capex: Making infrastructure happen. Goldman Sachs Equity Research. https://www.goldmansachs.com/insights/pages/gs-research/green-capex/green-capex-making-infrastructure-happen.pdf.

[clx] NT. 2020. Financing a sustainable economy. Technical paper 2020. Draft. National Treasury (NT), Republic of South Africa. http://www.treasury.gov.za/publications/other/Sustainability%20technical%20paper%202020.pdf.

[clxi] Green Finance Platform. 2021. Explore Green Finance. https://www.greenfinanceplatform.org/page/explore-green-finance.

European Commission. N.d. Overview of sustainable finance. European Commission. https://ec.europa.eu/info/business-economy-euro/banking-and-finance/sustainable-finance/overview-sustainable-finance_en.

OECD. N.d. Centre on Green Finance and Investment. OECD. https://www.oecd.org/cgfi/.

ISO. 2021. Green and Sustainable Finance International Organisation for Standardisation (ISO). https://www.iso.org/files/live/sites/isoorg/files/store/en/PUB100458.pdf.

Klier, D., Knight, Z., Bidgoli, F., Mo, C. and Bou, A. 2020. Why transition finance is vital to combat climate change. A white paper from HSBC. HSBC. https://www.hsbc.com/insight/topics/why-transition-finance-is-essential#:~:text=Transition%20finance%20means%20any%20form,the%20journey%20to%20net%20zero.

Caldecott, B. 2020. Defining transition finance and embedding it in the post-Covid-19 recovery. Journal of sustainable finance and investment. https://www.tandfonline.com/doi/pdf/10.1080/20430795.2020.1813478?needAccess=true.

[clxii] GSIA. 2021. Global Sustainable Investment Review 2020. Global Sustainable Investment Alliance (GSIA). http://www.gsi-alliance.org/wp-content/uploads/2021/08/GSIR-20201.pdf.

Bernow, S.; Godsall, J.; Klempner, B.; Merten, C. 2019. More than values: The value-based sustainability reporting that investors want. McKinsey. https://www.mckinsey.com/business-functions/sustainability/our-insights/more-than-values-the-value-based-sustainability-reporting-that-investors-want.

UNCTAD. 2021. World Investment Report 2021. Investing in sustainable recovery. United Nations (UN) publication issued by the United Nations Conference on Trade and Development (UNCTAD). https://unctad.org/system/files/official-document/wir2021_en.pdf.

[clxiii] Bloomberg NEF, Bloomberg L.P. From: Bhalla, A. 2022. Personal communications. Arjun Bhalla, Senior Operations Manager, IFC.

[clxiv] Source: Bloomberg NEF, Bloomberg L.P. in: De la Orden, R. and de Calonje, I. 2022. Sustainability-linked finance – mobilizing capital for sustainability in emerging markets. International Finance corporation (IFC). https://openknowledge.worldbank.org/bitstream/handle/10986/36872/Sustainability-Linked-Finance-Mobilizing-Capital-for-Sustainability-in-Emerging-Markets.pdf?sequence=5#:~:text=In%202021%2C%20sustainability%2Dlinked%20financing,non%2Dhigh%2D%20income%20countries.

[clxv] UNCTAD. 2021. World Investment Report 2021. Investing in sustainable recovery. United Nations (UN) publication issued by the United Nations Conference on Trade and Development (UNCTAD). https://unctad.org/system/files/official-document/wir2021_en.pdf.

Green Finance Platform. 2021. Explore Green Finance. https://www.greenfinanceplatform.org/page/explore-green-finance.

Gilchrist, D., Yu, J., and Zhong, R. 2021. The Limits of Green Finance: A Survey of Literature in the Context of Green Bonds and Green Loans. Sustainability, 13, 478. https://doi.org/10.3390/su13020478.

De la Orden, R. and de Calonje, I. 2022. Sustainability-linked finance – mobilizing capital for sustainability in emerging markets. International Finance corporation (IFC). https://openknowledge.worldbank.org/bitstream/handle/10986/36872/Sustainability-Linked-Finance-Mobilizing-Capital-for-Sustainability-in-Emerging-Markets.pdf?sequence=5#:~:text=In%202021%2C%20sustainability%2Dlinked%20financing,non%2Dhigh%2D%20income%20countries.

de Calonje, I. 2022. Personal communications. Ignacio de Calonje, Chief Investment Officer, IFC.

Van Steenis, H. 2020. Climate stress testing: the transformation of capital allocation. UBS Sustainability and Impact. https://www.ubs.com/global/en/sustainability-impact/2021/trends-climate-stress-testing.html.

CISL. 2019. Walking the talk: Understanding consumer demand for sustainable investing. Cambridge, UK: University of Cambridge Institute for Sustainability Leadership (CISL). https://www.cisl.cam.ac.uk/resources/sustainable-finance-publications/walking-the-talk-understanding-consumer-demand-for-sustainable-investing.

CISL. 2020. The six trends transforming finance for a sustainable economy. University of Cambridge. Cambridge Institute for Sustainability Leadership (CISL). https://www.cisl.cam.ac.uk/news/blog/the-six-trends-transforming-finance-for-a-sustainable-economy.

Douma, K., Scott, L., and Bulzomi, A. 2017. The SDG investment case. Principles for Responsible Investment (PRI); United Nations Environment Programme (UNEP) Finance Initiative. https://www.unpri.org/download?ac=5909.

[clxvi] Green Finance Platform. 2021. Explore Green Finance. https://www.greenfinanceplatform.org/page/explore-green-finance.

Gilchrist, D., Yu, J., and Zhong, R. 2021. The Limits of Green Finance: A Survey of Literature in the Context of Green Bonds and Green Loans. Sustainability, 13, 478. https://doi.org/10.3390/su13020478.

De la Orden, R. and de Calonje, I. 2022. Sustainability-linked finance – mobilizing capital for sustainability in emerging markets. International Finance corporation (IFC). https://openknowledge.worldbank.org/bitstream/handle/10986/36872/Sustainability-Linked-Finance-Mobilizing-Capital-for-Sustainability-in-Emerging-Markets.pdf?sequence=5#:~:text=In%202021%2C%20sustainability%2Dlinked%20financing,non%2Dhigh%2D%20income%20countries

PWC. 2021. Mine 2021. Great expectations, seizing tomorrow. https://www.pwc.com/gx/en/energy-utilities-mining/assets/mine-2021/pwc-mine-2021.pdf.

[clxvii] Friede, G., Busch, T., and Bassen, A. 2015. ESG and financial performance: aggregated evidence from more than 2000 empirical studies. Journal of Sustainable Finance and Investment, 5(4): 210-233. https://www.tandfonline.com/doi/full/10.1080/20430795.2015.1118917?scroll=top&needAccess=true.

Fidelity International. 2021. What is ESG investing? https://www.fidelity.com.sg/beginners/esg-investing/what-is-esg.

Walker, D. 2021. ESG insights: What does ESG mean for the mining industry? SLR. https://www.slrconsulting.com/news-and-insights/insights/esg-insights-what-does-esg-mean-mining-industry.

Stobart, B. 2021. ESG insights: Four reasons why the mining industry should act on ESG. SLR. https://www.slrconsulting.com/news-and-insights/insights/esg-insights-four-reasons-why-mining-industry-should-act-esg.

De la Orden, R. and de Calonje, I. 2022. Sustainability-linked finance – mobilizing capital for sustainability in emerging markets. International Finance corporation (IFC). https://openknowledge.worldbank.org/bitstream/handle/10986/36872/Sustainability-Linked-Finance-Mobilizing-Capital-for-Sustainability-in-Emerging-Markets.pdf?sequence=5#:~:text=In%202021%2C%20sustainability%2Dlinked%20financing,non%2Dhigh%2D%20income%20countries.

de Calonje, I. 2022. Personal communications. Ignacio de Calonje, Chief Investment Officer, IFC.

Raghunandan, A. and Rajgopal, S. 2021. Do socially responsible firms walk the talk? https://ssrn.com/abstract=3609056.

[clxviii] De la Orden, R. and de Calonje, I. 2022. Sustainability-linked finance – mobilizing capital for sustainability in emerging markets. International Finance corporation (IFC). https://openknowledge.worldbank.org/bitstream/handle/10986/36872/Sustainability-Linked-Finance-Mobilizing-Capital-for-Sustainability-in-Emerging-Markets.pdf?sequence=5#:~:text=In%202021%2C%20sustainability%2Dlinked%20financing,non%2Dhigh%2D%20income%20countries.

GFP. 2021. Browse policies and regulations. The Green Finance Platform. https://www.greenfinanceplatform.org/financial-measures/browse.

European Commission. N.d. Sustainable Mining: Objectives of the commitment. https://ec.europa.eu/growth/sectors/raw-materials/eip/raw-materials-commitment/sustainable-mining_en.

European Commission. 2020. A European Green Deal. https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en#thematicareas.

European Commission. N.d. Overview of Sustainable Finance. https://ec.europa.eu/info/business-economy-euro/banking-and-finance/sustainable-finance/overview-sustainable-finance_en.

European Commission. 2020. The European Green Deal Investment Plan and Just Transition Mechanism. https://ec.europa.eu/info/publications/200114-european-green-deal-investment-plan_en.

European Commission. 2020. Critical Raw Materials Resilience: Charting a path towards greater security and sustainability. https://ec.europa.eu/docsroom/documents/42849.

Gondjian, G. and Merle, C. 2021. Sustainable Taxonomy development worldwide: a stander-setting race between competing jurisdictions. Natixis Corporate and Investment Banking. https://gsh.cib.natixis.com/our-center-of-expertise/articles/sustainable-taxonomy-development-worldwide-a-standard-setting-race-between-competing-jurisdictions.

[clxix] For more information about various sustainable finance policies and regulations, please refer to the Green Finance Platform's "Green Finance Measures Database".

[clxx] IFRS. 2022. ISSB delivers proposals that create comprehensive global baseline of sustainability disclosures. https://www.ifrs.org/news-and-events/news/2022/03/issb-delivers-proposals-that-create-comprehensive-global-baseline-of-sustainability-disclosures/.

Skinner, R. 2021. Four sustainable finance takeaways from COP26. Forrester. https://www.forrester.com/blogs/four-sustainable-finance-takeaways-from-cop26/.

[clxxi] Green Finance Platform. 2021. Explore Green Finance. https://www.greenfinanceplatform.org/page/explore-green-finance.

Carbon Trust research.

[clxxii] Goldman Sachs. 2021. Accelerating Transition. https://www.goldmansachs.com/accelerating-transition/accelerating-transition-report.pdf.

Cox, Suzanne, Hellstern, Tom, Henderson, Kimberly, Nowski, Tracy, O'Flanagan, Maisie, Pinner, Dickon, Ray, Taylor, and Sabow, Adam. 2021. It's time for philanthropy to step up the fight against climate change. https://www.mckinsey.com/business-functions/sustainability/our-insights/its-time-for-philanthropy-to-step-up-the-fight-against-climate-change.

Green Finance Platform. 2021. Explore Green Finance. https://www.greenfinanceplatform.org/page/explore-green-finance.

IFC. 2021. Private equity and venture capital's role in catalyzing sustainable investment. https://www.ifcamc.org/sites/amc/files/G20%20Input%20Paper_%202018.pdf.

Mitchell, Olivia. 2021. Can Pension funds integrate environmental, social, and governance principles? https://pensionresearchcouncil.wharton.upenn.edu/blog/can-pension-funds-integrate-environmental-social-and-governance-principles/.

Eccles, Robert and Klimenko, Svetlana. 2019. The investor revolution. https://hbr.org/2019/05/the-investor-revolution.

Rutherford, John. 2021. The role of public sector issuers and investors in sustainable finance. https://www.bbva.com/en/opinion/the-role-of-public-sector-issuers-and-investors-in-sustainable-finance/.

United Nations. 2021. Financing for Sustainable Development Report 2021. https://unosd.un.org/sites/unosd.un.org/files/financing_for_sustainable_development_report_2021.pdf.

Nasdaq. 2022. Green Equity Indexes-Complete family of environmental indexes. https://www.nasdaq.com/solutions/green-equity-indexes.

Sangiorgi, Ivan and Schopohl, Lisa. 2021. Why do institutional investors buy green bonds: evidence from a survey of European asset managers. https://www.sciencedirect.com/science/article/abs/pii/S1057521921000818

Hale, J. 2021. The ESG advisor: index funds pose problems for asset manager net-zero commitments. https://www.morningstar.com/articles/1067786/the-esg-advisor-index-funds-pose-problems-for-asset-manager-net-zero-commitments.

[clxxiii] GCF. 2022. Democratic Republic of Congo. Green Climate Fund (GCF) https://www.greenclimate.fund/countries/dr-congo.

Mulenga, M. 2022. Green and Sustainable Finance in Zambia. https://www.moiramukuka.com/green-and-sustainable-finance-in-zambia/.

OECD. 2022. Sustainable finance definitions and taxonomies in China. https://www.oecd-ilibrary.org/sites/5abe80e9-en/index.html?itemId=/content/component/5abe80e9-en#:~:text=The%20five%20major%20green%20lenders,China%20and%20Bank%20of%20China.

IFC. 2022. IFC provides US$60 million loan to BBVA Peru to finance green buildings and fight climate change. https://pressroom.ifc.org/all/pages/PressDetail.aspx?ID=26798.

Bhandari, J. 2022. South Africa's Green Fund. https://www.greenfinanceplatform.org/sites/default/files/downloads/best-practices/GGBP%20Case%20Study%20Series_South%20Africa_Green%20Fund.pdf.

IFC. 2021. IFC and Absa bank partner on Africa's first certified green loan to support green energy projects. https://pressroom.ifc.org/all/pages/PressDetail.aspx?ID=26334.

GFL. 2021. IDB Invest and ENGIE Chile debut the world's first pilot project to monetize the cost of decarbonization. https://greenfinancelac.org/resources/news/idb-invest-and-engie-chile-debut-the-worlds-first-pilot-project-to-monetize-the-cost-of-decarbonization/.

CBI. 2019. Banco de Chile Green bond fact sheet. Climate Bonds Initiative (CBI). https://www.climatebonds.net/files/files/2019-08%20CL%20Banco%20de%20Chile.pdf.

REglobal. 2020. Opportunities for green finance in the Philippines. https://reglobal.co/opportunities-for-green-finance-in-the-philippines/#:~:text=To%20date%2C%20the%20Philippine%20banks,green%20infrastructure%20and%20renewable%20energy.

IFC. 2021. BDO issues first green bond for $150 million first green investment for IFC in East Asia and the Pacific. https://pressroom.ifc.org/all/pages/PressDetail.aspx?ID=18275.

Trofimova, E. and Luntovskiy, G. 2021. ESG Banking in Russia. https://asros.ru/upload/iblock/f6c/q0b1qh8xpem8vb3bsrh9oneb1241pnr1/ESG_banking-in-Russia.pdf

Yeap, J. 2022. Asian Development Bank sets up Indonesian green infrastructure fund. https://www.pinsentmasons.com/out-law/news/asian-development-bank-sets-up-indonesian-green-infrastructure-fund#:~:text=The%20Asian%20Development%20Bank%20(ADB,sustainable%20infrastructure%20projects%20in%20Indonesia.

IFC. 2018. IFC invests in Bank OCBC NISP for pioneering Green bond. https://pressroom.ifc.org/all/pages/PressDetail.aspx?ID=18372.

IFC. 2020. IFC invests up to IDR 2.75 trillion in Bank OCBC NISP's Gender and Green bonds to Empower Women Entrepeneurs and Women-owned SMEs, and Catalyze Green project financing. https://www.ocbcnisp.com/en/tentang-ocbc-nisp/informasi/siaran-pers/2020/11/13/IFC-salurkan-pinjaman-ke-Bank-OCBC-NISP.

[clxxiv] De la Orden, R. and de Calonje, I. 2022. Sustainability-linked finance – mobilizing capital for sustainability in emerging markets. International Finance corporation (IFC). https://openknowledge.worldbank.org/bitstream/handle/10986/36872/Sustainability-Linked-Finance-Mobilizing-Capital-for-Sustainability-in-Emerging-Markets.pdf?sequence=5#:~:text=In%202021%2C%20sustainability%2Dlinked%20financing,non%2Dhigh%2D%20income%20countries.

de Calonje, I. 2022. Personal communications. Ignacio de Calonje, Chief Investment Officer, IFC.

Gilchrist, D., Yu, J., and Zhong, R. 2021. The Limits of Green Finance: A Survey of Literature in the Context of Green Bonds and Green Loans. Sustainability, 13, 478. https://doi.org/10.3390/su13020478.

Legge, H., Müller-Falcke, C., Nauclér, T., and Östgren. 2021. Creating the zero-carbon mine. McKinsey & Company Metals and Mining Practice. https://www.mckinsey.com/~/media/mckinsey/industries/metals%20and%20mining/our%20insights/creating%20the%20zero%20carbon%20mine/creating-the-zero-carbon-mine-vf.pdf?shouldIndex=false.

IFC. N.d. Financing a sustainable future. A knowledge network for banking regulators. International Finance Corporation (IFC). https://www.ifc.org/wps/wcm/connect/011806ad-c8b6-4d32-9459-3f100fb162a3/sustFinance.pdf?MOD=AJPERES&CVID=kccKMIr.

Fidelity International. 2021. What is ESG investing? https://www.fidelity.com.sg/beginners/esg-investing/what-is-esg.

Walker, D. 2021. ESG insights: What does ESG mean for the mining industry? SLR. https://www.slrconsulting.com/news-and-insights/insights/esg-insights-what-does-esg-mean-mining-industry.

Stobart, B. 2021. ESG insights: Four reasons why the mining industry should act on ESG. SLR. https://www.slrconsulting.com/news-and-insights/insights/esg-insights-four-reasons-why-mining-industry-should-act-esg.

[clxxv] IFRS. 2022. ISSB delivers proposals that create comprehensive global baseline of sustainability disclosures. https://www.ifrs.org/news-and-events/news/2022/03/issb-delivers-proposals-that-create-comprehensive-global-baseline-of-sustainability-disclosures/.

Skinner, R. 2021. Four sustainable finance takeaways from COP26. Forrester. https://www.forrester.com/blogs/four-sustainable-finance-takeaways-from-cop26/.

clxxvi Green Finance Platform. 2021. Explore Green Finance. https://www.greenfinanceplatform.org/page/explore-green-finance.

Gilchrist, D., Yu, J., and Zhong, R. 2021. The Limits of Green Finance: A Survey of Literature in the Context of Green Bonds and Green Loans. Sustainability, 13, 478. https://doi.org/10.3390/su13020478.

De la Orden, R. and de Calonje, I. 2022. Sustainability-linked finance – mobilizing capital for sustainability in emerging markets. International Finance corporation (IFC). https://openknowledge.worldbank.org/bitstream/handle/10986/36872/Sustainability-Linked-Finance-Mobilizing-Capital-for-Sustainability-in-Emerging-Markets.pdf?sequence=5#:~:text=In%202021%2C%20sustainability%2Dlinked%20financing,non%2Dhigh%2D%20income%20countries.

Simmons and Simmons. 2019. Financing sustainability in the mining sector. https://www.simmons-simmons.com/en/publications/ck2nkylht5z630b12l59wq41z/financing-sustainability-in-the-mining-sector.

Condon, M. 2021. Market Myopia's Climate Bubble. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3782675

Goldman Sachs. 2021. Accelerating Transition. https://www.goldmansachs.com/accelerating-transition/accelerating-transition-report.pdf

Ritchie G. and Azevedo Rocha P. 2021. A $180 billion green-debt boom grows faster than its impact. https://www.bloomberg.com/news/articles/2021-12-22/a-180-billion-green-debt-boom-is-growing-faster-than-its-impact

Hale, J. 2021. The ESG Advisor: Index Funds Pose Problems for Asset Manager Net-Zero Commitments. https://www.morningstar.com/articles/1067786/the-esg-advisor-index-funds-pose-problems-for-asset-manager-net-zero-commitments

Swiss Sustainable Finance. 2020. Financing the Low-Carbon Economy: Instruments, Barriers, and Recommendations. https://www.sustainablefinance.ch/upload/cms/user/2020_11_19_Financing_the_Low_Carbon_Economy_EN_full_report_final.pdf

clxxvii ICMM. 2022. Social and economic reporting: Framework and guidance. https://www.icmm.com/en-gb/our-principles/validation/social-and-economic-reporting.

clxxviii Fortescue Metals Group. 2022. Sustainability Financing Framework. https://www.fmgl.com.au/docs/default-source/default-document-library/sustainability-financing-framework_final.pdf?sfvrsn=c812a13b_0.

clxxix Bnamericas. 2021. Chile's SQM announces US$700mn green bond issue. https://www.bnamericas.com/en/news/chiles-sqm-announces-us700mn-green-bond-issue.

SQM. 2021. Green Bond Framework. https://s25.q4cdn.com/757756353/files/doc_downloads/2021/09/SQM-Green-Bond-Framework_Sept2021.vFINAL.pdf.

ERM. 2020. ERM provides Second Party Opinion on the alignment of Livent Corporation's Green Bond Framework. https://www.erm.com/news/erm-provides-second-party-opinion-on-the-alignment-of-livent-corporations-green-bond-framework/.

ERM. 2020. Second Party Opinion. Livent Corporation Green Bond Framework. http://q4live.s22.clientfiles.s3-website-us-east-1.amazonaws.com/453302215/files/doc_downloads/2020/Livent-Green-Bond-Framework-SPO_vF-for-website.pdf.

clxxx Teck. 2021. Teck announces US$40 billion sustainable financing facility. https://www.teck.com/news/news-releases/2021/teck-announces-us-4-billion-sustainable-financing-facility.

clxxxi South32. 2021. South32 secured sustainability-linked revolving credit facility. https://www.south32.net/our-news/south32-secures-sustainability-linked-revolving-credit-facility.

clxxxii Anglo American. 2022. Anglo American agrees sustainability-linked loan with International Finance Corporation. https://www.angloamerican.com/media/press-releases/2022/09-06-2022#:~:text=Anglo%20American%20has%20signed%20a,Anglo%20American's%20Sustainable%20Mining%20Plan.

clxxxiii WBCSD. 2018. Power Purchase Agreement Structures. https://www.wbcsd.org/contentwbc/download/4468/60118.

clxxxiv Daszkiewicz, K. 2020. Policy and Regulation of Energy Transition. Hafner M., Tagliapietra S. (eds) The Geopolitics of the Global Energy Transition. Vol 73, 203-226.

clxxxv The relevance of all these indicators is explained in the methodology [clxxxvi] UNDP. 2022. Chile. https://www.ndcs.undp.org/content/ndc-support-programme/en/home/our-work/geographic/latin-america-and-caribbean/Chile.html.

International Bar Association. 2021. Chile's new Energy Efficiency Law. https://www.ibanet.org/chile-energy-efficiency-law.

Attwood, James. 2021. *Giant Copper Mines Start to Get Serious About Green Hydrogen.* https://www.bloomberg.com/news/articles/2021-04-12/giant-copper-mines-start-to-get-serious-about-green-hydrogen.

Attwood, James and Fuentes, Valentina. 2021. The World's Top Copper Nation Moves Closer to Giant Tax Hike. https://www.bloomberg.com/news/articles/2021-05-06/in-top-copper-nation-chile-a-giant-tax-hike-moves-a-step-closer#xj4y7vzkg.

Merco Press. 2021. *Chile pronto a suprimir el carbón como fuente para la generación de electricidad.* https://es.mercopress.com/2021/04/29/chile-pronto-a-suprimir-el-carbon-como-fuente-para-la-generacion-de-electricidad.

World Bank, 2021. What a Waste Global Database. https://datacatalog.worldbank.org/search/dataset/0039597.

Climate Change Performance Index. 2021. Climate Change Performance Index 2021. https://ccpi.org/download/the-climate-change-performance-index-2021/.

International Carbon Action Partnership. 2021. Chile ETS Map. https://icapcarbonaction.com/en.

World Hydrogen Leaders. 2021. World Hydrogen Chile. https://www.worldhydrogenleaders.com/events/event-one-77mbc-54xgd-g4max-xsszj-8mfte.

Ministerio del Ambiente. 2020. *Gobierno entrega la actualización de su compromiso de reducción de emisiones y medidas para enfrentar el cambio climático.* https://mma.gob.cl/gobierno-entrega-la-actualizacion-de-su-compromiso-de-reduccion-de-emisiones-y-medidas-para-enfrentar-el-cambio-climatico/.

Aures Project. 2020. Chile. https://www.auresproject.eu/sites/auresproject.eu/files/media/documents/chile_final.pdf.

Statista. 2020. *Major countries in copper mine production worldwide from 2010 to 2020.* https://cas.columbia.edu/cas/login?service=https%3a%2f%2fwww1.columbia.edu%2fsec-cgi-bin%2fcul%2fprox%2fezproxy-auth.cgi%3furl%3dezp.2aHR0cHM6Ly93d3cuc3RhdGlzdGEuY29tL3N0YXRpc3RpY3MvMjY0NjI2L2NvcHBlci.

Reporte Minero. 2020. *"La Innovación es la clave para adoptar una estrategia de Economía Circular".* https://www.reporteminero.cl/noticia/columnistas/2020/01/la-innovacion-es-la-clave-para-adoptar-una-estrategia-de-economia-circular.

Guven, Brooke, Toledano, Perrine, Johnson, Lise. 2020. Preparing Legal Frameworks for Environmental Disasters: Practical Considerations for Host States. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3660938.

Chaparro, Carlos Miguel. 2020. *Tax Incentive for Renewable Energy in Latin America.* https://www.pwc.com/co/es/publicaciones/tax-renewable/tax-incentives-renewable-energy-col.pdf.

Ministerio de Minería. 2020. *Ley 18097 - Ley Orgánica Constitucional sobre Concesiones Mineras.* https://www.bcn.cl/leychile/navegar?idNorma=29522.

Ministerio de Minería. 2020. *Ley 18248 - Código de Minería.* https://www.bcn.cl/leychile/navegar?idNorma=29668.

Ministerio de Energia. 2020. Carbono Neutralidad En El Sector Energía. https://energia.gob.cl/sites/default/files/pagina-basica/informe_resumen_cn_2019_v07.pdf.

Ministerio de Energia. 2020. Gobierno presenta la Estrategia Nacional para que Chile sea líder mundial en hidrógeno verde. https://energia.gob.cl/noticias/nacional/gobierno-presenta-la-estrategia-nacional-para-que-chile-sea-lider-mundial-en-hidrogeno-verde.

US Grains Council. 2020. Ethanol Market Profile Chile. https://grains.org/buying-selling/ethanol-2/ethanol-market-profiles/chile/

Bahamondez, Felipe. 2020. The e.nergy transition and renewable energy in Chile: Top points for foreign investors. https://www.dlapiper.com/en/spain/insights/publications/2020/10/energy-transition-and-renewables-in-chile-points-for-foreign-investors/.

Leprince-Ringuet, Noemie. 2020. Chile's Enhanced Climate Plan Sets an Example for Other Countries. https://www.wri.org/insights/chiles-enhanced-climate-plan-sets-example-other-countries.

Gobierno de Chile. 2020. *Contribución Determinada a Nivel Nacional (NDC) de Chile - Actualización 2020.* https://mma.gob.cl/wp-content/uploads/2020/04/NDC_Chile_2020_espan%CC%83ol-1.pdf.

Jimenez, Gonzalo, Cariola, Diez, and Perez-Cotapos. 2020. Electricity regulation in Chile: overview. https://uk.practicallaw.thomsonreuters.com/w-019-3060?transitionType=Default&contextData=(sc.Default)&firstPage=true.

Government of Sebastian Pinera. 2019. Plan for Decarbonisation And Closure Of Coalfired Power Plants in Chile. https://www.chilesustentable.net/wp-content/uploads/2019/09/EN_Minuta_Acuerdos-Descarbonizaci%C3%B3n_VF_CHS_REV2.pdf.

Ministerio de Energia. 2019. Chile Investment in the Energy Sector. https://www.energia.gob.cl/sites/default/files/investments-chile-v29-09.pdf.

OECD. 2019. Best Available Techniques (BAT) for Preventing and Controlling Industrial Pollution, Activity 3: Measuring the Effectiveness of BAT. https://www.oecd.org/chemicalsafety/risk-management/measuring-the-effectiveness-of-best-available-techniques-policies.pdf.

Montes, Carlos. 2019. *¿Qué pasó con la opción nuclear en Chile?* https://www.latercera.com/que-pasa/noticia/gobierno-cierra-la-puerta-a-la-energia-nuclear-en-chile/460613/.

Mitigation and Energy Working Group. 2019. Chilean NDC mitigation proposal: Methodological approach and supporting ambition. https://mma.gob.cl/wp-content/uploads/2020/03/Mitigation_NDC_White_Paper.pdf.

Gobierno de Chile. 2018. Energy Policies Beyond IEA countries. https://energia.gob.cl/sites/default/files/documentos/energy-policies-beyond-iea-countries-chile-2018-review.pdf.

Gobierno de Chile. 2017. *Plan de Acción Nacional de Cambio Climático 2017-2022.* https://mma.gob.cl/wp-content/uploads/2017/07/plan_nacional_climatico_2017_2.pdf.

Ministerio de Energía. 2017. *Plan de Mitigación de Gases de Efecto Invernadero para el sector energía.* https://www.energia.gob.cl/sites/default/files/plan_de_mitigacion_energia.pdf.

Centro de Estudios Públicos. 2017. *Energías renovables en Chile Hacia una inserción eficiente en la matriz eléctrica.* https://www.cepchile.cl/cep/site/docs/20180124/20180124191509/libro_energia_cep.pdf.

EBP Chile. 2017. *Informe 2 Final: Propuestas de ampliación del alcance del sistema actual de impuesto al carbono. Consultoría "Alternativas de Diseño y Medidas Complementarias para un Sistema más integral de Instrumentos del Precio del Carbón.* https://www.ebpchile.cl/sites/default/files/project/uploads/20170531_Alternativas-de-Dise%C3%B1o-y-Medidas-para-Sistema-Integral-de-IPC_-Inf-N%C2%B02-1.pdf.

Ministerio de Hacienda. 2016. *Ley Nº 20.780 Reforma Tributaria que modifica el Sistema de Tributación de la Renta e Introduce diversos ajustes en el Sistema Tributario.* https://www.bcn.cl/leychile/navegar?idNorma=1067194.

Ministerio de Hacienda. 2016. *Ley Nº 20.780 Reforma Tributaria que modifica el Sistema de Tributación de la Renta e Introduce diversos ajustes en el Sistema Tributario.* https://www.bcn.cl/leychile/navegar?idNorma=1067194.

Columbia Center on Sustainable Investment. 2016. Water Risks in the Mining Sector Chile. https://ccsi.columbia.edu/sites/default/files/content/docs/our%20focus/Water-Template-Chile.pdf.

Consejo Minero. 2016. *Desde el cobre a la innovación: Roadmap Tecnológico 2015-2035.* https://consejominero.cl/wp-content/uploads/2019/04/Roadmap-miner%C3%ADa.pdf.

Miniera Chilena. 2015. *Fundiciones en Chile: Una discusión necesaria.* https://www.mch.cl/reportajes/fundiciones-en-chile-una-discusion-necesaria/#.

Ministerio de Energía. 2015. *Energía 2050 - Política Energética de Chile.* https://energia.gob.cl/sites/default/files/energia_2050_-_politica_energetica_de_chile.pdf.

IUCN, 2014, Global Inventory of Biodiversity Offset Policies (GIBOP). https://portals.iucn.org/offsetpolicy/node/29.

BCN Ley Chile. 2014. Decreto 66. https://www.bcn.cl/leychile/navegar?idNorma=1059961.

Ministerio de Energía. 2013. *Ley 20698 - Propicia la ampliación de la Matriz Energética, mediante Fuentes Renovables No – Convencionales.* https://www.bcn.cl/leychile/navegar?idNorma=1055402.

[clxxxvii] Government of Peru. 2021. Annual Executive Summary. http://www.minem.gob.pe/minem/archivos/AnuarioEjecutivoFinal-Rev-Final2.pdf

Desdeadentro. 2021. El Perú deberá invertir más de US$ 93 mil millones para ser carbono neutral en el 2050. https://www.desdeadentro.pe/2021/06/el-peru-debera-invertir-mas-de-us-93-mil-millones-para-ser-carbono-neutral-en-el-2050/

PWC. 2021. Peru Corporate Taxes. https://taxsummaries.pwc.com/peru/corporate/other-taxes

Climate Action Tracker. 2021. Peru. https://climateactiontracker.org/countries/peru/pledges-and-targets/

U.S. Grains Council. 2021. Peru. https://grains.org/buying-selling/ethanol-2/ethanol-market-profiles/peru/

BP. 2021. Statistical Review of World Energy. https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2021-full-report.pdf

Grantham Research Institute on Climate Change and the Environment. 2020. Framework Law no 30754 on Climate Change. https://climate-laws.org/geographies/peru/laws/framework-law-no-30754-on-climate-change

MINAGRI. 2020. Energias Renovables. https://www.minagri.gob.pe/portal/45-sector-agrario/recurso-energetico/337-energia-renovable

Baker McKenzie. 2020. Global Mining Guide: Peru. https://resourcehub.bakermckenzie.com/en/resources/global-mining-guide/latin-america/peru/topics/global-mining-guide

APEC Energy Working Group. 2020. Follow-Up Peer Review on Energy Efficiency in Peru. https://aperc.or.jp/file/2020/4/7/Follow-Up_PREE_Peru.pdf

Delgado, A and Baracco, D. 2020. Mining in Peru: Overview. https://uk.practicallaw.thomsonreuters.com/w-008-1009?transitionType=Default&contextData=(sc.Default)&firstPage=true

Hamann, Carlos, Tarazona, German, and Canseco, Alejandro Diez. 2020. RENEWABLE ENERGY LAW AND REGULATION IN PERU. https://cms.law/en/int/expert-guides/cms-expert-guide-to-renewable-energy/peru

Saldarriaga, Juan. 2020. Engie: "Vamos a cerrar nuestras plantas térmicas a carbón en el Perú y Chile". https://elcomercio.pe/economia/dia-1/engie-vamos-a-cerrar-nuestras-plantas-termicas-a-carbon-en-el-peru-y-chile-energia-noticia/?ref=ecr

Miniterio de Energia y Minas. 2020. *Anuario ejecutivo de electricidad 2019*. http://www.minem.gob.pe/minem/archivos/AnuarioEjecutivoFinal-Rev-Final2.pdf

Andina. 2020. Perú: apuesta por energías renovables representará un beneficio de US$ 17,200 millones. https://andina.pe/agencia/noticia-peru-apuesta-energias-renovables-representara-un-beneficio-17200-millones-813156.aspx

Enerdata. 2020. Peru's updated NDC targets 30% GHG emissions cut by 2030. https://www.enerdata.net/publications/daily-energy-news/perus-updated-ndc-targets-30-ghg-emissions-cut-2030.html#:~:text=The%20government%20of%20Peru%20has,scenario%2C%20using%20its%20domestic%20resources

Baker McKenzie. 2018. The Rise of Corporate PPAs 2.0. https://www.bakermckenzie.com/-/media/files/insight/publications/2018/07/fc_emi_riseofcorporateppas_jul18.pdf

Columbia Center on Sustainable Investment. 2016. Water Risks in the Mining Sector Peru. https://ccsi.columbia.edu/sites/default/files/content/docs/our%20focus/Water-Template-Peru.pdf

Cole, Jack Dylan. 2017. Peru to reevaluate environmental laws over La Oroya smelter. https://perureports.com/peru-to-reevaluate-environmental-laws-over-la-oroya-smelter/5307/

IUCN. 2014. Peru. https://portals.iucn.org/offsetpolicy/node/46

Crousillat, Enrique. 2012. INTERNATIONAL EXPERIENCE WITH PRIVATE SECTOR PARTICIPATION IN POWER GRIDS. https://documents1.worldbank.org/curated/en/498461468000021182/pdf/101753-WP-P146042-Box393265B-PUBLIC-Private-Sector-Participation-in-Power-Grids-Peru.pdf

MINEM. 1992. Ley General de Mineria. http://www.minem.gob.pe/minem/archivos/file/Mineria/PUBLICACIONES/CDROM/2013/files/LGMINGLES.pdf

[clxxxviii] Climate Action Tracker. 2021. Russia. https://climateactiontracker.org/countries/russian-federation/pledges-and-targets/#:~:text=Our%20best%20estimate%20of%20the,1990%20levels%2C%20excluding%20LULUCF)

Balmforth, Tom. 2021. EXCLUSIVE Russian climate envoy calls race to tighten emissions targets "unreasonable". https://www.reuters.com/business/environment/exclusive-russian-climate-envoy-calls-race-tighten-emissions-targets-2021-05-13/

UNFCC. 2021. Russia's Far East in Race to Net Zero Emissions. https://unfccc.int/news/russia-s-far-east-in-race-to-net-zero-emissions

Baker McKenzie. 2021. Doing Business in Russia. https://www.bakermckenzie.com/en/-/media/files/insight/publications/2021/04/doing_business_in_russia_2021.pdf

The Moscow Times. 2021. Russia to Pay 1.1Bln Euros Per Year Under EU Carbon Tax – Reports. https://www.themoscowtimes.com/2021/07/26/russia-eyes-free-trade-zone-on-islands-disputed-by-japan-a74616

Heidemann, Thomas, and Bogdanov, Dmitry. 2021. The Renewable Energy Law Review: Russia. https://thelawreviews.co.uk/title/the-renewable-energy-law-review/russia

Enerdata. 2021. Russia. https://www.enerdata.net/estore/energy-market/russia/

Lanshina, Tatiana. 2021. RUSSIA'S WIND ENERGY MARKET: Potential for New Economy Development. https://russia.fes.de/fileadmin/user_upload/documents/SOET/210316-FESMOS-windenergy-en.pdf

Statista. 2021. Russia Nickel Production. https://www.statista.com/statistics/260770/russias-mine-production-of-nickel-since-2006/

Josefson, Jennifer and Rotar, Alexandra. 2021. Mining in the Russian Federation: Overview. https://uk.practicallaw.thomsonreuters.com/w-011-1888?transitionType=Default&contextData=(sc.Default&firstPage=true

Zharskiy, Andrey and Akhundov, Timur. 2020. Russia: Mining Laws and Regulations. https://iclg.com/practice-areas/mining-laws-and-regulations/russia

Josefson, Jennifer and Rotar, Alexandra. 2019. Electricity regulation in the Russian Federation: overview. https://uk.practicallaw.thomsonreuters.com/6-527-2969?transitionType=Default&contextData=(sc.Default)&firstPage=true

Hjort, Marit. 2019. BAT APPROACHES AROUND THE WORLD – RESULTS FROM A RESEARCH PROJECT. https://unece.org/fileadmin/DAM/env/documents/2019/AIR/Capacity_Building/BAT_workshop_2019/1_3_OECD_BATproject_Hjort.pdf

Circle of Blue. 2018. Pollutants and Heavy Metals Taint Moscow's Water Supply. https://www.circleofblue.org/2018/europe/pollutants-and-heavy-metals-taint-moscows-water-supply/

World Bank. 2016. Mongolia: Mining Infrastructure Investment Support (MINIS) Project. https://www.worldbank.org/en/country/russia/brief/mongolia-mining-infrastructure-investment-support-project

Soderholm, Kristina, Soderholm, Patrik, Pettersson, Maria, Svahn, Nanna, Viklund, Roine, and Helenius, Heidi. 2014. ENVIRONMENTAL REGULATION AND MINING SECTOR COMPETITIVENESS. https://www.ltu.se/cms_fs/1.124549!/file/rapport%20Environmental%20Regulation%20and%20Mining_low.pdf

OECD. 2008. Info on Economic Instruments for Water Management in Russia. https://www.oecd.org/env/outreach/Info%20on%20Economic%20Instruments%20for%20Water%20Management%20in%20Russia.pdf

ECOLEX. 1995. Federal Law No. 167-FZ Water Code. https://www.ecolex.org/details/legislation/federal-law-no-167-fz-water-code-lex-faoc021820/

[clxxxix] Min, Hu. 2021. China's net zero future. https://racetozero.unfccc.int/chinas-net-zero-future/

Holzmann, Anna and Grunberg, Nis. 2021. "Greening" China: An analysis of Beijing's sustainable development strategies. https://merics.org/en/report/greening-china-analysis-beijings-sustainable-development-strategies

Climate Action Tracker. 2021. China. https://climateactiontracker.org/countries/china

Xu, Muyu and Stanway, David. 2021. https://www.reuters.com/article/us-china-energy-climatechange-idUSKBN29Q0JT

Thomson Reuters. 2021. Electricity regulation in China: overview. https://uk.practicallaw.thomsonreuters.com/w-030-2966?originationContext=document&transitionType=DocumentItem&contextData=(sc.Default)&firstPage=true#co_anchor_a164402

Wu, Guohua, Li, Yingnan, Tongda, Jingcheng, and Neal, Jingcheng. 2021. Mining in China: overview. https://uk.practicallaw.thomsonreuters.com/w-011-1348?transitionType=Default&contextData=(sc.Default)&firstPage=true

ChinaPower. 2021. How Is China's Energy Footprint Changing? https://chinapower.csis.org/energy-footprint/#:~:text=In%202018%2C%20the%20industrial%20sector,percent%20of%20the%20country's%20coal.&text=China's%20dependence%20on%20coal%20for,contributed%20to%20urban%20air%20pollution

Carpenter, Scott. 2021. Toothless Initially, China's New Carbon Market Could Be Fearsome. https://www.forbes.com/sites/scottcarpenter/2021/03/02/toothless-at-first-chinas-carbon-market-could-be-fearsome/?sh=665f98d92af1

Shaw, Vincent. 2021. China set to mandate solar on at least 20% of residential roofs in pilot counties. https://www.pv-magazine.com/2021/07/01/china-set-to-mandate-solar-on-at-least-20-of-residential-roofs-in-pilot-counties/

Wu, Guohua and Li, Yingnam. 2021. China: Mining Laws and Regulations. https://iclg.com/practice-areas/mining-laws-and-regulations/china

Argus. 2021. China sets 2025 target for renewable power capacity. https://www.argusmedia.com/en/news/2202143-china-sets-2025-target-for-renewable-power-capacity#:~:text=China's%20national%20energy%20administration%20(NEA,NEA%20officials%20said%20last%20week

U.S. Grains Council. 2021. China. https://grains.org/buying-selling/ethanol-2/ethanol-market-profiles/china/

Luk, Julian. 2020. China to reassess domestic base metals mines. https://www.amm.com/Article/3954461/China-to-reassess-domestic-base-metals-mines.html

Yuan, Cihang and Riley, Daniel. 2020. 3 major policy trends to watch for in China's renewable energy market. https://www.utilitydive.com/news/three-major-policy-trends-to-watch-for-in-chinas-renewable-energy-market/581344/

EIA. 2020. China. https://www.eia.gov/international/analysis/country/CHN

Yi, Shi. 2020. Are China's new 2030 climate targets ambitious enough? https://chinadialogue.net/en/climate/are-chinas-new-2030-climate-targets-ambitious-enough/

Reuters. 2020. China to abolish access restrictions on foreign investment in energy sector - white paper. https://www.reuters.com/article/us-china-energy/china-to-abolish-access-restrictions-on-foreign-investment-in-energy-sector-white-paper-idUSKBN28V0RY

Hjort, Marit. 2019. BAT APPROACHES AROUND THE WORLD – RESULTS FROM A RESEARCH PROJECT. https://unece.org/fileadmin/DAM/env/documents/2019/AIR/Capacity_Building/BAT_workshop_2019/1_3_OECD_BATproject_Hjort.pdf

Terada, Rachael, Cook, Orrin, and Leschke, Michael. 2019. Accelerating Corporate Renewable Energy Engagement in China. https://resource-solutions.org/wp-content/uploads/2019/11/Accelerating-Corporate-RE-Engagement-in-China.pdf

Columbia Center on Sustainable Investment. 2016. Water Risks in the Mining Sector People's Republic of China. https://ccsi.columbia.edu/sites/default/files/content/docs/our%20focus/Water-Template-China.pdf

China Briefing. 2011. Selected Tax Incentives in China's Renewable Energy Sector. https://www.china-briefing.com/news/selected-tax-incentives-in-chinas-renewable-energy-sector/

IUCN. 2002. China. https://portals.iucn.org/offsetpolicy/node/56

cxc Mukendi, Eric. 2022. Significant Changes Currently Taking Place in Electrical Power Law in the Democratic Republic of Congo. https://www.hg.org/legal-articles/significant-changes-currently-taking-place-in-electrical-power-law-in-the-democratic-republic-of-congo-32288

PWC. 2022. Congo, Democratic Republic of the. https://taxsummaries.pwc.com/democratic-republic-of-the-congo/corporate/other-taxes

Forest Legality. 2022. DRC. https://forestlegality.org/sites/default/files/country_documents/5drc09.pdf

USAID. 2022. USAID Water and Development Country Plan for the Democratic Republic of Congo (DRC). https://www.globalwaters.org/sites/default/files/DRC%20Country%20Plan%20final.pdf

NDC Partnership. 2021. DRC. https://ndcpartnership.org/countries-map/country?iso=COD

IEA. 2021. DRC. https://www.iea.org/countries/democratic-republic-of-the-congo

Energypedia. 2021. DRC. https://energypedia.info/wiki/Democratic_Republic_of_the_Congo_Energy_Situation#cite_note-Kusakana.2C_K._.282016.29._A_Review_of_Energy_in_the_Democratic_Republic_of_Congo._Retrieved_from:_https:.2F.2Fwww.researchgate.net.2Fpublication.2F306380971_A_Review_of_Energy_in_the_Democratic_Republic_of_Congo-5

Statista. 2021. DRC. https://www.trade.gov/country-commercial-guides/democratic-republic-congo-mining-and-minerals

Kubokoso, Jivet Ndela. 2021. The general customs regime for mines and the customs regime for artisanal mining. https://legalrdc.com/2021/05/19/le-regime-douanier-general-des-mines-et-le-regime-douanier-pour-lexploitation-miniere-artisanale/#_ftn2

Pombo-Van Zyl, Nicolette. 2021. DRC hydropower strengthened by SNEL and mining group's PPP. https://www.esi-africa.com/industry-sectors/asset-maintenance/drc-hydropower-strengthened-by-snel-and-mining-groups-ppp/

World Bank. 2020. Increasing Access to Electricity in the Democratic Republic of Congo. https://documents1.worldbank.org/curated/en/743721586836810203/pdf/Increasing-Access-to-Electricity-in-the-Democratic-Republic-of-Congo-Opportunities-and-Challenges.pdf.

World Bank. 2019. Mozambique and Democratic Republic of Congo Sign Landmark Deals with World Bank to Cut Carbon Emissions and Reduce Deforestation. https://www.worldbank.org/en/news/press-release/2019/02/12/mozambique-and-democratic-republic-of-congo-sign-landmark-deals-with-world-bank-to-cut-carbon-emissions-and-reduce-deforestation

Justice et Paix. 2019. Mining Code in DR Congo: the challenges of the reform. https://www.justicepaix.be/code-minier-en-rd-congo-les-enjeux-de-la-reforme/

Power for All. 2018. Power for All Research Summary Mini-grid market opportunity assessment, DR Congo. https://www.powerforall.org/application/files/9915/4826/7886/DR_Congo.pdf

Cabinet du President de la Republique. 2018. Journal official de la republique democratique du Congo. https://www.mines-rdc.cd/fr/wp-content/uploads/Code%20minier/J.O._n%C2%B0_spe%C3%ACcial_du_28_mars_2018_CODE_MINIER%20DE%20LA%20RDC.PDF

DLA Piper. 2018. A new mining code for the DRC. https://www.dlapiper.com/en/morocco/insights/publications/2018/08/democratic-republic-of-congo-mining-code/

[cxci] Climate Action Tracker. 2021. Indonesia. https://climateactiontracker.org/countries/indonesia/

Jong, Hans Nicholas. 2021. https://news.mongabay.com/2021/04/indonesia-net-zero-emissions-target-coal-energy-2070/

Jong, Hans Nicholas. 2021. Activists take Indonesia's mining law to court, but don't expect much. https://news.mongabay.com/2021/07/indonesia-mining-law-judicial-review-constitutional-court/

Rodyanto, Fransiscus, and Suwana, Aldilla. 2021. Indonesia: Putting A Price On Emissions: Indonesian Government Plans To Impose Carbon Tax. https://www.mondaq.com/renewables/1096108/putting-a-price-on-emissions-indonesian-government-plans-to-impose-carbon-tax

Statista. 2021. Indonesia Electric Consumption by Sector. https://www.statista.com/statistics/1233761/indonesia-electricity-consumption-by-sector/

Fimansyah and Karim, Rizki. 2021. Electricity Regulation in Indonesia: Overview. https://uk.practicallaw.thomsonreuters.com/w-025-0669?transitionType=Default&contextData=(sc.Default)&firstPage=true#co_anchor_a485329

U.S. Grains Council. 2021. Indonesia. https://grains.org/buying-selling/ethanol-2/ethanol-market-profiles/indonesia/

Baker McKenzie. 2021. Global Mining Guide: Indonesia. https://resourcehub.bakermckenzie.com/en/resources/global-mining-guide/asia-pacific/indonesia/topics/global-mining-guide

Kurniawan, Paulus. 2021. Highlights on Indonesia's copper industry. https://www2.deloitte.com/content/dam/Deloitte/id/Documents/about-deloitte/id-about-dip-edition-2-chapter-5-en-feb2021.pdf

Treadgold, Tim. 2021. Indonesia On Track To Dominate The Supply Of Nickel To Make Batteries. https://www.forbes.com/sites/timtreadgold/2021/06/02/indonesia-on-track-to-dominate-the-supply-of-nickel-to-make-batteries/?sh=6a3dbf4f7488

El Discha, Fadhila. 2020. Indonesia needs a better clean energy policy. https://www.southpole.com/blog/indonesia-needs-a-better-clean-energy-policy

Johnson, Matthew, Diarot, Dwi, and Rifdaan, Randy. 2020. Indonesian mining bill passed into law, poses new challenges and opportunities. https://www.hoganlovells.com/en/publications/indonesian-mining-bill-passed-into-law-poses-new-challenges-and-opportunities

Jong, Hans Nicholas. 2020. With new law, Indonesia gives miners more power and fewer obligations. https://news.mongabay.com/2020/05/indonesia-mining-law-minerba-environment-pollution-coal/

Kitt Florian. 2020. Renewable Energy Tariffs and incentives in Indonesia: Review and Recommendations. https://www.adb.org/sites/default/files/publication/635886/renewable-energy-tariffs-incentives-indonesia.pdf

Enerdata. 2020. Indonesia Energy Information. https://www.enerdata.net/estore/energy-market/indonesia/

Government of Indonesia. 2019. Indonesia NDC. https://www4.unfccc.int/sites/submissions/INDC/Published%20Documents/Indonesia/1/INDC_REPUBLIC%20OF%20INDONESIA.pdf

Deloitte. 2019. Indonesian Customs Guide 2019. https://www2.deloitte.com/content/dam/Deloitte/id/Documents/tax/id-tax-indonesian-customs-guide-2019-en.pdf

Assegaf, Ibrahim Sjarief, Satwika, Kanya, and Siregar, Aisyah Rahmarani. 2019. Wading through Indonesia's New Water Resources Law. https://www.ahp.id/client-update-8-november-2019/?utm_source=Mondaq&utm_medium=syndication&utm_campaign=LinkedIn-integration

PWC. 2019. Mining in Indonesia, Investment and Taxation Guide. https://www.pwc.com/id/en/energy-utilities-mining/assets/mining/mining-guide-2019.pdf

World Bank. 2018. Report on Indonesian Mining Sector Diagnostic. https://openknowledge.worldbank.org/bitstream/handle/10986/33087/Report-on-Indonesia-Mining-Sector-Diagnostic.pdf?sequence=1&isAllowed=y

IUCN. 2016. Indonesia. https://portals.iucn.org/offsetpolicy/node/42

Halstead, Matthew, Mikunda, Tom, and Cameron, Lachlan. 2014. Mitigation Momentum. https://cdkn.org/sites/default/files/files/ECN-Policy-Brief-Indonesian-Feed-in-tariff-140304.pdf

[cxcii] World Bank. 2022. What a Waste Global Database. https://datacatalog.worldbank.org/search/dataset/0039597

Energy and Climate. 2021. Net Zero Scorecard. https://eciu.net/netzerotracker

Wallach, Omri. 2021. Race to Net Zero: Carbon Neutral Goals by Country. https://www.visualcapitalist.com/race-to-net-zero-carbon-neutral-goals-by-country/

World Bank. 2021. World Bank Group – Carbon Pricing Dashboard. https://www.greengrowthknowledge.org/tools-and-platforms/world-bank-group-carbon-pricing-dashboard#:~:text=The%20Carbon%20Pricing%20Dashboard%20is,pricing%20initiatives%20around%20the%20world.&text=Users%20can%20navigate%20key%20statistics,for%20implementation%20using%20interactive%20mapping

CCPI. 2020. Climate Change Performance Index 2021. https://ccpi.org/download/the-climate-change-performance-index-2021/

[cxciii] The relevance of all these indicators is explained in the methodology

[cxciv] Climate Action Tracker. 2021. Russia. https://climateactiontracker.org/countries/russian-federation/pledges-and-targets/#:~:text=Our%20best%20estimate%20of%20the,1990%20levels%2C%20excluding%20LULUCF)

Balmforth, Tom. 2021. EXCLUSIVE Russian climate envoy calls race to tighten emissions targets "unreasonable". https://www.reuters.com/business/environment/exclusive-russian-climate-envoy-calls-race-tighten-emissions-targets-2021-05-13/

UNFCC. 2021. Russia's Far East in Race to Net Zero Emissions. https://unfccc.int/news/russia-s-far-east-in-race-to-net-zero-emissions

Baker McKenzie. 2021. Doing Business in Russia. https://www.bakermckenzie.com/en/-/media/files/insight/publications/2021/04/doing_business_in_russia_2021.pdf

The Moscow Times. 2021. Russia to Pay 1.1Bln Euros Per Year Under EU Carbon Tax – Reports. https://www.themoscowtimes.com/2021/07/26/russia-eyes-free-trade-zone-on-islands-disputed-by-japan-a74616

Heidemann, Thomas, and Bogdanov, Dmitry. 2021. The Renewable Energy Law Review: Russia. https://thelawreviews.co.uk/title/the-renewable-energy-law-review/russia

Enerdata. 2021. Russia. https://www.enerdata.net/estore/energy-market/russia/

Lanshina, Tatiana. 2021. RUSSIA'S WIND ENERGY MARKET: Potential for New Economy Development. https://russia.fes.de/fileadmin/user_upload/documents/SOET/210316-FESMOS-windenergy-en.pdf

Statista. 2021. Russia Nickel Production. https://www.statista.com/statistics/260770/russias-mine-production-of-nickel-since-2006/

Josefson, Jennifer and Rotar, Alexandra. 2021. Mining in the Russian Federation: Overview. https://uk.practicallaw.thomsonreuters.com/w-011-1888?transitionType=Default&contextData=(sc.Default&firstPage=true

Zharskiy, Andrey and Akhundov, Timur. 2020. Russia: Mining Laws and Regulations. https://iclg.com/practice-areas/mining-laws-and-regulations/russia

Josefson, Jennifer and Rotar, Alexandra. 2019. Electricity regulation in the Russian Federation: overview. https://uk.practicallaw.thomsonreuters.com/6-527-2969?transitionType=Default&contextData=(sc.Default)&firstPage=true

Hjort, Marit. 2019. BAT APPROACHES AROUND THE WORLD – RESULTS FROM A RESEARCH PROJECT. https://unece.org/fileadmin/DAM/env/documents/2019/AIR/Capacity_Building/BAT_workshop_2019/1_3_OECD_BATproject_Hjort.pdf

Circle of Blue. 2018. Pollutants and Heavy Metals Taint Moscow's Water Supply. https://www.circleofblue.org/2018/europe/pollutants-and-heavy-metals-taint-moscows-water-supply/

World Bank. 2016. Mongolia: Mining Infrastructure Investment Support (MINIS) Project. https://www.worldbank.org/en/country/russia/brief/mongolia-mining-infrastructure-investment-support-project

Soderholm, Kristina, Soderholm, Patrik, Pettersson, Maria, Svahn, Nanna, Viklund, Roine, and Helenius, Heidi. 2014. ENVIRONMENTAL REGULATION AND MINING SECTOR COMPETITIVENESS. https://www.ltu.se/cms_fs/1.124549!/file/rapport%20Environmental%20Regulation%20and%20Mining_low.pdf

OECD. 2008. Info on Economic Instruments for Water Management in Russia. https://www.oecd.org/env/outreach/Info%20on%20Economic%20Instruments%20for%20Water%20Management%20in%20Russia.pdf

ECOLEX. 1995. Federal Law No. 167-FZ Water Code. https://www.ecolex.org/details/legislation/federal-law-no-167-fz-water-code-lex-faoc021820/

[cxcv] Climate Action Tracker. 2021. Climate Action Tracker. https://climateactiontracker.org/countries/philippines/

Commoner. 2021. What the Philippines' First Nationally Determined Contribution Means for the Country's Future Climate Actions. https://mediacommoner.medium.com/what-the-philippines-first-nationally-determined-contribution-means-for-the-country-s-future-fd6934ad2f92

Government of Philippines. 2021. Duterte OKs 75% emissions reduction PH commitment by 2030. https://www.pna.gov.ph/articles/1137085

Rivera, Danessa. 2021. Philippines has yet to establish net zero emission goal. https://www.philstar.com/business/2021/08/23/2121854/philippines-has-yet-establish-net-zero-emission-goal

O. de Vera, Ben. 2021. PH urged to impose $75/ton carbon tax. https://business.inquirer.net/320176/ph-urged-to-impose-75-ton-carbon-tax

London School of Economics. 2021. The Climate Change Act (RA 9729), and its Implementing Rules and Regulations (IRR, Administrative Order No. 2010-01). https://climate-laws.org/geographies/philippines/laws/the-climate-change-act-ra-9729-and-its-implementing-rules-and-regulations-irr-administrative-order-no-2010-01

London School of Economics. 2021. Philippine Green Jobs Act no 10771/2016. https://climate-laws.org/geographies/philippines/laws/philippine-green-jobs-act-no-10771-2016

Government of Philippines. 2021. DOE Secretary Cusi declares moratorium on endorsements. https://www.doe.gov.ph/press-releases/doe-sec-cusi-declares-moratorium-endorsements-greenfield-Tcoal-power-plants?withshield=1

Our World in Data. 2021. Philippines. https://ourworldindata.org/energy/country/philippines

Dimagiba, Atty. 2021. No more Feed In Tariff!. https://mb.com.ph/2021/05/15/no-more-feed-in-tariff/

Department of Energy. 2021. RE Developers. https://www.doe.gov.ph/re-developers?withshield=1

Department of Energy. 2021. Power Statistics. https://www.doe.gov.ph/energy-statistics/philippine-power-statistics

Department of Environment and Natural Resources. 2021. RA 9275 – The Philippine Clean Water Act. https://r12.emb.gov.ph/ra-9275-the-philippine-clean-water-act/

U.S. Grains Council. 2021. Philippines. https://grains.org/buying-selling/ethanol-2/ethanol-market-profiles/philippines/

Dime, Ronald, and Eviota, Edward. 2021. The Renewable Energy Law Review: Philippines. https://thelawreviews.co.uk/title/the-renewable-energy-law-review/philippines

International Trade Administration. 2021. Philippines Energy Market. https://www.trade.gov/market-intelligence/philippines-energy-market

PIPPA. 2021. Philippines. https://www.pippaonline.org/about

Reuters. 2021. Philippines set sights on hydrogen to diversify energy sources. https://www.reuters.com/article/philippines-energy-hydrogen/philippines-set-sights-on-hydrogen-to-diversify-energy-sources-idUSL4N2K40T8

Statista. 2021. Philippine's nickel mine production 2010-2020. https://www.statista.com/statistics/260753/philippine-mine-production-of-nickel-since-2006/

Cruz, Enrico. 2021. Philippines lifts nine-year ban on new mines to boost revenues. https://www.reuters.com/business/energy/philippines-lifts-nine-year-old-ban-new-mines-boost-revenues-2021-04-15/

Japanese Government. 2021. High Energy-Efficient Equipment and Labeling Program. https://openjicareport.jica.go.jp/pdf/12058228_02.pdf

Talavera, Catherine. 2020. Philippine renewable energy capacity boosted by 16%. https://www.philstar.com/business/2020/11/18/2057584/philippine-renewable-energy-capacity-boosted-16

Department of Energy. 2020. DEPARTMENT CIRCULAR NO. DC2020. https://www.doe.gov.ph/sites/default/files/pdf/announcements/draft_dc_green_energy_auction_program.pdf?withshield=1

Magno, Cielo. 2020. Water, transparency and mining concerns in the Philippines. https://www.bworldonline.com/editors-picks/2020/03/08/282503/water-transparency-and-mining-concerns-in-the-philippines/

Clean Energy Investment Accelerator. 2019. Clean Energy Procurement Guidebook for the Philippines. https://static1.squarespace.com/static/5b7e51339772aebd21642486/t/5d4b0734bbb4c40001a0b3bf/1565198136423/CEIA+Philippines+RE+Procurement+Guidebook.pdf

Department of Energy. 2017. The Philippines Energy Efficiency and Conservation Roadmap 2017-2040. https://www.doe.gov.ph/sites/default/files/pdf/energy_efficiency/ee_roadmap_book_2017-2040.pdf

Ani, Princess. 2016. The Philippine Environmental Assessment Policies. https://ap.fftc.org.tw/article/1058

Columbia Center on Sustainable Investment. 2016. Water Risks in the Mining Sector Philippines. https://ccsi.columbia.edu/sites/default/files/content/docs/our%20focus/Water-Template-Philippines.pdf

Torres, Quisumbing. 2015. Primer on the Philippine Minerals Industry. https://www.bakermckenzie.com/-/media/files/insight/publications/2015/02/primer-on-the-philippine-minerals-industry/files/read-publication/fileattachment/bk_manila_primermineralsindustry_2015.pdf

Government of Philippines. 2007. Republic Act No. 9367. https://www.officialgazette.gov.ph/2007/01/12/republic-act-no-9367/

[cxcvi] Climate Action Tracker. 2021. Indonesia. https://climateactiontracker.org/countries/indonesia/

Jong, Hans Nicholas. 2021. https://news.mongabay.com/2021/04/indonesia-net-zero-emissions-target-coal-energy-2070/

Rodyanto, Fransiscus, and Suwana, Aldilla. 2021. Indonesia: Putting A Price On Emissions: Indonesian Government Plans To Impose Carbon Tax. https://www.mondaq.com/renewables/1096108/putting-a-price-on-emissions-indonesian-government-plans-to-impose-carbon-tax

Statista. 2021. Indonesia Electric Consumption by Sector. https://www.statista.com/statistics/1233761/indonesia-electricity-consumption-by-sector/

Fimansyah and Karim, Rizki. 2021. Electricity Regulation in Indonesia: Overview. https://uk.practicallaw.thomsonreuters.com/w-025-0669?transitionType=Default&contextData=(sc.Default)&firstPage=true#co_anchor_a485329

U.S. Grains Council. 2021. Indonesia. https://grains.org/buying-selling/ethanol-2/ethanol-market-profiles/indonesia/

Baker McKenzie. 2021. Global Mining Guide: Indonesia. https://resourcehub.bakermckenzie.com/en/resources/global-mining-guide/asia-pacific/indonesia/topics/global-mining-guide

Kurniawan, Paulus. 2021. Highlights on Indonesia's copper industry. https://www2.deloitte.com/content/dam/Deloitte/id/Documents/about-deloitte/id-about-dip-edition-2-chapter-5-en-feb2021.pdf

Treadgold, Tim. 2021. Indonesia On Track To Dominate The Supply Of Nickel To Make Batteries. https://www.forbes.com/sites/timtreadgold/2021/06/02/indonesia-on-track-to-dominate-the-supply-of-nickel-to-make-batteries/?sh=6a3dbf4f7488

El Discha, Fadhila. 2020. Indonesia needs a better clean energy policy. https://www.southpole.com/blog/indonesia-needs-a-better-clean-energy-policy

Johnson, Matthew, Diarot, Dwi, and Rifdaan, Randy. 2020. Indonesian mining bill passed into law, poses new challenges and opportunities. https://www.hoganlovells.com/en/publications/indonesian-mining-bill-passed-into-law-poses-new-challenges-and-opportunities

Jong, Hans Nicholas. 2020. With new law, Indonesia gives miners more power and fewer obligations. https://news.mongabay.com/2020/05/indonesia-mining-law-minerba-environment-pollution-coal/

Kitt Florian. 2020. Renewable Energy Tariffs and incentives in Indonesia: Review and Recommendations. https://www.adb.org/sites/default/files/publication/635886/renewable-energy-tariffs-incentives-indonesia.pdf

Enerdata. 2020. Indonesia Energy Information. https://www.enerdata.net/estore/energy-market/indonesia/

Government of Indonesia. 2019. Indonesia NDC. https://www4.unfccc.int/sites/submissions/INDC/Published%20Documents/Indonesia/1/INDC_REPUBLIC%20OF%20INDONESIA.pdf

Deloitte. 2019. Indonesian Customs Guide 2019. https://www2.deloitte.com/content/dam/Deloitte/id/Documents/tax/id-tax-indonesian-customs-guide-2019-en.pdf

Assegaf, Ibrahim Sjarief, Satwika, Kanya, and Siregar, Aisyah Rahmarani. 2019. Wading through Indonesia's New Water Resources Law. https://www.ahp.id/client-update-8-november-2019/?utm_source=Mondaq&utm_medium=syndication&utm_campaign=LinkedIn-integration

PWC. 2019. Mining in Indonesia, Investment and Taxation Guide. https://www.pwc.com/id/en/energy-utilities-mining/assets/mining/mining-guide-2019.pdf

World Bank. 2018. Report on Indonesian Mining Sector Diagnostic. https://openknowledge.worldbank.org/bitstream/handle/10986/33087/Report-on-Indonesia-Mining-Sector-Diagnostic.pdf?sequence=1&isAllowed=y

IUCN. 2016. Indonesia. https://portals.iucn.org/offsetpolicy/node/42

Halstead, Matthew, Mikunda, Tom, and Cameron, Lachlan. 2014. Mitigation Momentum. https://cdkn.org/sites/default/files/files/ECN-Policy-Brief-Indonesian-Feed-in-tariff-140304.pdf

[cxcvii] World Bank. 2022. What a Waste Global Database. https://datacatalog.worldbank.org/search/dataset/0039597

Energy and Climate. 2021. Net Zero Scorecard. https://eciu.net/netzerotracker

Wallach, Omri. 2021. Race to Net Zero: Carbon Neutral Goals by Country. https://www.visualcapitalist.com/race-to-net-zero-carbon-neutral-goals-by-country/

World Bank. 2021. World Bank Group – Carbon Pricing Dashboard. https://www.greengrowthknowledge.org/tools-and-platforms/world-bank-group-carbon-pricing-dashboard#:~:text=The%20Carbon%20Pricing%20Dashboard%20is,pricing%20initiatives%20around%20the%20world.&text=Users%20can%20navigate%20key%20statistics,for%20implementation%20using%20interactive%20mapping

CCPI. 2020. Climate Change Performance Index 2021. https://ccpi.org/download/the-climate-change-performance-index-2021/

[cxcviii] Brauch, Martin Dietrich. 2022. "Climate Action Needs Investment Governance, Not Investment Protection and Arbitration". https://ccsi.columbia.edu/news/climate-action-needs-investment-governance-not-investment-protection-isds

Merrill, Ella and Brauch, Martin Dietrich. 2021. "U.S. Climate Leadership Must Reject ISDS: As the United States Faces Another $15 Billion Suit from the Fossil Fuel Industry, it's Time for President Biden to Take a Decisive Stance". https://ccsi.columbia.edu/news/us-climate-leadership-must-reject-isds-united-states-faces-another-15-billion-suit-fossil-fuel

Carbon Tracker. 2021. Utilities risk losing billions as surging fuel prices compound problems facing gas industry. https://carbontracker.org/utilities-risk-losing-billions-as-surging-fuel-prices-compound-problems-facing-gas-industry/

Barker, Paul. 2021. Sustainable Investment, Deep Decarbonization, and Investor-State Dispute Settlement: The Failure to Align The Investment Treaty System With Climate Change Law & Policy? https://law.stanford.edu/publications/sustainable-investment-deep-decarbonization-and-investor-state-dispute-settlement-the-failure-to-align-the-investment-treaty-system-with-climate-change-law-policy/

Government of Canada. 2021. 2021 Model FIPA. https://investmentpolicy.unctad.org/international-investment-agreements/treaty-files/6341/download

OECD. 2021. The future of investment treaties - possible directions. https://www.oecd.org/publications/the-future-of-investment-treaties-possible-directions-946c3970-en.htm

Goldthau, Andreas. 2021. Widening the EU's Geoeconomic and Regulatory Approach to Climate Policy. https://carnegieeurope.eu/2021/07/12/widening-eu-s-geoeconomic-and-regulatory-approach-to-climate-policy-pub-84877

Billimoria, Sherri and Henchen, Mike. 2020. Regulatory Solutions for Building Decarbonization. https://rmi.org/insight/regulatory-solutions-for-building-decarbonization/

Leal-Arcas, Rafael. 2020. The Contribution of Free Trade Agreements and Bilateral Investment Treaties to a Sustainable Future. https://www.qmul.ac.uk/law/news/2020/items/the-contribution-of-free-trade-agreements-and-bilateral-investment-treaties-to-a-sustainable-future.html

Brauch, Martin Dietrich. 2020. Reforming International Investment Law for Climate Change Goals. https://academiccommons.columbia.edu/doi/10.7916/d8-300v-7h63

Daszkiewicz, Karolina. 2020. Policy and Regulation of Energy Transition. https://link.springer.com/chapter/10.1007/978-3-030-39066-2_9

Toledano, Perrine, Shah, Aniket, Maennling, Nicolas, and Lasnick, Ryan. 2020. Electric utility alignment with the SDGs & the Paris Climate Agreement. https://ccsi.columbia.edu/sites/default/files/content/docs/ELECTRIC-UTILITY-ALIGNMENT-WITH-THE-SDGs-THE-PARIS-CLIMATE-AGREEMENT_0.pdf

Van Asselt, Harro and Mehling, Michael A. 2020. Border Carbon Adjustments in a Post-Paris World: Same Old, Same Old, but Different? https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3595988

LaMonaca, Sarah, Matsuo, Tyeler, O'Hanlon, Brian, and Kessler, Lucy. 2020. Charting the Course to Climate-Aligned Finance. https://rmi.org/insight/navigating-five-barriers-to-climate-aligned-finance/

Cosbey, Aaron, Droege, Susanne, Fischer, Carolyn, and Munnings, Clayton. 2019. Developing Guidance for Implementing Border Carbon Adjustments: Lessons, Cautions, and Research Needs from the Literature. https://www.journals.uchicago.edu/doi/full/10.1093/reep/rey020

Economist. 2018. Climate change and trade agreements: Friends or foes? https://pages.eiu.com/March-19-ICC-Public-Policy-webinar-USEMEA-MKT_.html

Johnson, Lise, Sachs, Lisa, Guven, Brooke, and Coleman, Jesse. 2018. Costs and Benefits of Investment Treaties: Practical Considerations for States. https://ccsi.columbia.edu/sites/default/files/content/docs/our%20focus/Cost-and-Benefits-of-Investment-Treaties-Practical-Considerations-for-States-ENG-mr_0.pdf

European Commission. 2018. Final Report of the High-Level Panel of the European Decarbonisation Pathways Initiative. https://ec.europa.eu/info/publications/final-report-high-level-panel-european-decarbonisation-pathways-initiative_en

Johnson, Lise, Guven, Brooke, and Coleman, Jesse. 2017. "Investor-State Dispute Settlement: What Are We Trying to Achieve? Does ISDS Get Us There?" https://ccsi.columbia.edu/news/investor-state-dispute-settlement-what-are-we-trying-achieve-does-isds-get-us-there

Johnson, Lise and Sachs, Lisa. 2016. "The Outsized Costs of Investor–State Dispute Settlement". https://ccsi.columbia.edu/sites/default/files/content/docs/blog/AIB-Insights-Vol.-16-Issue-1-The-outsized-costs-of-ISDS-Johnson-Sachs-Feb-2016.pdf

Brandi, Clara, Bruhn, Dominique, and Lindenberg, Nannette. 2015. The Global Regulatory Framework For Decarbonization: 3x3 Starting Points for The Reform of Global Economic Governance. https://www.die-gdi.de/en/briefing-paper/article/the-global-regulatory-framework-for-decarbonisation-3x3-starting-points-for-the-reform-of-global-economic-governance/

EU. 2011. Official Journal of the European Union. https://investmentpolicy.unctad.org/international-investment-agreements/treaty-files/2602/download

Cossy, M. and Marceau, Gabrielle. 2009. Institutional challenges to enhance policy Co-Ordination — How WTO rules could be utilised to meet climate objectives? https://www.researchgate.net/publication/292485385_Institutional_challenges_to_enhance_policy_Co-Ordination_-_How_WTO_rules_could_be_utilised_to_meet_climate_objectives

Green, Andrew. 2005. Climate Change, Regulatory Policy and the WTO: How Constraining Are Trade Rules? https://academic.oup.com/jiel/article-abstract/8/1/143/822993?redirectedFrom=fulltext

Energy Charter Secretariat. 1998. The Energy Charter Treaty, Trade Amendment and Related Documents. https://investmentpolicy.unctad.org/international-investment-agreements/treaty-files/2427/download

United Kingdom, Republic of Ireland, Republic of Turkey. Free trade agreement between the United Kingdom of Great Britain and Northern Ireland and the Republic Of Turkey. https://investmentpolicy.unctad.org/international-investment-agreements/treaty-files/6058/download

Republic of Ecuador. Comprehensive economic partnership agreement between the EFTA States and the Republic of Ecuador. https://investmentpolicy.unctad.org/international-investment-agreements/treaty-files/5800/download

Kingdom of Netherlands. Netherlands model Investment Agreement. https://investmentpolicy.unctad.org/international-investment-agreements/treaty-files/5832/download

Slovak Republic. Agreement between the Slovak Republic and for the promotion and reciprocal protection of investments. https://investmentpolicy.unctad.org/international-investment-agreements/treaty-files/5917/download

Republic of Colombia. Bilateral investment treaty between the Republic of Colombia. https://investmentpolicy.unctad.org/international-investment-agreements/treaty-files/6082/download

Government of Israel and Government of UAE. Agreement between The Government of the State of Israel and The Government of the United Arab Emirates on Promotion and Protection of Investments. https://investmentpolicy.unctad.org/international-investment-agreements/treaty-files/6084/download

PRC and Republic of Korea. Free Trade Agreement between the Government of The People's Republic of China and the Government of The Republic of Korea. https://investmentpolicy.unctad.org/international-investment-agreements/treaty-files/3461/download

[cxcix] The Warren Centre. 2020. Zero Emission Copper Mine of the Future, Sydney: The University of Sydney. https://ses.library.usyd.edu.au/handle/2123/24317.

RMF and CCSI. 2020. Mining and the SDG: a 2020 status update. The Responsible Mining Foundation (RMF) and Columbia Center on Sustainable Investment (CCSI). https://www.responsibleminingfoundation.org/app/uploads/RMF_CCSI_Mining_and_SDGs_EN_Sept2020.pdf.

[cc] The Warren Centre. 2020. Zero Emission Copper Mine of the Future, Sydney: The University of Sydney. https://ses.library.usyd.edu.au/handle/2123/24317.

RMF and CCSI. 2020. Mining and the SDG: a 2020 status update. The Responsible Mining Foundation (RMF) and Columbia Center on Sustainable Investment (CCSI). https://www.responsibleminingfoundation.org/app/uploads/RMF_CCSI_Mining_and_SDGs_EN_Sept2020.pdf.

Bartlett, N., Whittington, E., Reuvers, S. and Thoday, K. 2016. Driving Low-Carbon Growth through Business and Investor Action. Contributing paper for Seizing the Global Opportunity: Partnerships for Better Growth and a Better Climate. New Climate Economy, London and Washington, DC. http://newclimateeconomy.report/misc/working-papers.

Enright, S., Oger, C., Pruzan-Jorgensen, P.M., and Farrag-Thibault, A. 2018. Private sector collaboration for sustainable development. Report. BSR, San Francisco. https://www.bsr.org/reports/BSR_Rockefeller_Private-Sector_Collaboration_for_Sustainable_Development.pdf.

[cci] Bartlett et al. (2016).

[ccii] The Warren Centre. 2020. Zero Emission Copper Mine of the Future, Sydney: The University of Sydney. https://ses.library.usyd.edu.au/handle/2123/24317.

RMF and CCSI. 2020. Mining and the SDG: a 2020 status update. The Responsible Mining Foundation (RMF) and Columbia Center on Sustainable Investment (CCSI). https://www.responsibleminingfoundation.org/app/uploads/RMF_CCSI_Mining_and_SDGs_EN_Sept2020.pdf.

UNFCCC. 2021. Climate Action Pathway: Industry Action Table. United Nations Framework Convention on Climate Change (UNFCCC), Global Climate Action (GCA) and Marrakech Partnership. https://unfccc.int/climate-action/marrakech-partnership/reporting-tracking/pathways/industry-climate-action-pathway.

[cciii] ICMM. 2022. Member Requirements. International Council on Mining and Metals (ICMM). https://www.icmm.com/en-gb/about-us/member-requirements.

The Copper Mark. 2022. https://coppermark.org/.

The Copper Mark Company, the International Lead Association (ILA), the Nickel Institute (NI), the International Zinc Association (IZA), and the Responsible Business Alliance, Inc. 2021. Joint Due Diligence Standard for Copper, Lead, Nickel and Zinc. https://nickelinstitute.org/media/8d9df3bf5c9da34/joint-due-diligence-standard_v2_1jan2022.pdf.

IRMA. N.d. Standard. Initiative for Responsible Mining Assurance (IRMA). https://responsiblemining.net/what-we-do/standard/.

IRMA. N.d. Certification. Initiative for Responsible Mining Assurance (IRMA). https://responsiblemining.net/what-we-do/certification/.

[cciv] ICMM. 2021. Our commitment to a goal of net zero by 2050 or sooner. ICMM. https://www.icmm.com/en-gb/environmental-stewardship/climate-change/net-zero-commitment.

TPI. N.d., Transition Pathway Initiative. TPI. https://www.transitionpathwayinitiative.org/.

[ccv] ICMM. 2022. Guidance. International Council on Mining and Metals (ICMM). https://www.icmm.com/en-gb/news-and-resources/guidance.

CA. 2022. The International Copper Association and the Copper Alliance. https://copperalliance.org/about-ica/about-ica-and-copper-alliance/.

NI. 2022. What we do. Nickel Institute (NI). https://nickelinstitute.org/about-us/what-we-do/.

[ccvi] WIPO Green. N.d. WIPO Green – the market place for sustainable technology. https://www3.wipo.int/wipogreen/en/.

ICMM. 2022. Innovation for Cleaner, Safer Vehicles initiative. https://www.icmm.com/en-gb/innovation/cleaner-safer-vehicles.

GMG. 2019. The Electric Mine Working Group. Global Mining Guidelines Group (GMG). https://gmggroup.org/groups/the-electric-mine/.

UNCTCN. N.d. Climate Technology Centre and Network. https://www.ctc-n.org/.

[ccvii] GHC. 2022. About the Catapult. Green Hydrogen Catapult (GHC). https://greenh2catapult.com/.

EMF. 2022. What we do. The Ellen MacArthur Foundation (EMF). https://ellenmacarthurfoundation.org/about-us/what-we-do.

[ccviii] Gold Standard. 2022. About us. https://www.goldstandard.org/about-us/about-us.

Climate Action Reserve. N.d. Offsets Marketplace. https://www.climateactionreserve.org/how/offsets-marketplace/.

[ccix] Third Derivative. 2022. About Third Derivative. https://www.third-derivative.org/about.

MPP. 2022. Our Approach. Mission Possible Partnership (MPP). https://missionpossiblepartnership.org/our-approach/.

[ccx] CA. 2022. The International Copper Association and the Copper Alliance. https://copperalliance.org/about-ica/about-ica-and-copper-alliance/.

[ccxi] JTI. 2022. About JTI. https://justtransitioninitiative.org/about/.

ICMM. 2022. Skills for our Common Future initiative. https://www.icmm.com/en-gb/innovation/skills-for-our-common-future.

[ccxii] Amira Global. 2021. Projects. https://amira.global/projects/n.

Climate Action Reserve. N.d. Offsets Marketplace. https://www.climateactionreserve.org/how/offsets-marketplace/.

Charge On Innovation Challenge. 2022. About the challenge. https://chargeoninnovation.com/about-the-challenge/.

ERGI. N.d. About us. https://ergi.tools/about.

EITI. N.d. Implementing the Standard. https://eiti.org/about/how-we-work.

EITI. N.d. What we do. https://eiti.org/About.

EMC. 2021. The Electric Mine Consortium. https://www.electricmine.com/.

EMF. 2022. What we do. The Ellen MacArthur Foundation (EMF). https://ellenmacarthurfoundation.org/about-us/what-we-do.

GMG. 2019. About us. What is Global Mining Guidelines Group? https://gmggroup.org/about-gmg/.

Gold Standard. N.d. Vision and Mission. https://www.goldstandard.org/about-us/vision-and-mission.

Green Hydrogen Catapult. 2022. About the catapult. https://greenh2catapult.com/.

Green Hydrogen Coalition. N.d. About GHC. https://www.ghcoalition.org/about-ghc.

ICA. 2021. About ICA. https://copperalliance.org/about-ica/.

ICCT. 2021. About the ICCT. https://theicct.org/about/.

ICMM. 2021. About us. https://www.icmm.com/en-gb/about-us.

ICSG. 2015. Who we are. https://www.icsg.org/index.php/who-we-are.

IGF. 2021. Our Work. https://www.igfmining.org/our-work/.

INSG. 2021. The study group: International Nickel Study Group. https://insg.org/index.php/organization/the-study-group/.

IRMA. N.d. About us. https://responsiblemining.net/about/about-us/.

ITUC. N.d. Just Transition Centre. International Trade Union Confederation. https://www.ituc-csi.org/just-transition-centre.

JTI. 2022. About JTI. Just Transition Initiative. https://justtransitioninitiative.org/about/.

LeadIT. 2021. What we do. https://www.industrytransition.org/what-we-do/.

MPP. 2021. About Us. Missions Possible Partnership (MPP). https://missionpossiblepartnership.org/about/.

NI. 2021. About NiPERA Inc. https://nickelinstitute.org/science/about-nipera-inc/.

NI. 2021. About us. The Nickel Institute (NI). https://nickelinstitute.org/about-us/.

OZ Minerals. 2017. Think & Act Differently. https://www.ozminerals.com/uploads/docs/TAD-SingleSide-A4.pdf.

RE100. 2021. About us. https://www.there100.org/about-us.

RM. 2021. ReThink Mining. https://www.rethinkmining.org/.

RMF. 2022. About us. Foundation. Responsible Mining Foundation (RMF). https://www.responsibleminingfoundation.org/foundation/.

RMI. 2022. About the Responsible Minerals Initiative. https://www.responsiblemineralsinitiative.org/about/rmi-initiative/.

SFC. N.d. Our Achievements. We're proud of what we've achieved since 2013. https://www.smartfreightcentre.org/en/how-to-implement-items/our-achievements-1/251/.

The B Team. N.d. Our Work. https://bteam.org/our-work/what-we-do.

The Climate Group. 2021. About EV100. https://www.theclimategroup.org/about-ev100

The CopperMark. 2021. About the Copper Mark. https://coppermark.org/about/

The World Bank. 2021. Climate-Smart Mining: Minerals for Climate Action. https://www.worldbank.org/en/topic/extractiveindustries/brief/climate-smart-mining-minerals-for-climate-action

The World Bank. 2019. New World Bank Fund to Support Climate-Smart Mining for Energy Transition. https://www.worldbank.org/en/news/press-release/2019/05/01/new-world-bank-fund-to-support-climate-smart-mining-for-energy-transition

Third Derivative. 2020. About: Mission Driven, Market Focused. https://third-derivative.org/about/

Tonsley. N.d. Oz Minerals collaboration unlocks value for mining, renewable energy. https://tonsley.com.au/news/oz-minerals-collaboration-unlocks-value-for-mining-renewable-energy/.

TPI. 2021. About Us. The Partnering Initiative (TPI). https://thepartneringinitiative.org/about-us/

The TPI. 2021. Overview of the Transition Pathway Initiative (TPI). https://www.transitionpathwayinitiative.org/overview

UNCTCN. N.d. Climate Technology Centre and Network. https://www.ctc-n.org/.

Verra. N.d. What we do. World Economic Forum (WEF). https://verra.org/about-verra/what-we-do/.

WEF. 2021. The Global Battery Alliance (GBA). World Economic Forum (WEF). https://www.weforum.org/global-battery-alliance/home.

WEF. 2021. Digital Transformation Initiative (DTI), Workd Economic Forum (WEF). http://reports.weforum.org/digital-transformation/?doing_wp_cron=1618467612.1286211013793945312500.

WEF. 2021. GBA, Action. https://www.weforum.org/global-battery-alliance/action.

WEF. 2021. Introducing the Digital Transformation Initiative. http://reports.weforum.org/digital-ransformation/introducing-the-digital-transformation-initiative/

WEF. 2021. Mining and Metals Industry Community. https://www.weforum.org/communities/mining-and-metals.

WIPO Green. n.d. WIPO Green - the marketplace for sustainable technology. https://www3.wipo.int/wipogreen/en/.

[ccxiii] Gold Standard. 2022. About us. https://www.goldstandard.org/about-us/about-us.

Verra. 2022. About Verra. https://verra.org/about-verra/what-we-do/.

CAR. 2022. About us. Climate Action Reserve (CAR). https://www.climateactionreserve.org/about-us/.

ACR. N.d. How it works – What we do. American Carbon Registry (ACR). https://americancarbonregistry.org/how-it-works/what-we-do.

ICROA. 2021. About – Our objectives. International Carbon Reduction & Offset Alliance (ICROA). https://www.icroa.org/about.

[ccxiv] CDP. 2022. Engaging the chain: Driving speed and scale. CDP global supply chain report 2021. https://cdn.cdp.net/cdp-production/cms/reports/documents/000/006/106/original/CDP_SC_Report_2021.pdf#page=24.

Cherel-Bonnemaison, C., Erlandsson, G., Ibach, B., and Spiller, P. 2021. Buying into a more sustainable value chain. McKinsey and Company. https://www.mckinsey.com/business-functions/operations/our-insights/buying-into-a-more-sustainable-value-chain.

[ccxv] These scope 3 interventions were adapted from: SBTi. 2018. Value change in the value chain: Best practices in Scope 3 greenhouse gas management. Science Based Targets Initiative (SBTi). https://sciencebasedtargets.org/resources/files/SBT_Value_Chain_Report-1.pdf.

[ccxvi] ICMM. N.d. Good practice guidance for mining and biodiversity. https://guidance.miningwithprinciples.com/good-practice-guide-mining-biodiversity/#:~:text=The%20Good%20Practice%20Guidance%20For,by%20promoting%20enhanced%20mutual%20understanding.

[ccxvii] RMF. 2020. Raw data. 2020 Responsible Mining Index company results. Responsible Mining Foundation. https://2020.responsibleminingindex.org/en/raw-data.

[ccxviii] Mancini, L.; Sala, S. 2018. Social impact assessment in the mining sector: Review and comparison of indicators frameworks. Resources Policy. 57: 98-111. https://doi.org/10.1016/j.resourpol.2018.02.002.