Leveraging the Growth in Demand for Minerals and Metals in the Transition to a Low Carbon Economy

Infrastructure and Energy (INE)
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Inter-American Development Bank

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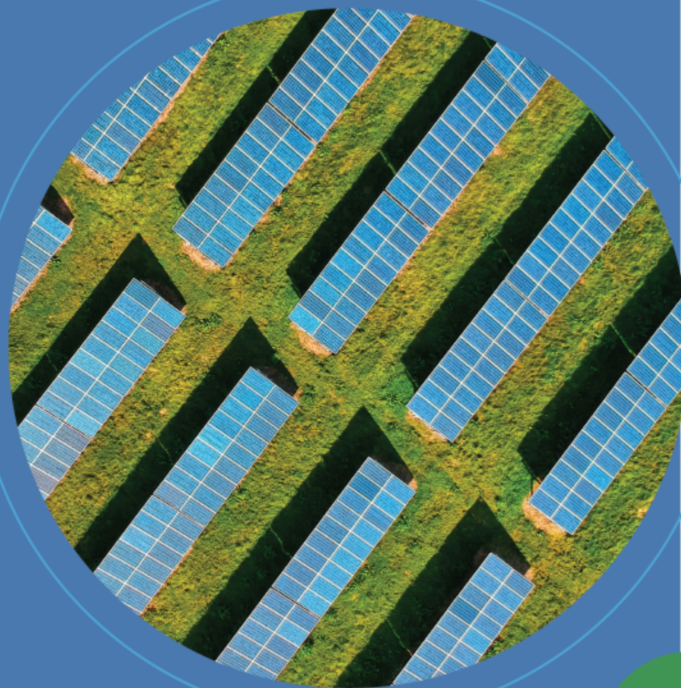

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List of acronyms

Acronym	Definition
AMD	Acid Mine Drainage
BEV	Battery Electric Vehicles
BSI	British Standards Institution
CAMCHAL	German-Chilean Chamber of Commerce
CCS	Carbon Capture and Storage
CMVAP	Participatory Environmental Monitoring and Surveillance Committees
ECLAC	Economic Commission for Latin America and the Caribbean
EIAS	Environmental Impact Assessment Systems
EOL	End of Useful Life
ESG	Environmental, Social and Governance
ETSAP	Energy Technology Systems Analysis Program
EV	Electric Vehicles
GDP	Gross Domestic Product
GEI	Greenhouse Gases
GIS	Geographic Information System
GIZ	German Society for International Cooperation
ICMM	International Council on Mining and Metals
IDB	Inter-American Development Bank
IEA	International Energy Agency
IGF	Intergovernmental Forum on Mining, Minerals and Sustainable Development
IPCC	Intergovernmental Panel on Climate Change
IRMA	Initiative to Ensure Responsible Mining
IRR	Initial Recycling Rate
LAC	Latin America and the Caribbean
LME	London Metal Exchange

Acronym	Definition
LMO	Lithium ion manganese oxide
METS	Mining Equipment, Technologies & Services
MRV	Monitoring, Reporting and Verification
NDC	Nationally Determined Contributions
NGO	Non-Governmental Organization
NMC	Nickel, Cobalt and Manganese
PRI	Principles for Responsible Investment
SASB	Sustainability Accounting Standards Board
TCFD	Working Group on Climate-Related Financial Disclosures
TIAM	TIMES Integrated Model
TSC	Total Sustainment Cost
UNEP	United Nations Environment Program
VSI	Voluntary Sustainability Initiatives

About the Report

This report quantifies the economic opportunity provided by the growth of minerals relevant to the transition to a low carbon economy. It examines demand growth to 2050 with targets currently set by different countries, and considers the case where there is greater ambition for decarbonization. The report highlights that, in order to realize social and economic benefits without putting the environment at risk, socio-environmental factors must be safeguarded by allowing mining companies to have the required social and environmental license to operate and attract more investment, taking advantage of the great potential of Latin America and the Caribbean (LAC) with its abundant mineral resources needed in a low carbon economy. This report provides recommendations to maximize the capture of economic benefits related to increased demand for minerals and metals (copper, lead, lithium, manganese and zinc) that, when properly managed, have the potential to drive development and create prosperity in the region. This report analyzes the opportunities and potential social and environmental challenges related to increased demand for Argentina, Bolivia, Brazil, Chile, Mexico and Peru.

The report seeks to:

(i) develop and compare existing demand scenarios for 2030 and 2050 for key minerals and metals associated with a transition to low carbon energy technologies;

(ii) assess the economic, environmental and social opportunities and challenges of increased demand in LAC countries; and

(iii) provide recommendations on how LAC can capture the benefits of the potential significant growth in demand for minerals in anticipation of the environmental, social and governance standards required by buyers and investors in the rapid global trend of adopting ESG standards, which also contribute to the proper management of mineral resources to drive development.

This report was written in consortium by the Carbon Trust, Vivid Economics and Implementa Sur. It was edited by Adriana Unzueta, Carlos Sucre, and Natascha Nunes Da Cunha of the Infrastructure and Energy Department of the Inter-American Development Bank, which sponsored the research with technical cooperation resources from the Government of Canada under the Canadian Extractive Sector Finance Facility (CANEF).

CARBON TRUST

Carbon Trust
International not-for-profit consulting firm based in the UK, with offices in seven countries including Mexico, China, and South Africa, with a mission to accelerate the transition to a low carbon economy. Provides specialized support to governments, institutions and the private sector in designing strategies and programs to reduce carbon emissions.

:vivideconomics

Vivid Economics
UK-based consulting firm, a leading strategic economist with global reach, a top-tier consultant in the trade-policy interface and the resource-intensive and environmental sectors.

ImplementaSur CLIMATE ACTION

ImplementaSur
Chile-based consulting firm dedicated to accelerating climate change adaptation and mitigation actions in Latin America. With an institutional vision of "turning climate change into a value creation opportunity".

We are grateful for the support of all the experts who participated in the interviews and online surveys used as input for this report (see Annex for more details).

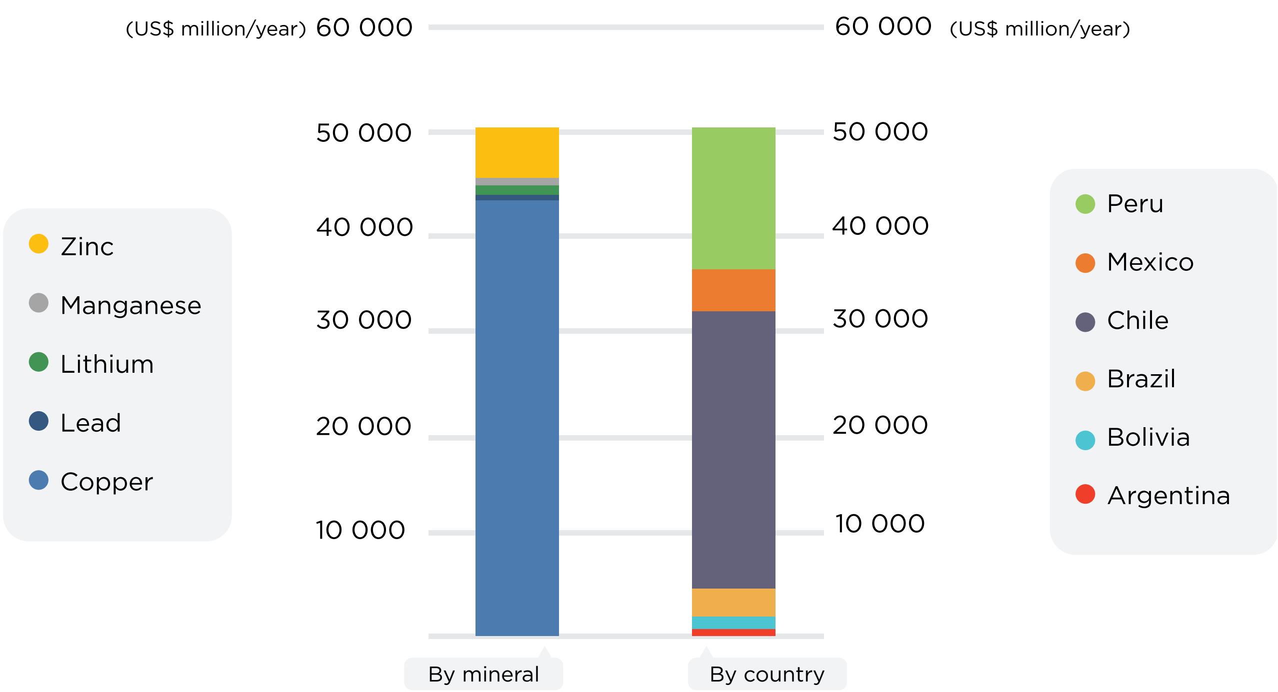
We would also like to thank Lenin H. Balza, Nicolás Gomez, Julio Rojas Lara, Carolina Rojas Hayes, and Osvaldo Urzua for their helpful comments. The views expressed in this document are solely those of the authors, and do not necessarily reflect the views of the Inter-American Development Bank, its Board of Directors or the countries they represent.

Executive Summary

Climate change brings great challenges, but also great opportunities from which Latin America and the Caribbean can benefit. To avoid the huge negative impacts of climate change, we are forced to reduce greenhouse gas (GHG) emissions by limiting the increase in global temperature to 1.5°C.

There is an economic opportunity for Latin America and the Caribbean (LAC) estimated at USD 50 billion per year in 2050 (equivalent to Uruguay's nominal gross domestic product [GDP] in 2020) due to increased demand for minerals for decarbonization (Figure 1.1 and Figure 1.2). This economic benefit highlights the region's opportunity to leverage its mineral reserves for decarbonization while limiting the increase in global temperature to 1.5°C.

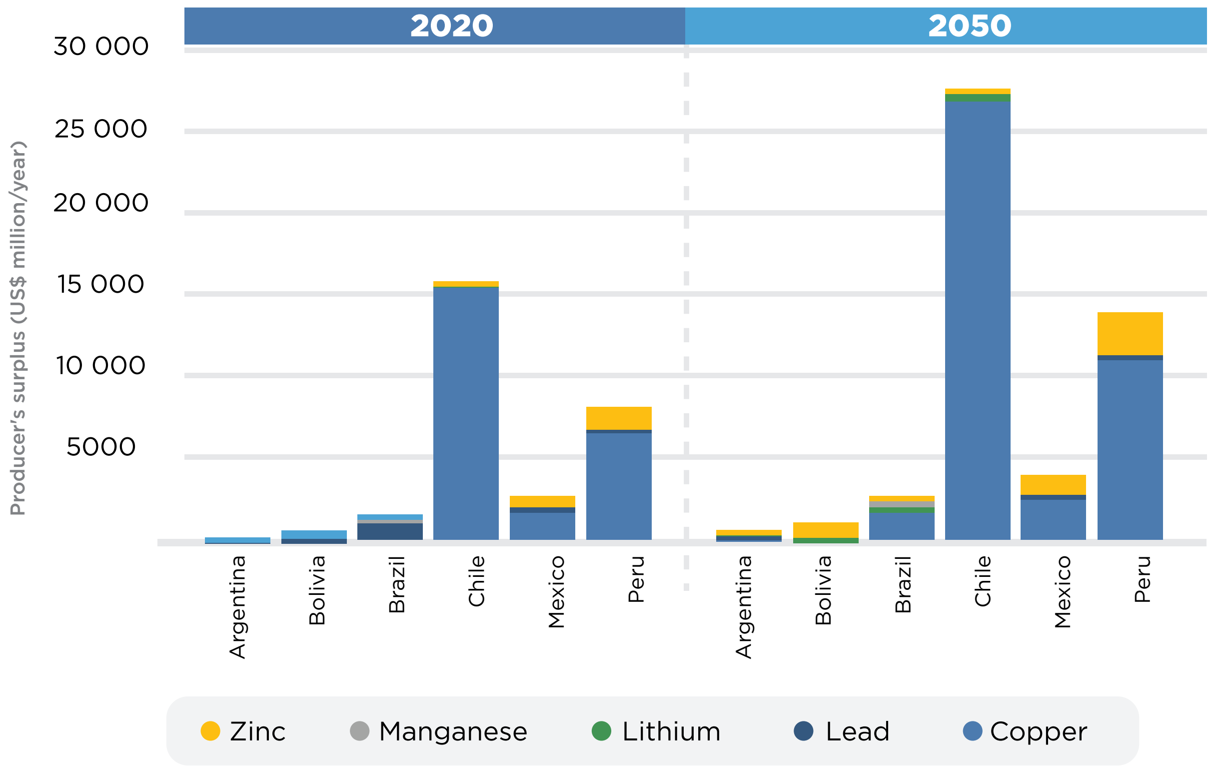
Figure 1.1 - Economic opportunity by mineral and by country in 2050 in the 1.5°C scenario



Comments: Under the central recycling scenario of 1.5°C – Estimated by calculating the producer's surplus
Source: Own elaboration based on results of the Vivid Economics model.

Copper, lithium, manganese, lead, and zinc are defined as the focus minerals given their relevance to decarbonization and the LAC region (Figure 1.2). These minerals are part of technologies related to decarbonization such as electric vehicles, renewable energies, electrical systems, and carbon capture and storage technology.

Figure 1.2 – Breakdown of producer surplus by mineral and by country in 2020 and 2050 under the 1.5°C scenario



Comments: Under the central recycling scenario of 1.5°C
Source: Own elaboration based on results of the Vivid Economics model.

A large part of the economic benefit results from the demand for minerals required to meet nationally determined contributions (NDCs). Some USD 45 billion of net benefits are estimated in a baseline scenario where the 2015 NDCs are met and 3.3 thousand Gt of CO2 are not exceeded. This scenario results in a global temperature increase of 3.0°C, as indicated by the Climate Action Tracker platform [1]. This reference case and the two low carbon scenarios, where the temperature increase is limited to 1.5°C and 2.0°C, imply a significant increase in the global generation of non-conventional renewable

[1] For more information see the following link.

energy, energy storage, electric vehicles and carbon capture and storage (CCS), which require minerals and metals as raw-material inputs that LAC can provide.

Copper accounts for the majority of total profits: 86% of the total, i.e. USD 43 billion. Today, copper already accounts for the largest share of mineral production revenues[2] in the countries most relevant to focus metals: Argentina, Bolivia, Brazil, Chile, Mexico, and Peru. As demand for copper increases along with the growing market shares of the focal countries, their earnings from copper production continue to rise. Between 2020 and 2050, lithium revenues will grow more than tenfold to almost USD 1 billion. This is due to the fact that lithium has a higher production growth rate and a higher profit margin than other minerals. However, with only 2% of total mineral revenues, the lithium market is still much smaller than the copper market, as copper is produced in much larger volumes. Chile has the highest absolute annual gain (USD 28 billion)[3] of all countries in 2050 resulting mainly from copper, while Argentina has the highest annual growth rate (5.2%) in gains between 2020 and 2050.

In both low carbon scenarios, more energy will be produced from renewable sources such as wind and solar, and the use of electric and green hydrogen vehicles will increase. Electrification of the passenger vehicle fleet is much faster in the low carbon scenarios than in the 3.0°C reference case. These transitions also require extensive upgrades to power grids, particularly to improve energy storage and distribution infrastructure, as well as to expand electric vehicle charging infrastructure. Carbon sequestration is highest in the 1.5°C scenario, slightly lower in the 2.0°C scenario and negligible in the reference case.

The 3.0°C reference case considers a 92% increase in demand for focus minerals compared to 2020. Of this estimated increase of 62,500 kt, 20% is due to the increase in demand for technologies relevant to decarbonization. The increase ranges from -20% for lead to 1010% for lithium, with an increase in manganese of 145% and copper and zinc of about 100% during the same period. The scale of this increase in mineral demand is relatively similar in all scenarios, particularly due to the strong uptake of electric vehicles. This incorporates the latest policy announcements from many countries on bans on the sale of conventional internal combustion engine vehicles. These large increases in mineral demand are in line with the findings of other reports, detailed in Section 2.4.

[2] Profit is the product of production, the mineral price and the expected profit margin for that mineral. Profits are equivalent to the concept of producer surplus, which describes the benefits a producer derives from production. Therefore, it is equal to gross income minus direct production costs. In the case of miners, the cost of production is the "total cost of maintenance". This is the cost to miners of maintaining mineral production at the current rate.
[3] in constant 2019 dollars.

Mineral demand is higher in the low carbon scenarios than in the 3.0°C reference case, and demand is higher in the 1.5°C scenario than in the 2.0°C scenario. By 2050, in a 1.5°C scenario, focus minerals increase by 2% to 12% compared to the 3.0°C reference scenario, with manganese being the lowest and lead the highest. In the 2.0°C scenario, demand in 2050 increases by 0.8% (manganese) to 2.4% (lithium) compared to the 3.0°C reference scenario. This difference is due to a higher deployment of power, distribution and stationary storage technologies in the 1.5°C scenario.

Copper and lithium are the minerals that have the greatest impact on a commitment to a low carbon transition. Copper and lithium increase by 1% to 10% when the decarbonization ambition is increased compared to the 3.0°C reference case. This is due to the growth in demand from the light passenger vehicle and electric sectors. Copper is widely used in energy storage, distribution and storage infrastructure. Lithium is a key element in lithium batteries used in electric vehicles and charging points. By 2050, annual copper demand will be more than double the 2020 level, while lithium demand will be more than ten times higher.

Copper producers benefit from more aggressive decarbonization. By 2050, the difference in copper demand relative to the 3.0°C reference case is seven times larger in the 1.5°C scenario than in the 2°C scenario, compared to about four times for lithium and zinc. Major copper producers such as Chile and Peru therefore stand to benefit if the world follows a 1.5°C transition path.

In the event that the NDCs are met and the temperature increase is limited to 3.0°C, the focus countries (Argentina, Brazil, Bolivia, Chile, Mexico, and Peru) increase their production of minerals relevant to decarbonization by 30% in 2050 compared to 2020. Lithium increases by 990%, zinc by 74%, copper by 54%, manganese by 28% and lead by 62%. The increase is considerable even in the 3.0°C reference case.

By 2050, the most relevant countries will produce 10% more lithium and copper, 2% more manganese and 7% more zinc in the 1.5°C scenario than in the 3.0°C reference case. Key lithium and copper producers such as Chile, Argentina, and Peru have large and growing market shares, allowing them to capitalize on the strong growth in global demand for these minerals. Meanwhile, the rapid growth in demand for manganese and zinc more than offsets the decline in countries' market shares for those minerals. Between now and 2050, total production in the focal countries grows at an annual rate of 8% for lithium, 2% for zinc and copper, 1% for manganese and -2% for lead.

While these results establish the potential benefits of the low carbon transition for LAC countries, actual output will depend on country-specific environmental, social and governance factors. Mining is a key factor in the economy of many LAC countries. The significant demand for minerals such as copper and lithium from low carbon technologies also means that LAC countries will play a key role in global decarbonization efforts. However, mining often involves significant environmental and social risks that must be carefully managed to ensure sustainable development. This is developed in later sections of this report.

The adoption of ESG standards are an enabler for capturing economic opportunities in mining, mainly for three reasons. First, it contributes to obtaining the environmental and social licenses required to operate. Second, it reduces potential strikes or local demonstrations that involve significant delays in mining operations that have a negative impact on project cash flows and profitability. Third, there is a rapid global trend in the adoption of ESG standards demanded by buyers and investors.

A growth in the production of focus minerals can imply a significantly high socio-environmental footprint. Examples of these footprints include challenges around energy management, water management, waste and hazardous materials management, including the proper management of tailings, and impacts on biodiversity. In addition, mining exploitation has been associated with tensions in the territories, mainly due to the opposition of host communities to the installation of projects that negatively impact on their traditional ways of life and the surrounding environment.

The adoption of best practices that both reduce the negative impact of mining and bring social benefits can enable growth in mining production in LAC. The importance of alliances to create communication mechanisms to promote innovation, better management of socio-environmental impacts, and create synergies with other industries is highlighted. In the short term, water and energy management were identified as the most relevant factors due to their impact on other socio-environmental factors and, therefore, on mining operations. In the long term, public perception was identified as a highly relevant element for mining companies in their social license, which was identified in this study as a promoter of more socio-environmentally conscious activities.

The adoption of best practices requires the participation of investors, the final customers of the minerals and/or final products and the government. The same participation is required to promote an environment where mining companies can and should consider socio-environmental factors in their operations.

Investors are in a position to have a proactive involvement in the corporate governance of some mining companies, to make transparent and disclose their efforts in socio-environmental matters. Reaching the 1.5°C target necessarily implies an accelerated evolution of traditional finance towards sustainable finance that will allow the necessary investment to reach the 1.5°C target. This translates into the adoption of environmental and social best practices such as environmental, social and governance (ESG) standards, which are enabling tools to help investors redirect their capital flows to projects that generate socio-environmental value.

The demand for socio-environmentally responsible supply chains is increasing, and the ability of demand to articulate the value chain based on responsible sourcing (RS) will promote better socio-environmental practices. This implies that manufacturers of low carbon transition technologies have the role of promoting the harmonization and interoperability of the large number of existing standards, so that, on the one hand, they reflect the expectations of end customers and, on the other, encourage the adoption of these practices by the mining industry.

The government, its public policies and regulations should be part of this harmonization, in order to address the particularities of large companies in relation to medium and small ones (considering the limitations and diversity in size or maturity of the supply of mining companies in LAC). Local regulation is identified as a mechanism to evolve in line with the lessons learned from the local implementation of voluntary standards.

Institutional weaknesses are an obstacle to obtaining the full benefit of regulation. For regulation to be effective, certain conditions must be met, such as the presence of strong institutions with the capacity for oversight and the application of clear sanctions when necessary. In this sense, the laws governing the operation of mining facilities are framed in a virtuous circle together with voluntary standards, where the regulation defines a floor for the obligations to which mining operations must abide, and the voluntary standards support the weaker edges of the regulation, playing the role of a natural laboratory for the implementation and subsequent enforcement of new, stricter regulations.

The main recommendations and concrete actions that can be taken by the public sector, the private sector and multilateral institutions are presented in Table 1.1:

Table 1.1 - Summary table of recommendations and concrete actions in Chapter 4

Stakeholder	Recommendation	Public policy strategies
Regulation	Regulation must evolve in line with the lessons learned from the local implementation of voluntary standards.	Support the generation of evidence on the impacts of the different voluntary standards (observatory of responsible practices associated with the body in charge of legislative evaluation) and in the improvement of transparency.
	Robust government oversight capacity, to ensure enforceable minimum standards and the application of clear sanctions when necessary.	a. Strengthen the institutional framework for social and environmental oversight by the State (considering attributions and resources). b. Capacity building to empower monitoring from affected parties/complainants (e.g. monitoring and surveillance committees). c. Provide resources to strengthen monitoring and surveillance systems, including new traceability solutions (example: Blockchain).
	Promote the signing of international agreements that serve as enabling frameworks for greater information transparency.	Promote instances to generate consensus around international agreements that reflect an evolution in the region's minimum socio-environmental standards.
	Design a regulation that considers the limitations of medium and small companies.	Clear diagnosis of the capacities of local companies to meet the demands of implementing voluntary standards and best socio-environmental practices.
Final consumers (Demand)	Promote the harmonization and interoperability of current standards.	Promote instances of agreement among mining clients for the convergence of standards.
	Promote the implementation of reliable monitoring, reporting and independent verification systems throughout the production chain.	Financial support and capacity building for the adoption of standards and independent verification.
	Generate a precedent of "responsible sourcing" in public procurement processes for products derived from mining by state-owned companies in the region.	Generation of financial instruments to reduce price uncertainty in responsible sourcing processes. Capacity building at the level of state-owned companies for the implementation of these responsible sourcing criteria.
	Move toward traceability in the origin of inputs for refineries and smelters, so that in the long term they can focus exclusively on responsibly sourced minerals.	a. Application to international funds or generation of demand-side funds for the adoption of standards by service providers. b. Identify companies that could take on this role in the medium and long term. c. Identify gaps to incorporate minerals with socio-environmental responsibility criteria and support the establishment of goals to make the transition to an exclusively responsible operation.

Investors	Proactive involvement of investors in identifying socio-environmental risks and adopting standards to mitigate them.	Capacity building at the investor level to generate attention to existing standards and market trends. Promote regulation of the financial sector around new socio-environmental risk assessment and reporting requirements.
	Collaboration by investors in the development and promotion of standards.	Instances of dialog and consensus building around responsible standards, in conjunction with initiatives such as the Principles for Responsible Investment (PRI).

To ensure the economic and social benefit of mining in LAC driven by global decarbonization, socio-environmental factors need to be considered in mining operations. If socio-environmental impacts are not considered, they may jeopardize mining operations in LAC. Beyond determining the relevant factors and trying to safeguard them individually, the environment in which mining companies make decisions to be socio-environmentally responsible with their activities must be promoted. The adoption of best practices by mining companies is considered the most effective way to promote socio-environmental protection. Even in a scenario with no major NDC ambitions, production is estimated to increase by 1 to 10 times from 2020, highlighting the importance of accelerating the adoption of best practices as soon as possible. Public policy and regulation play a key role in accelerating adoption. The government needs to formulate a public policy that facilitates investor and mineral demand access to relevant information to promote sustainable mining.

1. Introduction

Climate change brings great challenges, but also great opportunities from which Latin America and the Caribbean can benefit. To avoid the huge negative impacts of climate change, we are obliged to reduce GHG emissions by limiting the increase in global temperature to 1.5-2.0°C. To achieve this goal, we must decarbonize our energy sources, decarbonize transportation, and minimize the impact of agribusiness. The first two actions imply an increase in minerals and metals that LAC can provide by having a competitive advantage in access to these resources. This report quantifies the potential economic benefits for LAC and provides recommendations for capturing the benefits of the transition to a low carbon economy.

Limiting global temperature increase to 1.5°C or 2.0°C will require the large-scale deployment of low carbon technologies in many economic sectors, particularly in the energy and transportation sectors. To reduce energy and transportation emissions, renewable and low carbon energy sources will replace fossil fuels, while passenger vehicle fleets will need to be largely electrified. Electricity grids will be reinforced, and stationary storage will be installed to integrate intermittent renewable energies and meet the resulting increase in electricity demand. Carbon sequestration will also be widely implemented to further reduce net emissions.

The deployment of these technologies will generate a significant increase in global mineral demand due to the mineral intensity of key technologies such as vehicle batteries. For example, copper serves as an electrical conductor in power grids and electric vehicles. Similarly, batteries used in electric vehicles and stationary storage require large amounts of lithium and manganese. Combining the mineral intensities of each technology with the scale of its deployment under each temperature scenario allows estimating the resulting increase in mineral demand. This analysis focuses on a set of minerals that have significant demand potential in the transition to a low carbon economy: copper, lead, lithium, manganese, and zinc.

The increase in global demand leads, in turn, to an increase in mineral production, with significant potential for LAC economies. To determine each country's mineral production, each country's historical production trends are used to estimate its future market shares. These market shares are then used to distribute global demand among producing countries. Among LAC countries, this analysis focuses on a set of focal countries that are important producers of key minerals: Argentina, Bolivia, Brazil, Chile,

Mexico, and Peru. Chile and Peru were included as they are the world's largest and second largest copper producers, respectively, while zinc mining is a key economic activity in Bolivia, Argentina, Brazil, and Mexico.

Given the social and environmental consequences of the mining industry, the concern for consuming products that have been manufactured in a sustainable and responsible manner is growing. This increased interest is reflected in the creation of initiatives aimed at promoting responsible sourcing practices to ensure that companies' mineral supply chains are sustainable, minimizing their negative impacts on communities and the environment. There are a wide variety of initiatives with different characteristics to address the complexities of implementing strategies to protect the socio-environmental context of mining in a way that is rigorous, transparent, of high quality and flexible enough to address differences within mining activities. Examples of these initiatives include the Initiative for Responsible Mining Assurance IRMA, Responsible Mining Index, and the Sustainability Accounting Standards Board (SASB).

This report identifies the socio-environmental risks and opportunities in which mining can contribute to their local contexts while producing the required mining in a 1.5°C scenario. Experts with significant years of experience in the mining sector, a proven track record of knowledge of relevant mining operations and strategic positioning contributed to expand the knowledge gathered and to validate and adapt heat maps obtained for the socio-environmental dimensions through surveys and interviews[4]. **The maps generated show the most relevant positive and negative impacts for mining operations in the following years**, and serve as a basis for identifying socio-environmental opportunities and challenges assuming the projected demand of the 1.5°C scenario.

Based on the above, the limiting factors for increasing production are not related to the geological availability of deposits, but to the administrative, social and environmental conditions for operating. If extractive companies do not meet the demands for improved standards in their relations with communities and in environmental protection, it is difficult to imagine that the projects needed to meet the demand for materials will be carried out in the time required for the decarbonization of the economy.

There is a significant global trend by buyers and investors in the adoption of ESG standards. LAC is still far from effectively incorporating responsible mining practices, which will be an obstacle to capturing the benefits of increased demand. 87% of the world's 23 largest mining companies engaged in the extraction of key minerals for an energy transition (cobalt, copper, lithium, manganese, nickel, and zinc) have been

[4] See online questionnaire and interviews section "Environmental and social opportunities and challenges of select metals in LAC countries" .

subject to various complaints regarding the violation of human rights to land use, with LAC leading the complaints (61% of global complaints) (Business & Human Rights Center, 2020).

Chapter 2 that reveals significant increase in the extraction, processing and production of critical minerals is necessary to move towards a low carbon economy. LAC is well positioned to meet the increase in world demand for some of these "critical" minerals, such as copper, lithium, and manganese, due to existing deposits and comparatively lower production costs. Such an opportunity can be a source of income that, if properly exploited, would positively influence the economic and social development of the region thanks to the fact that mining attracts investment, generates economic wealth, and provides direct and indirect employment and has an initially favorable disposition on the part of governments (OECD, 2019).

Chapter 3 identifies the socio-environmental opportunities and challenges of increased production of "critical" minerals assuming a 1.5°C scenario. Challenges surrounding energy management, water management, waste and hazardous materials management, including the proper management of tailings, and impacts on biodiversity are highlighted with greater emphasis. In addition, mining exploitation has been associated with tensions in the territories, mainly due to the opposition of neighboring communities to the installation of projects that negatively impact on their traditional ways of life and the surrounding environment, and this chapter highlights as challenges the rights of indigenous communities and the preservation of human rights.

Chapter 0 presents measures that can be taken to ensure that mining operations manage their socio-environmental impacts, adapting to the global trend of buyers and investors in adopting ESG standards and ensuring the social and environmental license to operate, and avoiding operational delays that negatively affect project cash flows and profitability. Different strategies are explored for accelerating the effective adoption of socio-environmental management and reporting systems. The role of public policy in carrying out this management effectively is highlighted.

2. Growth in demand and supply in Latin America and the Caribbean (LAC)

This chapter details the results of the models produced to project growth in copper, lithium, lead, manganese, and zinc production in the focal countries: Argentina, Brazil, Bolivia, Chile, Mexico, and Peru. The projected growth details the context of the most relevant socio-environmental factors over the next 30 years.

This analysis includes two low carbon scenarios, one of 1.5°C and one of 2.0°C, and a reference scenario of 3.0°C (Figure 2.1). The temperature scenarios are characterized by carbon budgets. Carbon budgets define the amount of carbon that can be emitted into the atmosphere, to limit global warming to a certain temperature. In each of its recent assessments and special reports on climate change, the Intergovernmental Panel on Climate Change (IPCC) has published estimated carbon budgets to stay below 1.5°C and 2.0°C warming with 50% and 66% probability. Here, the carbon budgets associated with staying below 1.5°C and below 2.0°C with a 50% probability are used. Therefore, carbon budgets of approximately 580 Gt CO2 for a 1.5°C scenario and 1500 Gt CO2 for the 2.0°C scenario are used[5]. The carbon budget of the reference scenario is around 3,300 Gt CO2 and assumes that the Nationally Determined Contribution (NDC) commitments applied in the Paris Agreement (NDC) are implemented.

[5] For more details see Special Report: Global warming of 1.5°C.

Figure 2.1 – Description of decarbonization scenarios (1.5°C and 2.0°C) and the reference scenario (3.0°C).

1.5°C	2.0°C	3.0°C
Low carbon emissions scenario.	Low carbon emissions scenario.	Reference case / baseline.
Half of all electricity will be generated by renewable energy by 2050.	Energies produce only one third of all electricity.	Coal remains the main source of electricity worldwide.
Passenger and freight vehicle fleets are almost entirely electrified or hydrogen-powered.	A smaller proportion of the freight vehicle fleet is decarbonized.	Passenger vehicles electrify at a slower rate than in low carbon scenarios, but reach a similar proportion of electrification by 2050.
Significant increase in electric vehicle (EV) charging infrastructure.	Passenger vehicles continue to be almost completely electrified.	The decarbonization of the freight vehicle fleet is similar to scenario 2°C.
Power grids are expanded and stationary energy storage is built to cope with the increasing proportions of variable renewables in generation.	Less upgrading of power grids and fewer stationary storage facilities.	Power grids receive minimal upgrades and there is negligible deployment of stationary storage.
One third of the remaining emissions are captured through carbon capture technologies.	Reduced deployment of carbon capture technologies.	There is negligible deployment of carbon sequestration.

Source: Authors' own elaboration

The chapter begins with a brief explanation of the methodology of how the model for global demand and supply of mining in LAC was constructed (for detailed information on the methodology, see Annex A). After the methodology, it presents the results on global demand and concludes by presenting the results of production in the focal countries.

2.1 Methodology for global demand

To model the global growth of copper, lithium, lead, manganese, and zinc, the Vivid Economics model complemented by the TIMES integrated assessment model (TIAM Model) was used (see Annex A). Demand was divided into "energy transition-related demand" and "non-energy transition-related demand" (Figure 2.2).

The demand related to the energy transition is driven by the energy (including CCS) and transportation sectors that will need these materials to adapt their activities (change of machinery or processes) in accordance with a low carbon economy. Within these sectors, the contribution of traditional and low carbon technologies is modeled in the demand for minerals. The following low carbon technologies are modeled:

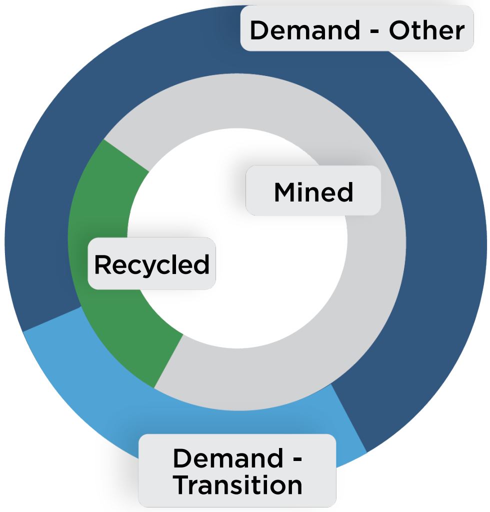
- Passenger and freight vehicles (internal combustion engine, battery electric, hydrogen, etc.);
- Electric vehicle chargers (slow and fast chargers);
- Industrial and pipeline carbon capture and storage (CCS);
- Wind, solar, nuclear, gas, oil, etc. power generation;
- Electricity transmission and distribution infrastructure and stationary storage.

The forecasts were based on the material use factors for the manufacture of the above technologies and the projections of these technologies in different scenarios according to the *TIMES Integrated Assessment Model (TIAM).*

Material-use factors are obtained from the literature, assuming that these factors remain constant over time, with the exception of those associated with stationary storage technologies and electric, passenger and freight vehicles. This is because the usage factors for these technologies change over time according to the market shares of key battery chemistries.

Non-energy transition demand is the portion of current demand that is not explained by transition-related sectors, and is assumed to grow in line with population and GDP projections consistent with TIAM scenarios. The demand is also divided into "recycled demand" and "mined demand" (Figure 2.2) to sum up the **total demand.**

Figure 2.2 - Illustrative graph to show demand division



Total demand is divided into: **mined demand** and **recycled demand**. The former is all demand met through the mineral extraction activity, while the latter corresponds to the demand met through the recycling of that mineral. The total demand will therefore be the sum of the mined demand and the recycled demand.
Three recycling scenarios describing possible evolutions of recycling rates over time were considered:

- **Low:** recycling rates remain constant at current levels;
- **Central:** overall recycled content increases at current EU end-of-life recycling rates, which tend to be higher compared to the rest of the world (Mathieux et al., 2017);
- **High:** overall recycled content increases to a level that is consistent with end-of-life recycling rates of 100%.

Table 2.1 - Recycling scenarios per mineral

Mineral	Current recycling rate	Projected recycling rate in 2050 by scenario		
		Low	Central	High
Copper	35%	35%	55%	59%
Lead	54%	54%	75%	85%
Lithium	0%	0%	20%	39%
Manganese	12%	12%	37%	60%
Zinc	25%	25%	31%	60%

Source: Authors' own elaboration

For the mineral demand of batteries in stationary storage, the analysis also considers the market for second-life batteries. When electric vehicle batteries reach the end of their useful life in the transportation sector, they are likely to continue to be used in the stationary storage sector, where battery specifications are less stringent. While this market for second-life batteries has not yet developed, this market is expected to grow significantly as the deployment of electric vehicles increases (Engel et al., 2019). To account for this expected change, the analysis assumes that reused batteries meet 50% of the demand for lithium, manganese and copper from stationary storage by 2050, increasing linearly from zero, which is the current market share[6]. This assumption is the same for all temperature and recycling scenarios. This analysis does not consider the impact of a second-life battery market to meet transportation storage demand, as there is currently little evidence that this can be done on a commercial level (Hund et al., 2020).

2.2 Methodology for regional sourcing

The supply of focus minerals was modeled using a Vivid Economics model.

The focus minerals were selected based on the expected demand for energy technologies that are crucial to enable a low carbon transition. First, key low carbon technologies were identified in each sector based on literature and expert judgment. For instance, the decarbonization of transportation depends largely on the deployment of electric vehicles, while renewable energies, such as solar photovoltaic panels, and wind turbines, are needed to decarbonize the electricity industry. The selection was also based on the experience of the consortium working with stakeholders in the minerals and low carbon sectors to estimate the exposure of each mineral to the low carbon transition. To ensure that these estimates were reasonable, a review of existing literature on critical minerals and mineral demand was conducted, including studies by the World Bank and the European Commission[7]. At the end of this process, copper, lithium, lead, manganese, and zinc were identified as the minerals most likely to be significantly affected by a low carbon transition due to their importance in low carbon technologies.

[6] The possibility of a secondary market developing for lead-acid batteries is not considered due to the high recycling rate of lead. The lifetime of a lead-acid battery is much shorter than a lithium-ion battery and the fact that second-life lithium-ion batteries could outperform new lead-acid batteries (see here). Zinc is not used in any of the battery chemistries considered in this study, so it is not necessary to assume how the second-life battery market will affect zinc demand. This assumption is aligned with the World Bank. (2020). Minerals for climate action: The mineral intensity of the clean energy transition.
[7] See more detail in World Bank (2017), Moss et al. (2011), Moss et al. (2013).

The mineral supply model calculates the annual mineral production of LAC countries required to meet global demand projections, as well as the resulting earnings. The analysis consists of four steps:

1. **The future market share of each country is estimated.** This step estimates each country's future production through 2050, based on historical production trends. The market share projection uses the current share of each country in the total production projection. To obtain each country's future market share, the supply model projects each country's future production using historical trends and finds its share of total production. The assumption is that the countries' historical production trends will continue to be maintained.

2. **Implied production is calculated for each country given global demand in all demand scenarios if production were not constrained by resources ("unconstrained" scenario).** This scenario does not limit the future production of countries by currently known resources. Each country's production is composed of its projected market share in Step (1), multiplied by the global demand under each temperature and recycling scenario, which are outputs of the demand model.

3. **Implied production is calculated for each country given the global demand in the demand scenarios if production were constrained by currently known resources ("constrained" scenario).** In this scenario, countries gradually deplete their currently known resources through their production. This scenario uses the market shares calculated in Step (1) to determine "unconstrained" production as in Step (3) above, but continuously checks whether cumulative production implies that a country exhausts its currently known resources. If so, production drops to zero for that country. The "production gap" left by the depleted country is covered by other countries, in proportion to their market shares.

4. **The producer surplus is estimated for the LAC focal countries.** Producer surplus is a measure of the amount of monetary benefit a producer receives for supplying a given quantity of product. This involves projecting the price of each mineral and the likely profit margin for the producers of each mineral.

The assumptions underlying the model are:

- **Global demand is always satisfied by supply.** The model assumes that supply always meets the demand projections resulting from the demand model.

- **Future market share evolves in line with historical production trends.** For each country, future market share is assumed to be the share of future production if all countries continue to produce according to a 30-year historical trend. The future production of the countries in the supply model is determined by multiplying market share projections by world demand.

- **Currently known resources do not limit production.** Current resource estimates are assumed to be inaccurate representations of future mineral availability and are therefore not considered in the country's production forecast in the central supply analysis. The model is complemented by a sensitivity analysis in which supply is constrained by currently known resources. This analysis assumes that the country's production cannot exceed currently known resources. When this occurs, the remaining demand is distributed among other producing countries based on market share.

- **Prices remain constant in real terms during the period to 2050.** Given the lack of clear upward or downward trends in mineral prices over extended periods, this analysis assumes that prices remain constant in real terms.

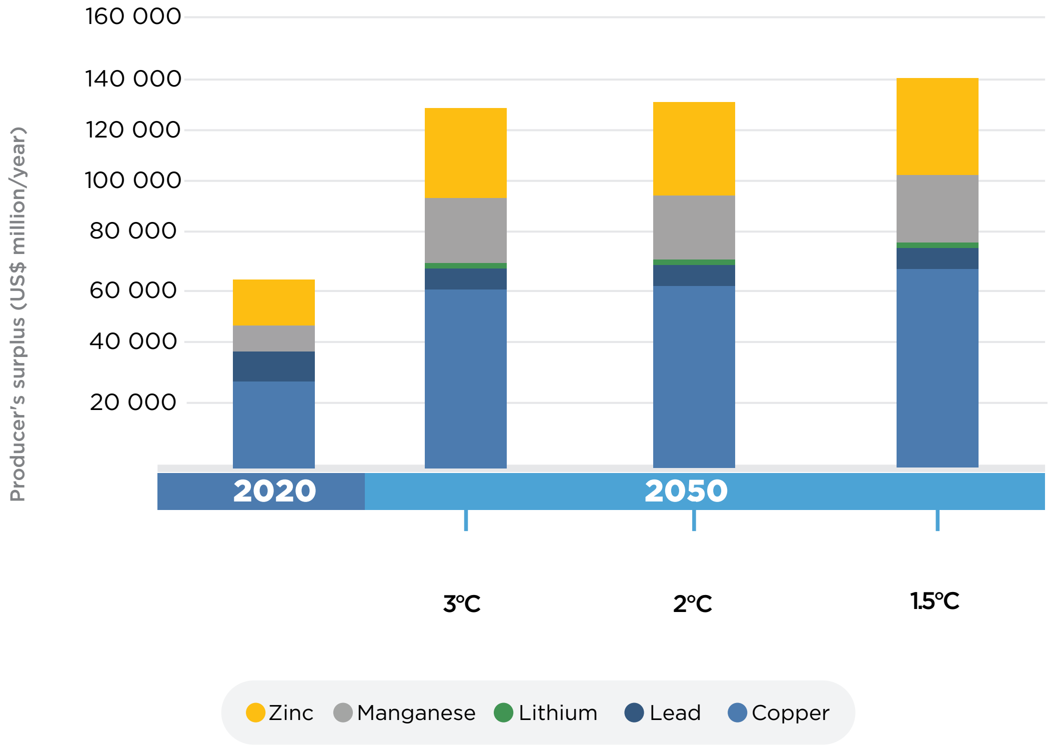
- **Profit margins in LAC countries are in line with world averages.** The profit margins of Latin American mining companies are assumed to be broadly in line with average global profit margins per mineral.

- **Domestic profits can be calculated as production multiplied by price multiplied by profit margin.** This analysis defines profits as the product of the country's production, the constant price and the average profit margin. All earnings estimates are in 2019 U.S. dollars.

2.3 Global demand results

The model results highlight the significant increase in global demand for minerals in 2050 compared to 2020. It reveals a doubling of current production by 2050. The model results also suggest that between the decarbonization scenarios (1.5°C and 2.0°C) and the reference case results (3.0°C) there are less than 1-8 % increases in demand for the focus metals. This is because even in the reference case, where country decarbonization targets are expected to be met, there will be significant growth in global demand.

Figure 2.3 - Approach to mineral demand from sectors affected by transition in different scenarios, 2020 and 2050



Comments: The results displayed are for the central recycling scenario
Source: Own elaboration based on results of the Vivid Economics model.

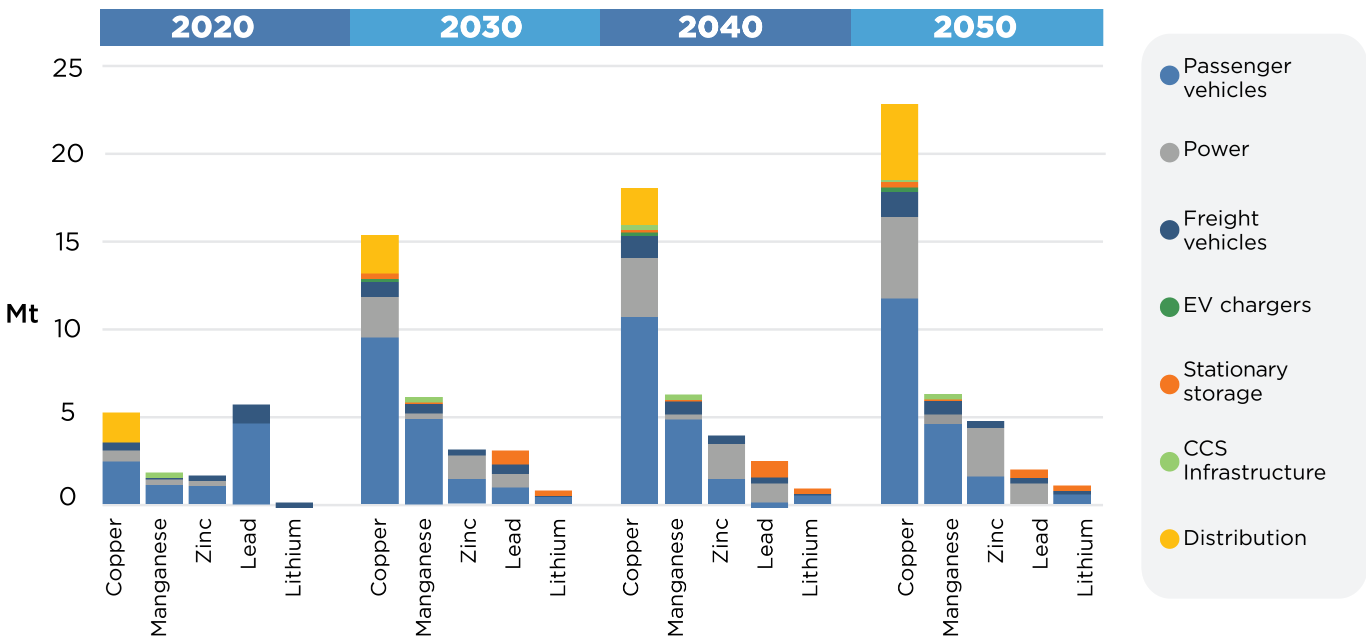
2.3.1 Projected demand between 1.5°C, 2.0°C and 3.0°C scenarios

By 2050, mineral demand in the 2.0°C scenario is only between 0.8% (manganese) and 2.4% (lithium) higher than in the reference scenario. In both low carbon scenarios, mineral demand does not increase linearly between 2020 and 2050. Instead, demand

grows rapidly between 2020 and 2030, and then gradually increases until 2050. This increase is related to the rapid deployment of electric vehicles in road transport and the significant expansion of renewable energy and associated infrastructure from 2020. Figure 2.4 shows the demand for key minerals in the 1.5°C scenario from transition-related sectors.

By 2050, the 1.5°C scenario results in 2-12% higher demand for key minerals than the reference scenario (3.0°C), with the largest difference in demand for lead. Differences in mineral demand between the temperature scenarios arise from the sectors that are affected by the low carbon transition, with the light passenger-vehicle sector being the most affected. Of the sectors in Figure 2.4, the passenger vehicle sector constitutes the largest share of mineral demand in both low carbon scenarios due to its electrification. By 2050, passenger vehicles will contribute 71% of lithium demand, 20% of manganese demand and 17% of copper demand. As the cost of abatement in road passenger transport is cheap compared to other sectors, electrification of passenger vehicles occurs just as quickly in the 1.5°C and 2.0°C scenarios. This results in a similar mineral demand for passenger transport in both scenarios.

Figure 2.4 - Focus on mineral demand from sectors affected by the transition in the 1.5°C scenario, 2020-2050



Comments: The results displayed are for the central recycling scenario
Source: Own elaboration based on results of the Vivid Economics model.

The increase in mineral demand in the 1.5°C scenario compared to the 2.0°C scenario is mainly due to increased deployment of power, distribution and stationary storage technologies. These technologies are mineral intensive and are widely deployed as part of the electrification needed to achieve a 1.5°C target. In particular, batteries used in the stationary storage sector require large quantities of minerals. In the 1.5°C scenario, the stationary storage demand for all minerals (except zinc) is about two and a half times higher than in the 2.0°C scenario. Similarly, the energy and distribution sectors require more than three times as much lead and almost twice as much copper and zinc in the 1.5°C scenario as in the 2.0°C scenario.

Although the annual mineral demand from passenger vehicles in 2050 is similar between the reference (3.0°C) and low carbon (1.5°C and 2.0°C) scenarios, the cumulative mineral demand is higher in the low carbon scenarios. This is because the vehicle fleet will be largely electrified by 2050, even in the reference scenario (3.0°C). However, since both low carbon scenarios achieve high levels of fleet electrification between 2030 and 2040, while the reference scenario mainly electrifies during the period from 2040 to 2050, the cumulative mineral demand by 2050 is higher in the 1.5°C scenario than in the reference case.

2.3.2 Projected demand between 2020 and 2050

Based on the results of the model used in this report, the growth in mineral demand with respect to 2020 in the 1.5°C scenario is between -10% (lead) and 1100% (lithium) (Table 2.2).

Table 2.2 - Growth in demand for different decarbonization scenarios compared to 2020 demand.

Growth in demand compared to 2020							
Year	Scenario	Copper	Lead	Lithium	Manganese	Zinc	Total
2050	3.0°C	105%	-20%	1009%	145%	102%	92%
	2.0°C	108%	-19%	1036%	147%	105%	95%
	1.5°C	126%	-10%	1124%	149%	116%	108%

Comments: The results displayed are for the central recycling scenario
Source: Own elaboration based on results of the Vivid Economics model.

In the central 1.5°C recycling scenario, where recycling rates globally are equal to those of the European Union, minerals from new mines cover between 25% (lead) and 81% (lithium) of mineral demand by 2050 and recycling supplies the remainder. In the low recycle scenario, mine production is between 9% and 84% higher than in the central recycle scenario, with zinc being the lowest and lead the highest. In the high recycling scenario, mine production is between 9% (copper) and 42% (zinc) lower than in the central scenario. This variation in mined demand in recycling scenarios is driven to varying degrees by different minerals. This is because the evolution of the recycling rate over time differs for each mineral, as described in Table 2.1 and in more detail in Appendix A.

In the 1.5°C scenario, total world **copper** demand grows from 32 Mt in 2020 to 72 Mt in 2050, and the contribution of the transition-related sectors doubles over the same period, from 17% to 32% of total demand for the mineral. In the central recycling scenario, mined copper production grows from 21 Mt in 2020 to 32 Mt in 2050 in the 1.5°C scenario, highlighting how much of the increase in total demand is met by recycling. Copper demand growth is driven by low carbon technologies in the transportation and energy sectors. Copper demand from passenger vehicles is very similar in all scenarios, but the contribution of the electricity sector is higher in the 1.5°C scenario.

In the 1.5°C scenario, total global **lead** demand falls from 10 Mt in 2020 to 9 Mt in 2050 and transition-related demand is halved from 55% to 21% of the total over the same period. The recycling scenarios have a significant impact on the outlook for lead, reflected in the range of mined demand between 1 Mt and 4 Mt in 2050 depending on the recycling scenario. In the low recycling rate scenario, in which current global recycling rates are maintained, the extracted production represents 4 Mt in 2050, while in the central and high recycling scenario the extracted production is only 2 Mt and 1 Mt, respectively. Of the minerals considered in this report, lead has the highest current global recycling rate at 54 % (International Lead Association, 2015)[8]. The drop in demand for lead is due to a shift away from lead-acid batteries in the vehicle sector. The key difference between the lead temperature scenarios lies in the growth in demand from the energy sectors, which is higher in the 1.5°C scenario.

Lithium demand exhibits the highest relative growth to 2050 in the 1.5°C scenario among the focus minerals at 1100%, increasing from less than 0.1 Mt in 2020 to 1.1 Mt in 2050, driven by demand for light electric vehicles. Given the low recycling rate of lithium at present, the recycling scenarios show three significantly different futures in terms of demand for mined lithium, ranging from 0.7 Mt (high) to 1.1 Mt (low) in 2050. Light-duty vehicles provide the largest source of growth for lithium demand through 2050, followed by charging vehicles and stationary storage.

[8] See more details in the following link.

In the 1.5°C scenario, total global **manganese** demand doubles from 10 Mt in 2020 to 24 Mt in 2050 and the contribution of transition-related sectors increases from 19% to 27% of the total. The demand for mined manganese in 2050 varies from 10 Mt in the high recycling scenario to 21 Mt in the low recycling scenario, illustrating the importance of the potential expansion of manganese recycling. Similar to lithium, passenger vehicles are the key source of manganese demand through 2050, followed by freight vehicles.

Total global **zinc** demand grows from 16 Mt in 2020 to 35 Mt in 2050 in the 1.5°C scenario, and the contribution of transition-related sectors increases from 10% to 14% of the total over the period. The demand for mined zinc in 2050 ranges from 14 Mt in the high scenario to 26 Mt in the low-recycling scenario, with the central scenario reaching 24 Mt, highlighting the significant ambition of the high scenario. Zinc demand is driven by three transition-related sectors: power generation, passenger vehicles and freight vehicles.

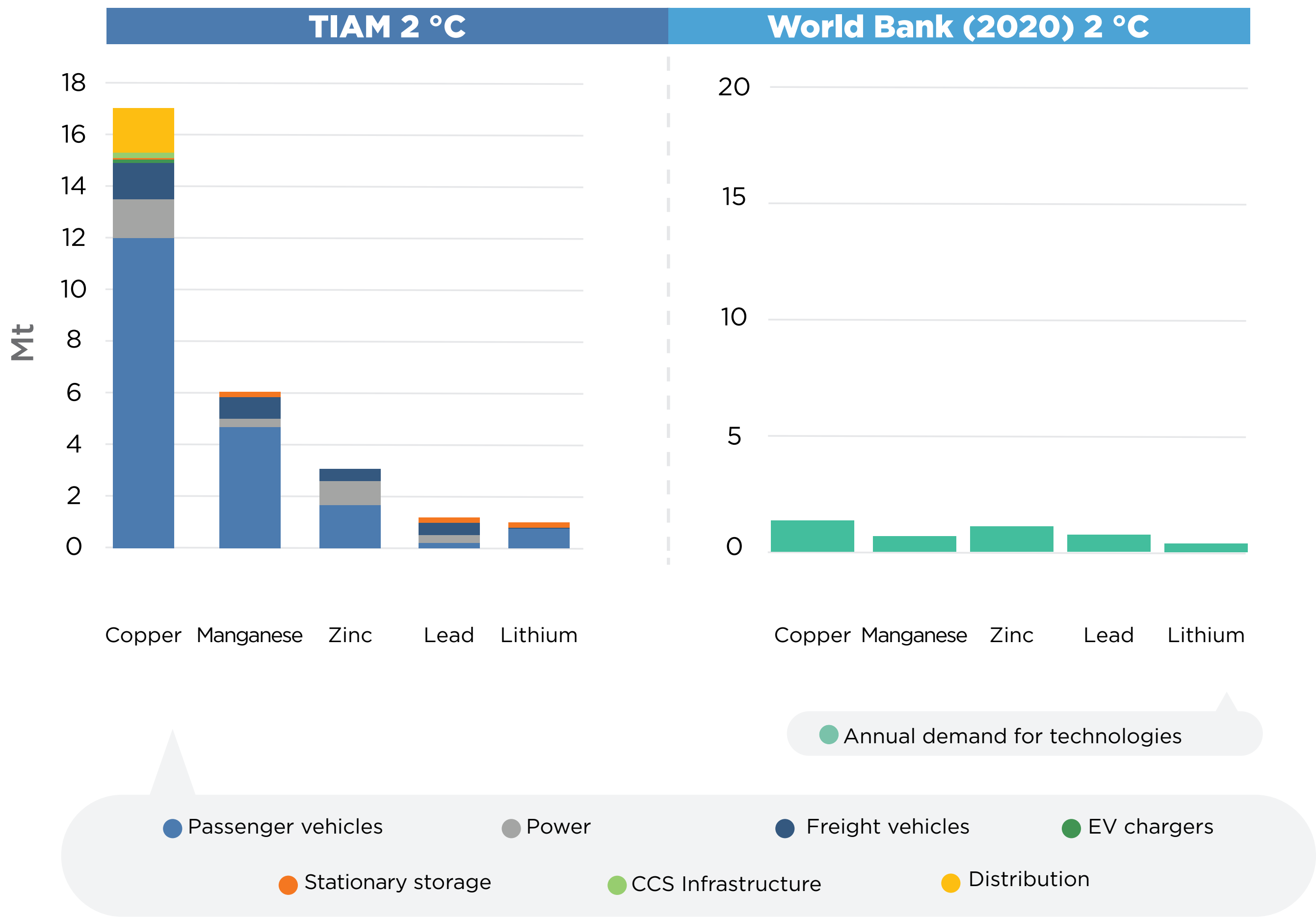
2.3.3 Benchmarking - comparative analysis of results

This section compares the global mineral demand results provided in this study with a recent World Bank report that assesses mineral demand arising from the deployment of energy and energy storage technologies through 2050 (Hund et al., 2020). The purpose of this comparison is to set the results of this analysis in the context of similar recent literature.

The World Bank report uses a similar methodology to this analysis, where it uses literature inputs, data from the International Energy Agency (IEA), to determine mineral factors by technology and to obtain a projection of demand growth. Mineral factors by technology are applied to the results of an energy system model. The results presented in the World Bank report therefore lend themselves well to comparison with the results presented here. However, there are differences in the coverage of the analysis and the results are presented here using different temperature scenarios from a different power system model. As the World Bank report does not produce results for a 1.5°C scenario, this comparative analysis is done with the 2.0°C scenarios.

When comparing the demand results of this analysis with those of the World Bank, there is a significant difference (Figure 2.5) due to differences in the technologies covered. This report includes analysis of technologies in the sectors of energy, passenger vehicles, freight vehicles, stationary storage, CO_2 capture and storage infrastructure, electric vehicle chargers and energy distribution. Whereas the World Bank's analysis only focuses on energy and energy storage technologies.

Figure 2.5 - Comparison of the results of the World Bank's 2°C scenario (2020) with that of the TIAM model used for this report

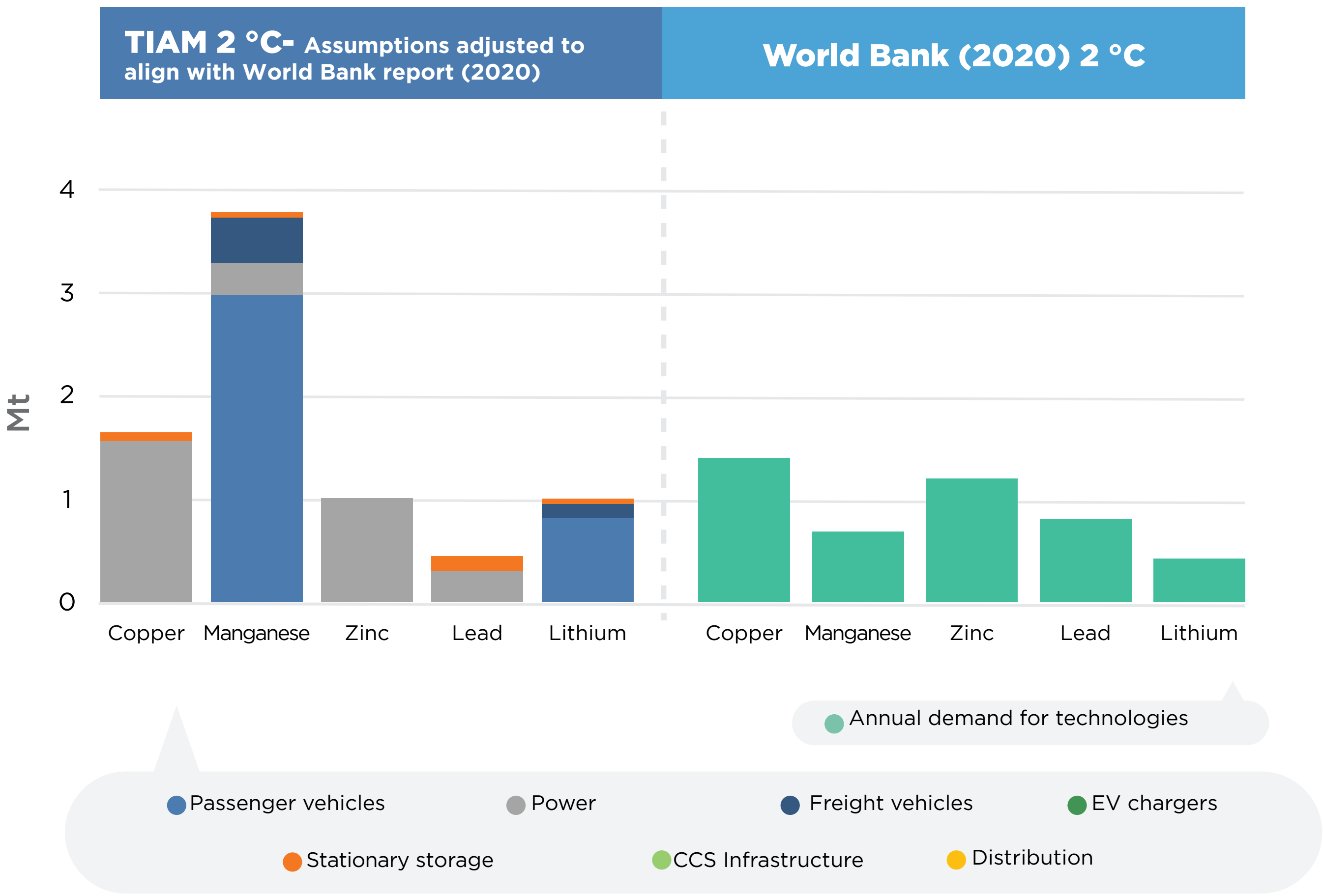


Source: Own elaboration based on World Bank (2020) and results of the Vivid Economics model

Among the sectors covered by both analyses, the biggest difference in the results is the demand for minerals from passenger vehicles. The World Bank report's analysis of electric vehicles is limited to the battery component, while this analysis extends to the minerals and metals contained in the car body. This is particularly relevant for copper, as most of the copper in a vehicle comes from the wiring around the battery, rather than the battery itself. Similarly, the manganese demand of passenger vehicles in our estimates includes manganese used in the steel body of the vehicle. This difference in coverage explains most of the large discrepancy in the results for copper and manganese.

Once the energy technologies considered are aligned with those used in the World Bank report, the results are very similar for all minerals except manganese and lithium. This is shown in Figure 2.6, which reproduces the estimates from this report, but excludes mineral demand from vehicle bodies and does not include distribution, CO2 capture and storage infrastructure, and electric vehicle chargers as does the World Bank report. The World Bank also assumes that all lead-acid car batteries will be replaced by lithium-ion by 2030, so this assumption has also been aligned.

Figure 2.6 - Comparison with World Bank results, aligning assumptions



Source: Own elaboration based on World Bank (2020) and result of the Vivid Economics model

Two key factors are likely to drive the remaining differences in lithium and manganese demand between the two analyses:

1. First, the World Bank report uses a 2°C scenario of 2017, whereas the scenarios used in this analysis consider the latest developments in energy technology costs. Since the TIAM scenarios used to model demand in this report are based on the most recent electric vehicle cost assumptions, they include increased electrification of road

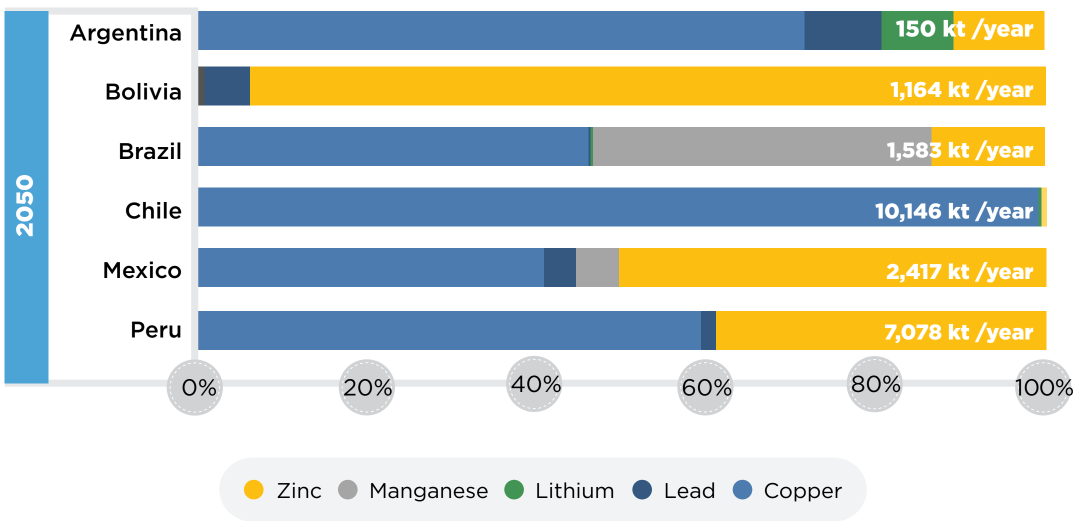
transportation and, therefore, increased mineral demand from passenger vehicles. Given that automotive energy storage in the TIAM 2°C scenario is about twice as high as in the 2.0°C scenario used by the World Bank, this difference probably explains the overall discrepancy in the results for lithium.

2. Second, the World Bank does not publish the biochemical assumptions of the lithium-ion batteries it uses in its analysis. The analysis presented in this report assumes a gradual, but not total, phase-out of the lithium-ion manganese oxide (LMO) battery, which has a substantially higher manganese intensity than the nickel-cobalt-manganese (NMC) NMC 111 battery and the NMC 811. If the World Bank report assumes a total LMO phase-out, this could explain the rest of the difference in manganese estimates.

2.4 Regional supply results

This section presents the results of mining production growth in Argentina, Bolivia, Brazil, Chile, Mexico and Peru (focal countries). These countries were selected because they are key mineral producers that are affected by the transition to a low carbon economy.

Figure 2.7 - Mineral production approach by country as % of national total in a 1.5°C scenario in 2050



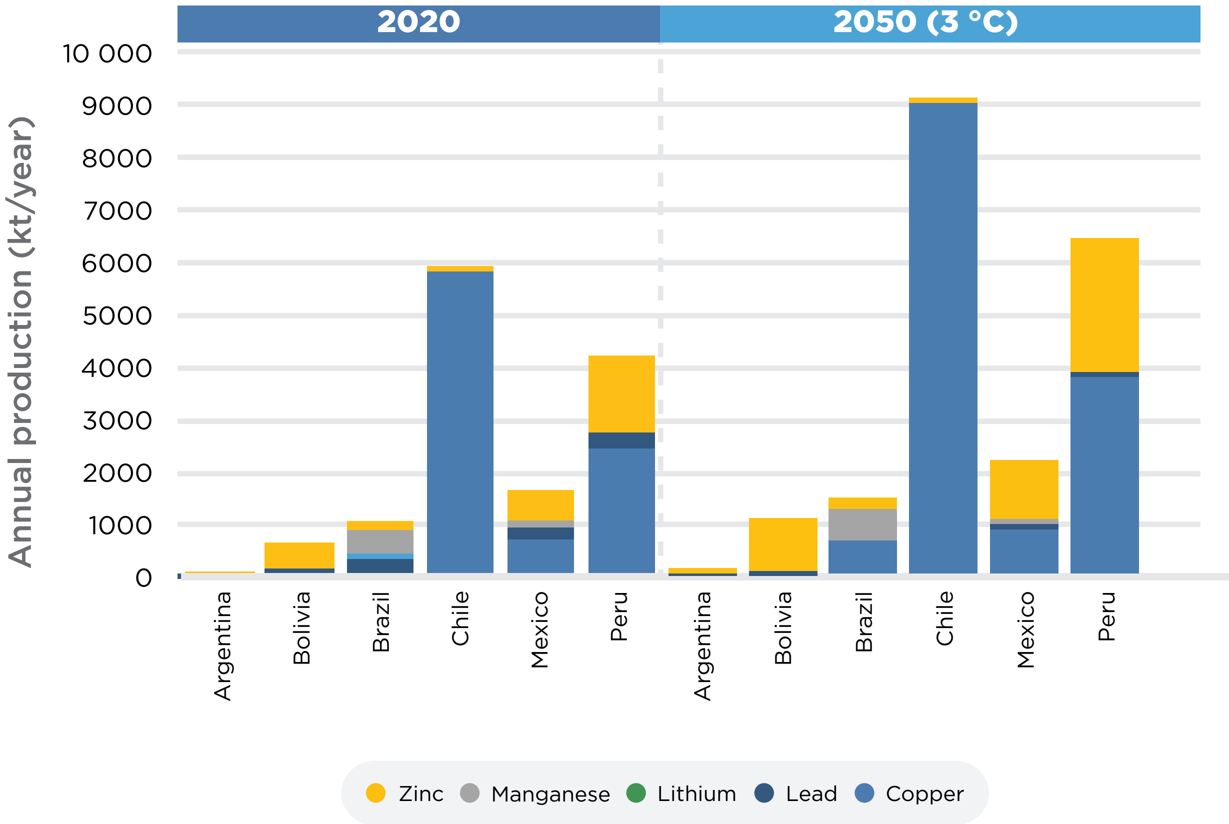
Comments: The results displayed are for the central recycling scenario
Source: Own elaboration based on results of the Vivid Economics model.

The first part (2.4.1) presents an overview of the results for all countries of interest; the second section (2.4.2) provides detailed results by country.

2.4.1 Overview of results for all countries of interest

Meeting decarbonization targets (3.0°C scenario), LAC production in focus minerals increases by 52 % by 2050 compared to 2020. The largest increase is expected in lithium, 990 %, followed by zinc (74 %), copper (54 %), manganese (28 %), and with a decrease in lead (-62 %) (Figure 2.8). This growth highlights the potential for increased production in LAC.

Figure 2.8 - Focus on mineral production by country in a 3.0°C scenario in 2050



Comments: The results displayed are for the central recycling scenario
Source: Own elaboration based on results of the Vivid Economics model.

Mineral production growth in the focal countries is driven primarily by growth in global demand for key minerals. By 2050, the focal countries will produce between 2% and 12% more minerals annually in the 1.5°C scenario relative to **the reference case (3.0°C),** with manganese being the lowest and lead the highest.

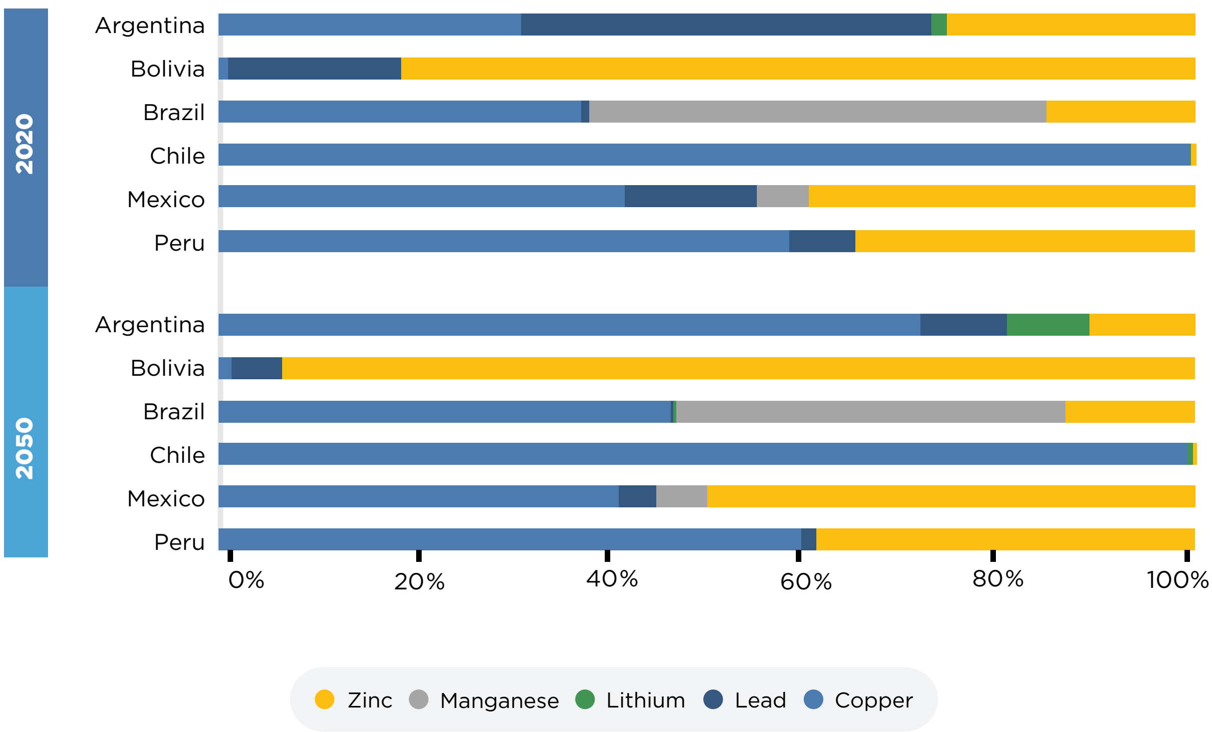
The focal countries produce 10% more lithium and copper in the 1.5°C scenario than the reference case (3.0°C), due to their growing market share coupled with strong demand growth. Major lithium and copper producers, such as Chile, Argentina, and Peru, already have large market shares that are increasing over time. For example, Chile currently provides approximately 28% of the world's mined copper, which will increase to 31% by 2050. Argentina's share of the lithium market increases from 1.1% today to 1.4% by 2050. The large and growing market share of these countries allows them to capitalize on the strong growth in world demand for these minerals.

The focal countries produce approximately 2% more manganese and 7% more zinc in the 1.5°C scenario than in the reference scenario (3.0°C). Rapid growth in demand for manganese and zinc more than offset declining country market shares for these minerals.

By 2050, lead production is 12% higher in the 1.5°C scenario compared to the reference scenario (3.0°C), although lead demand falls over time as it is gradually discarded for health and environmental reasons. The importance of lead for stationary storage applications means that it remains a key mineral for a low carbon transition. Lead is kept relevant by its use in the sheathing of submarine power cables for offshore wind energy and lead acid batteries for stationary storage.

Although mineral production is generally higher in the 1.5°C scenario than in the 2°C scenario, copper producers are especially likely to benefit from more aggressive decarbonization (Figure 2.4). By 2050, the focal countries will produce 2.4% more lithium and 1.5% more copper and zinc in the 2°C scenario compared to the reference scenario (3.0°C). In other words, the increase in copper demand (when compared to the reference scenario) is seven times higher in the 1.5°C scenario than in the 2°C scenario. This is compared to an increase of approximately four times for lithium and zinc. Major copper producers such as Chile and Peru therefore face a greater advantage if the world follows a 1.5°C transition path rather than a 2°C path.

Figure 2.9 - Production by mineral as a % of total production in the country



Source: Own elaboration based on results of the Vivid Economics model.

In the 1.5°C scenario, mineral production grows between -3% and 9% per year from 2020 to 2050. Lead has the lowest growth rate, while lithium has the highest.

Lithium has the highest production growth rate of all minerals, at more than 8% per year. The highest growth rates are found in Argentina (8.8% per year), Chile (8.6%) and Brazil (8.4%). When measured in absolute terms, Chile's lithium production is growing at more than 1 kt/year per year. This rate is more than double that of Argentina (0.4 kt/year per year) and almost ten times higher than that of Brazil (0.1 kt/year per year). This is because Chile is already the world's third largest supplier of lithium, allowing it to capitalize on demand from the growing deployment of electric vehicles and stationary storage.

Zinc has the highest production growth rate of just over 2% per year. The highest growth rate of 2.5% is found in Bolivia, followed by Peru with 2.1% and Mexico with 2.0%. However, Peru has the highest absolute production growth of more than 42 kt/year. This is more than double that of Bolivia and Mexico, both of which increase annual production by approximately 18 kt/year.

Copper production is growing by 1.8% per year. The highest growth rates are found in Argentina (5.3% per year), Bolivia (2.8%) and Brazil (2.1%). As the world's largest copper producer, Chile has the highest absolute growth, increasing its annual production rate by 139 kt/year each year.

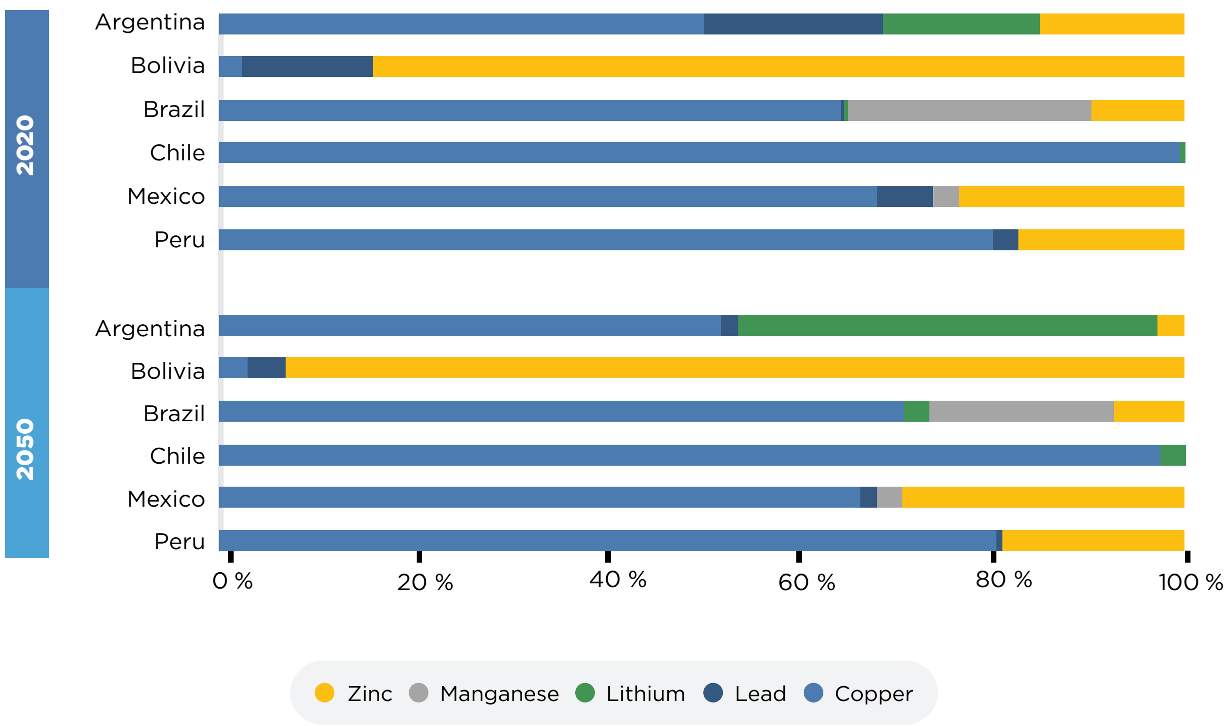
Manganese, which is produced by only two focal countries, has a relatively low production growth rate of 0.9% per year. Manganese production in Brazil is growing by 0.8% or almost 5 kt per year, while Mexico is increasing its production by 1.2% or more than 1 kt per year.

Lead production decreases by approximately 2% each year, due to the drop in world demand for lead. This decline ranged from 0.8% in Chile to 2.4% in Peru. However, lead currently accounts for less than 2% of total mineral earnings in the focal countries, which would limit the downside of declining lead demand.

Copper production growth is the main driver of mining profits and copper is expected to contribute approximately USD 43 billion by 2050. This is a 70% increase compared to copper earnings in 2020 and is equivalent to 1.2% of the combined 2019 GDP of the focal countries. In all focal countries except Bolivia, copper already accounts for the largest share of key mineral revenues. By 2020, copper accounts for half of all mineral revenues in Argentina and almost 100% of Chile's mineral revenues. As demand for copper increases along with the growing market shares of the focal countries, their earnings from copper production will continue to increase.

A smaller but significant portion of earnings comes from lithium, as it has a higher production growth rate and a higher profit margin than other minerals. The total share of lithium production revenues in the focal countries increases from 0.3% to 2% between 2020 and 2050. Total lithium earnings in 2050 are USD 990 million, more than ten times the earnings in 2020. In Argentina, lithium revenues increase more than tenfold, from approximately USD 19 million (16% of total revenues) today to more than USD 240 million (43% of total revenues) in 2050. However, the lithium market remains much smaller than the copper market, as copper is produced in much larger volumes.

Figure 2.10 - Utility breakdown by mineral in 2020 and 2050 in the 1.5°C scenario



Comments: Under the central recycling scenario of 1.5°C
Source: Own elaboration based on results of the Vivid Economics model.

Chile has the highest absolute gain of all countries, with USD 28 billion per year by 2050. Chile also has the highest absolute earnings growth, with annual earnings increasing by almost USD 0.4 billion each year. This is due to the enormous size of the country's copper mining sector, which accounted for 9.2% of Chile's GDP in 2016 (OECD, 2018). Copper will contribute 97% of Chile's total mining revenues by 2050, amounting to USD 24 billion annually. Almost all of the remainder (2.4% or USD 0.6 billion per year) comes from lithium production.

The highest profit growth rate is in Argentina, with an annual growth rate of 5.2% due to the benefits of lithium and copper. This translates into annual mineral earnings that increase by more than USD 14 million each year. By 2050, 52% of Argentina's mineral revenues come from copper and lithium contributes approximately 43%.

2.4.2 Detailed description by country

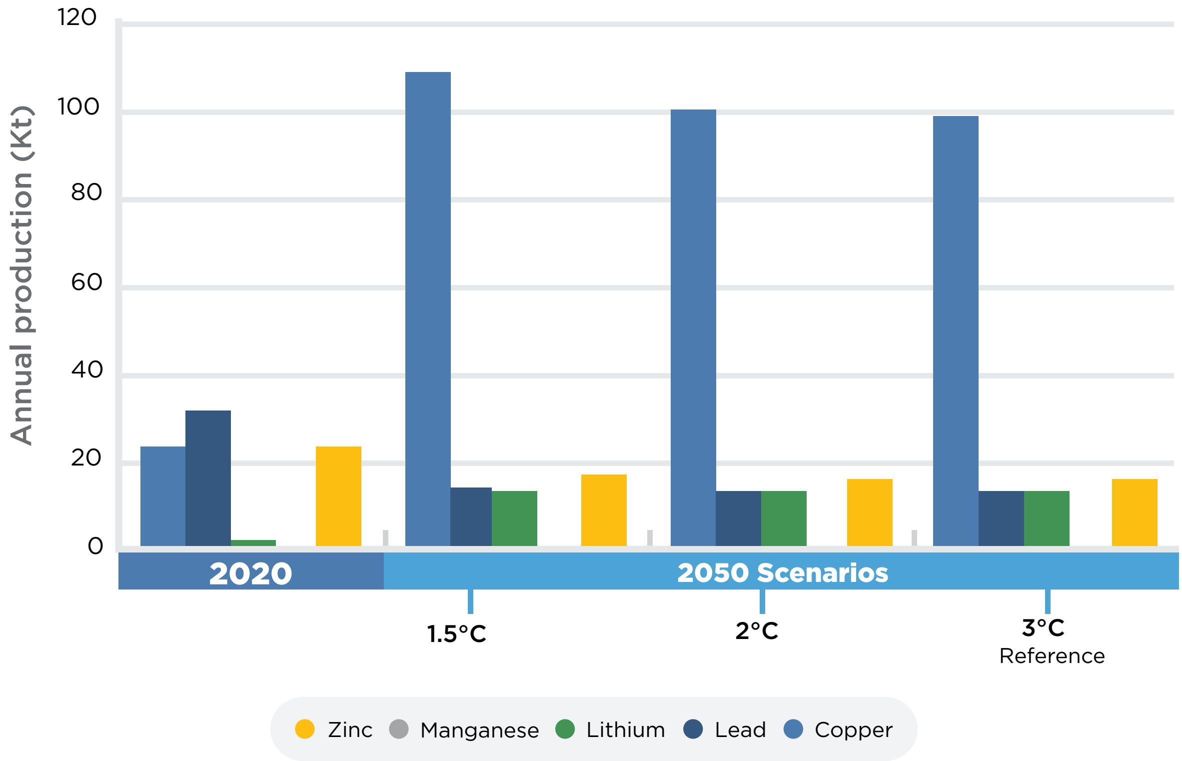
2.4.2.1 Argentina

Among the focus minerals, Argentina currently produces copper, lead, lithium, and zinc. Argentina does not produce significant amounts of manganese. Argentina's currently known resources of all focus minerals (except zinc) are sufficient to sustain production in the 1.5°C scenario until at least 2050. Based on the production projections in this analysis, Argentina would exhaust its currently known zinc resources by 2047 unless new zinc resources are discovered. This is not taken into account in the analysis of production or economic benefits presented in this section. In Annex B the impacts of supply limits are explored in a sensitivity analysis.

Argentina's share of world lithium and copper production increases between 2020 and 2050, while the market share of lead and zinc remains constant and falls, respectively. Argentina has a 1.1% market share for lithium today, which will grow to 1.4% by 2050, in line with the strong growth in production over the last 30 years. Argentina also has relatively small market shares of lead (0.6%), zinc (0.2%) and copper (0.1%). Assuming historical trends continue, its share of the copper market will triple to 0.3% by 2050. Its share of the lead market will remain constant, while its share of the zinc market will fall to less than 0.1%.

In the 1.5°C scenario, Argentina produces 108 kt of copper, 13 kt of lead, 13 kt of lithium and 16 kt of zinc annually by 2050. Compared to 2020, production in 2050 will be approximately four times higher for copper and 12 times higher for lithium. Lead production is 57% lower due to the drop in lead demand, while zinc production is 14% lower due to the drop in Argentina's market share. The large increase in lithium production is due to the fact that the growing market share of lithium in Argentina coincides with a strong growth in world lithium demand. In the high recycling scenario, Argentina produces 98 kt of copper, 8 kt of lead, 10 kt of lithium and 9 kt of zinc annually by 2050. This compares to its annual production of 156 kt of copper, 25 kt of lead, 16 kt for lithium and 18 kt for zinc in the low recycling scenario. In the base scenario, annual production in 2050 is 98 kt of copper, 12 kt of lead, 12 kt of lithium and 15 kt of zinc.

Figure 2.11 - Annual mineral production in Argentina in 2050 under low carbon scenarios and the reference case



Comment: Assuming a central recycling scenario
Source: Own elaboration based on results of the Vivid Economics model.

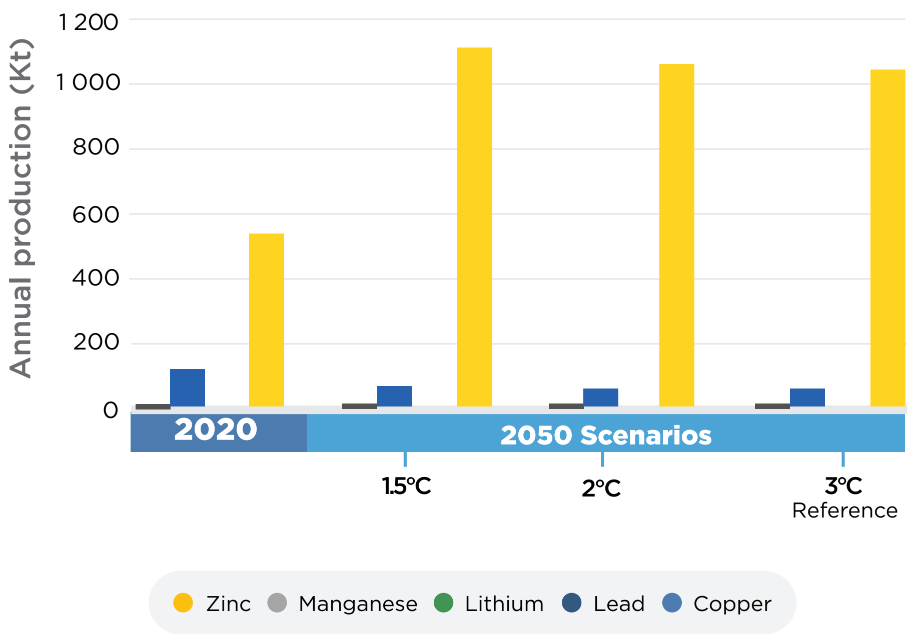
Argentina earns USD 550 million per year in total mineral revenues by 2050 in the 1.5°C scenario, of which 52% is attributable to copper. This is equivalent to 0.12% of its 2019 GDP, or more than three times the estimated mining profits in 2020. By 2050, annual earnings amount to USD 290 million from copper, USD 10 million from lead, USD 242 million from lithium and USD 60 million from zinc. While copper still contributes the largest share of mineral revenues in 2050, the rapid growth of lithium production and its higher profit margin means that lithium's profit share among minerals of interest increases from 16% to 43% between 2020 and 2050. In contrast, the share of earnings attributable to copper decreases slightly, from 52% to 50% between 2020 and 2050. Total mineral gains in 2050 are USD 462 million per year in the high recycling scenario and USD 754 million per year in the low recycling scenario. Total mineral revenues under the central scenario in 2050 are USD 505 million per year, of which USD 263 million from copper, USD 9 million from lead, USD 219 million from lithium and USD 15 million from zinc.

2.4.2.2 Bolivia

Of the focus minerals, Bolivia currently produces copper, lead and zinc and does not produce significant amounts of lithium or manganese, despite having one of the largest lithium reserves in the world. Based on the production forecasts in this analysis, Bolivia would exhaust its currently known lead and zinc resources by 2032 and 2028, respectively, in the 1.5°C scenario, unless new resources are discovered. There was insufficient data on the size of copper resources in Bolivia to perform a similar analysis for copper. This is not taken into account in the analysis of production or economic benefits presented in this section. In Annex B the impacts of supply limits are explored in a sensitivity analysis.

Bolivia's shares of the world lead and zinc markets increase slightly between 2020 and 2050, while its share of the copper market remains constant over the same period. Bolivia currently has a market share of 2.4% for lead, 4.3% for zinc and less than 0.1% for copper. Its market share for copper remains below 0.1% between 2020 and 2050. Assuming historical trends continue, by 2050 its shares in the lead and copper markets will increase slightly to 2.7% and 4.5%, respectively, while its share in copper will remain constant.

Figure 2.12 - Annual mineral production in Bolivia in 2050 under low carbon scenarios and the reference case



Comment: Assuming a central recycling scenario
Source: Own elaboration based on results of the Vivid Economics model.

In the 1.5°C scenario, Bolivia produces 13 kt of copper, 62 kt of lead and 1.1 Mt of zinc annually by 2050. Copper and zinc production is approximately twice as high in 2050 as in 2020. Lead production is 46% lower due to a drop in lead demand. Under the high recycling scenario, Bolivia produces 11 kt of copper, 37 kt of lead and 631 kt of zinc per year by 2050. This compares to its annual production of 18 kt of copper, 114 kt of lead and 1.2 Mt of zinc under the low recycling scenario. In the central scenario, annual production in 2050 is 11 kt of copper, 55 kt of lead and 1.0 Mt of zinc.

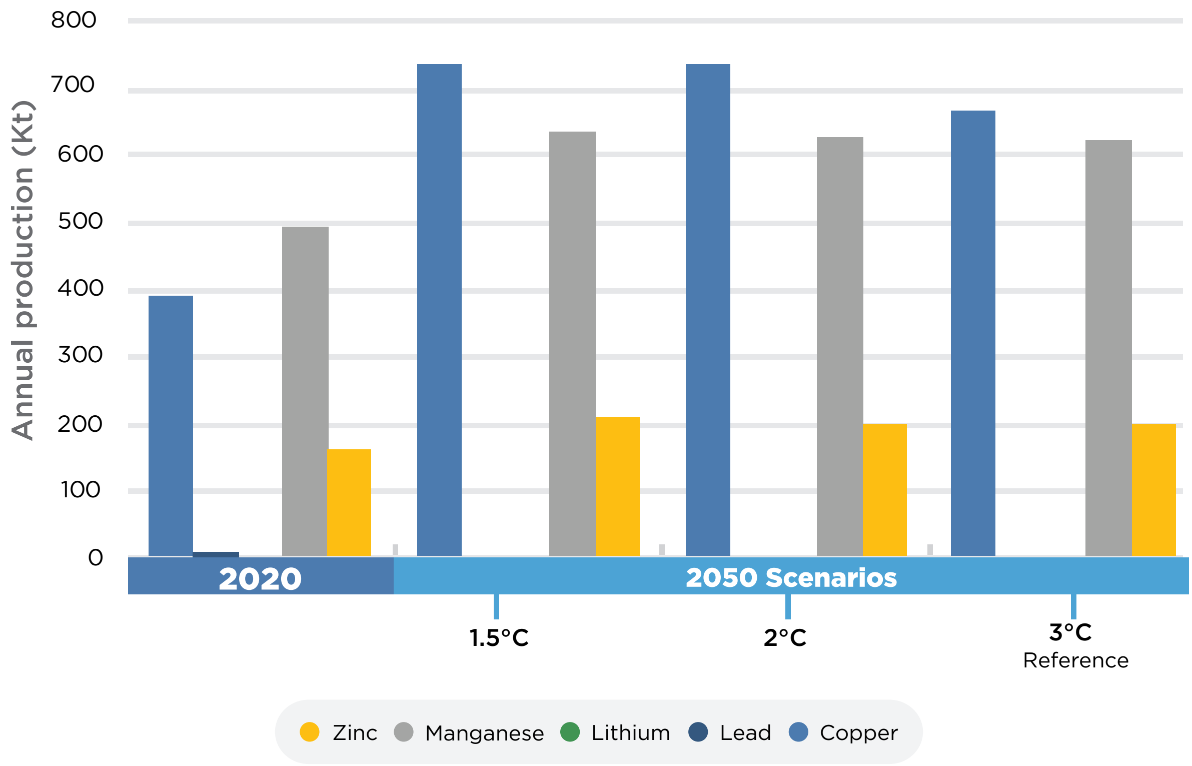
Bolivia earns USD 1.1 billion per year in total mineral earnings by 2050 in the 1.5°C scenario, of which 93% is attributable to zinc. This is equivalent to 2.7% of its 2019 GDP, or 87% more than its estimated 2020 mineral earnings. By 2050, annual earnings amount to USD 34 million from copper, USD 45 million from lead and USD 1.1 billion from zinc. The share of profits attributable to zinc increases from 84% to 93% between 2020 and 2050. In contrast, the profit share of lead production falls from 14% to 4% during the same period due to the decline in world lead demand. Total mineral gains in 2050 are USD 1.2 billion per year in the high recycling scenario and USD 667 million per year in the low recycling scenario. Total mineral earnings under the base scenario in 2050 are USD 1.1 billion per year, of which USD 31 million from copper, USD 40 million from lead and USD 984 million from zinc.

2.4.2.3 Brazil

Brazil produces all five minerals: copper, lead, lithium, manganese, and zinc. Brazil's currently known lead and manganese resources are sufficient to sustain production in the 1.5°C scenario until at least 2050. According to the production projections of this analysis, Brazil would exhaust its currently known lithium and zinc resources by 2042, unless new resources are discovered. There was insufficient data on the size of the copper resources to perform a similar analysis for copper. This is not taken into account in the analysis of production or economic benefits presented in this section. In Annex B the impacts of supply limits are explored in a sensitivity analysis.

Brazil's share of the world copper market increases between 2020 and 2050, while its share of the lead, manganese and zinc markets decreases. Its share of the lithium market remained constant during the period. Brazil currently has a market share of 1.9% for copper, 0.2% for lead, 0.4% for lithium, 5.8% for manganese and 1.3% for zinc. Assuming historical trends continue, by 2050 its share of the copper market will increase to 2.3%, while its shares of the lead, manganese and zinc markets will decrease to 0.1%, 4.2% and 0.9%, respectively. Its lithium market share remains at 0.4%.

Figure 2.13 - Annual mineral production in Brazil in 2050 under low carbon scenarios and in the reference case



Comments: Assuming a central recycling scenario
Source: Own elaboration based on results of the Vivid Economics model.

In the 1.5°C scenario, Brazil produces 733 kt of copper, 3 kt of lead, 4 kt of lithium, 632 kt of manganese and 211 kt of zinc annually by 2050. Copper production is 88% higher in 2050 than in 2020, with manganese 29% higher and zinc 31% higher. Lithium production is growing significantly and will increase more than 10 times by 2050. Lead production is 46% lower. In the high recycling scenario, Brazil annually produces 668 kt of copper, 2 kt of lead, 3 kt of lithium, 401 kt of manganese and 122 kt of zinc by 2050. This compares to its annual production of 1.1 Mt of copper, 6 kt of lead, 5 kt of lithium, 883 kt of manganese and 229 kt of zinc in the low recycling scenario. In the central scenario, annual production in 2050 is 664 kt of copper, 3 kt of lead, 3 kt of lithium, 620 kt of manganese and 197 kt of zinc.

Brazil earns USD 2.7 billion per year in total mineral earnings by 2050 in the 1.5°C scenario, of which 71% is attributable to copper. This is equivalent to 0.15% of its 2019 GDP, or 71% more than its estimated 2020 mineral earnings. By 2050, annual earnings amount to USD 1 billion from copper, USD 5 million from lead, USD 6 million from

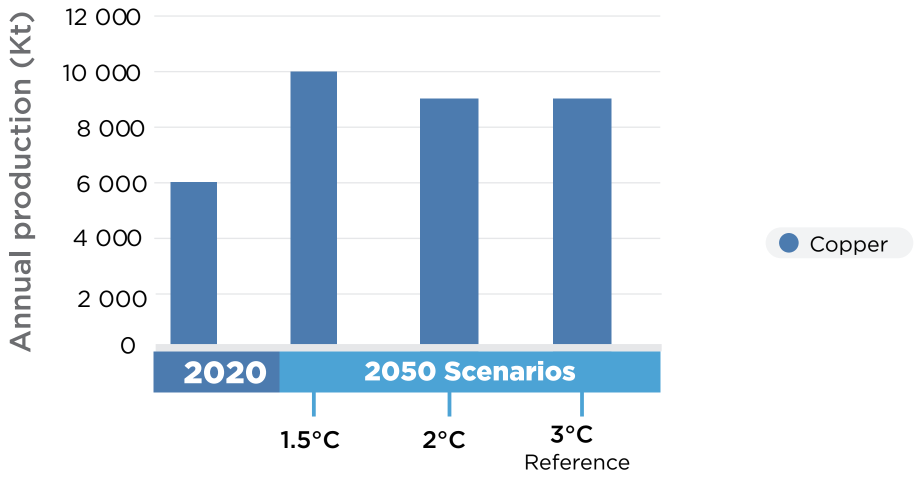
lithium, USD 412 million from manganese and USD 155 million from zinc. The share of earnings attributable to copper increases from 65% to 71% between 2020 and 2050, and lithium's share of earnings also increases from 0.4% to 2.6%. In contrast, the profit share of zinc production fell from 10% to 7% during the same period. Total mineral gains in 2050 are USD 2.3 billion per year in the high recycling scenario and USD 3.9 billion per year in the low recycling scenario. Total mineral earnings under the reference scenario in 2050 are USD 2.6 billion per year, of which USD 1.7 billion from copper, USD 2 million from lead, USD 65 million from lithium, USD 520 million from manganese and USD 190 million from zinc.

2.4.2.4 Chile

Of the focus minerals, Chile currently produces copper, lead, lithium and zinc; it does not produce significant amounts of manganese. Chile's currently known copper and lead resources are sufficient to sustain production in the 1.5°C scenario until at least 2050. According to the production forecasts of this analysis, Chile would exhaust its currently known lithium and zinc resources by 2050 and 2041 respectively, unless new resources are discovered. This is not taken into account in the analysis of production or economic benefits presented in this section. In Annex B the impacts of supply limits are explored in a sensitivity analysis.

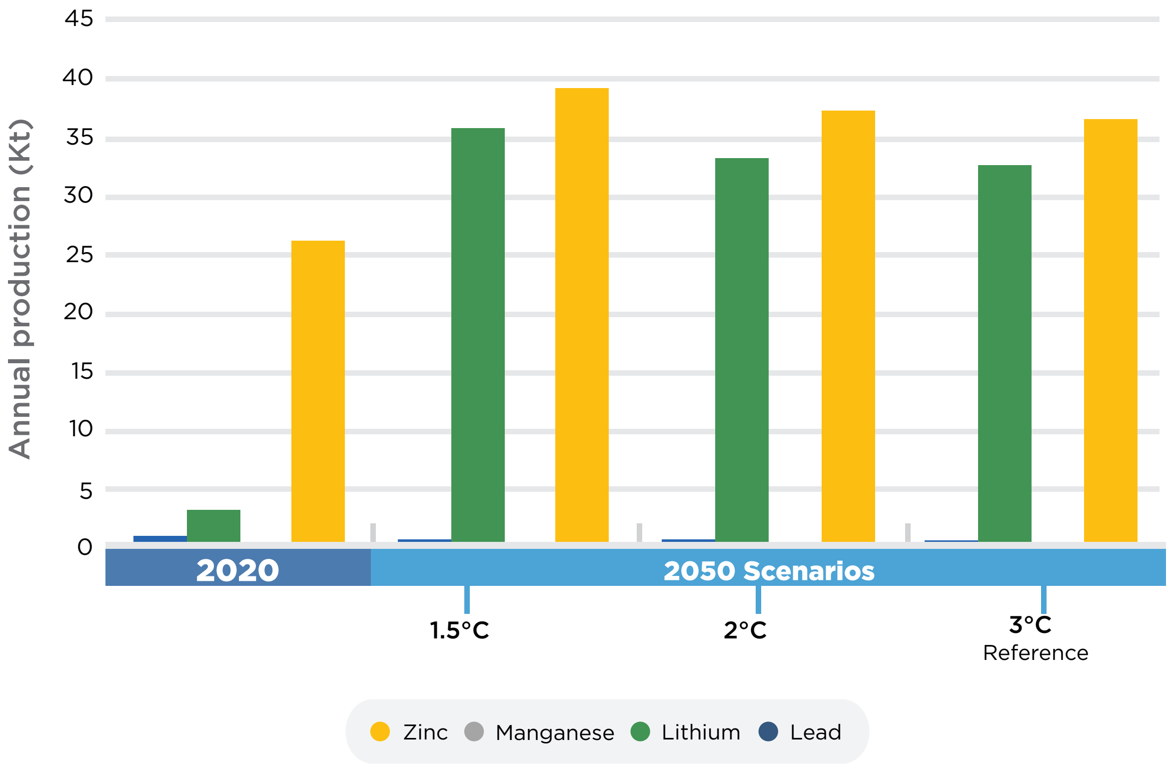
Chile's shares in the world copper and lithium markets increase between 2020 and 2050, while its shares in the lead, manganese and zinc markets remain constant over the same period. In 2019, Chile was estimated to be the world's largest copper producer and the third largest lithium producer. It currently has a market share of 29% for copper, less than 0.1% for lead, 3.3% for lithium, less than 0.1% for manganese and 0.2% for zinc. Assuming historical trends continue, by 2050 its share of the copper market will increase to 31% and its share of the lithium market will increase to 4.0%. Its market shares of the lead, manganese and zinc markets remained constant during the same period.

Figure 2.14 - Annual copper production in Chile in 2050 under low carbon scenarios and the reference case



Comment: Assuming a central recycling scenario. Copper results are presented separately for Chile due to the large scale of copper production.
Source: Own elaboration based on results of the Vivid Economics model.

Figure 2.15 - Annual mineral production (excluding copper) in Chile in 2050 under low carbon scenarios and the reference case



Comment: Assuming a central recycling scenario
Source: Own elaboration based on results of the Vivid Economics model.

In the 1.5°C scenario, Chile produces 10 Mt of copper, 0.5 kKt of lead, 36 kt of lithium and 39 kt of zinc annually by 2050. Copper production is 71% higher in 2050 than in 2020, while zinc production is 49% higher. Lithium production is growing significantly and will increase more than 10 times by 2050. In contrast, lead production is 36% lower. Under the high recycling scenario, Chile produces 9 Mt of copper, 0.3 kKt of lead, 27 kt of lithium and 23 kt of zinc per year by 2050. This compares to its annual production of 14 Mt of copper, 0.9 kt of lead, 44 kt of lithium and 42 kt of zinc in the low recycling scenario. In the central scenario, annual production in 2050 is 9.1 Mt of copper, 0.4 kt of lead, 32 kt of lithium and 37 kt of zinc.

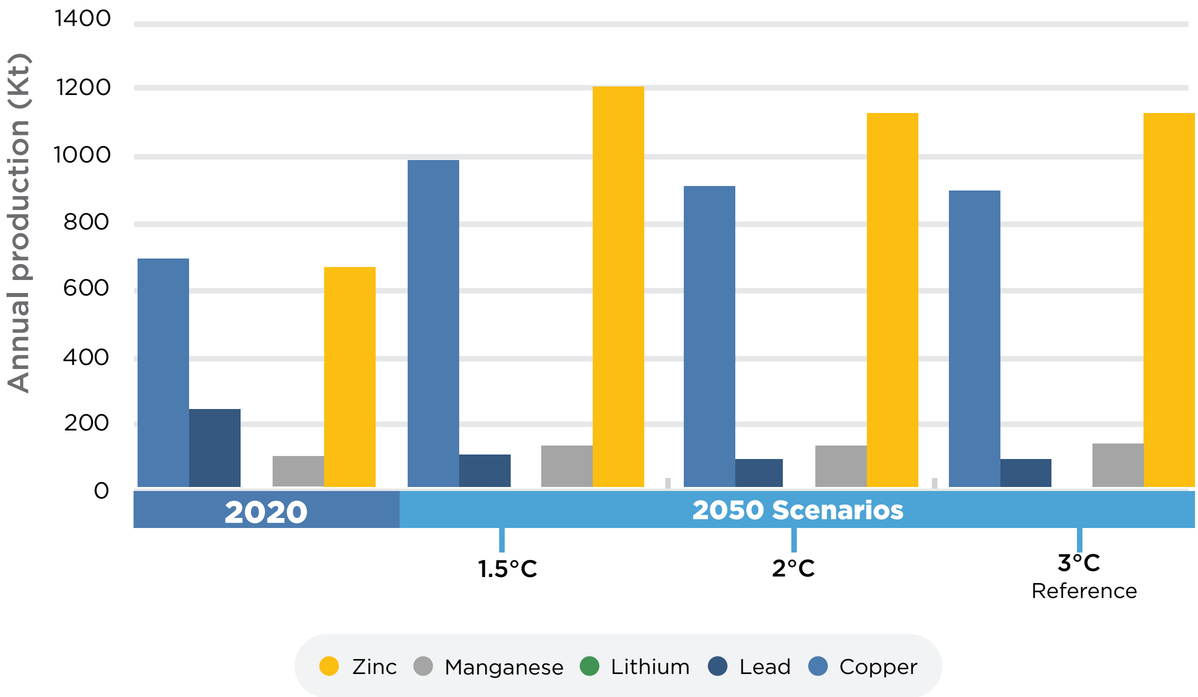
Chile earns USD 28 billion per year in total mineral earnings by 2050 in the 1.5°C scenario, of which 97% is attributable to copper. This equates to 9.8% of its 2019 GDP, or 74% more than its estimated 2020 mineral earnings. By 2050, annual revenues amount to USD 27 billion from copper, USD 0.3 million from lead, USD 675 million from lithium, and USD 38 million from zinc. The share of earnings attributable to lithium grows from 0.4% to 2.4% between 2020 and 2050, while copper's share of earnings falls from 99% to 97%. Total mineral gains in 2050 are USD 25 billion per year in the high recycling scenario and USD 40 billion per year in the low recycling scenario. Total mineral revenues under the reference scenario in 2050 are USD 25 billion per year, of which USD 24 billion from copper, USD 0.3 million from lead, USD 611 million from lithium and USD 35 million from zinc.

2.4.2.5 Mexico

Mexico currently produces copper, lead, manganese and zinc, and does not produce significant amounts of lithium. Mexico's currently known copper, lead and manganese resources are sufficient to sustain production in the 1.5°C scenario until at least 2050. According to the production forecasts in this analysis, Mexico would exhaust its currently known zinc resources by 2043, unless new resources are discovered. This is not taken into account in the analysis of production or economic benefits presented in this section. However, in Annex B the impacts of supply limits are explored in a sensitivity analysis.

Mexico's shares in the copper, lead, manganese, and zinc markets fall slightly between 2020 and 2050. Currently, Mexico has a market share of 3.4% for copper, 4.8% for lead, 1.0% for manganese and 5.4% for zinc. Assuming historical trends continue, their market shares will be reduced to 3.1% for copper, 3.9% for lead, 0.8% for manganese and 5.0 % for zinc by 2050.

Figure 2.16 - Annual mineral production in Mexico in 2050 under low carbon scenarios and the Reference Case



Comment: Assuming a central recycling scenario
Source: Own elaboration based on results of the Vivid Economics model.

In the 1.5°C scenario, Mexico produces 991 kt of copper, 91 kt of lead, 124 kt of manganese and 1.2 Mt of zinc annually by 2050. Copper production is 43% higher in 2050 than in 2020, while manganese is 44% higher and zinc is 83% higher. Lead production is 60% lower. Under the high recycling scenario, Mexico annually produces 903 kt of copper, 55 kt of lead, 79 kt of manganese and 701 kt of zinc by 2050. This compares to its annual production of 1.4 Mt of copper, 168 kt of lead, 174 kt of manganese and 1.3 Mt of zinc in the low recycling scenario. In the central scenario, annual production in 2050 is 897 kt of copper, 81 kt of lead, 122 kt of manganese and 1.1 Mt of zinc.

Mexico generates USD 4 billion per year in total mineral revenues by 2050 under the 1.5°C scenario, of which 67 % is attributable to copper. This is equivalent to 0.3% of its 2019 GDP, or 47% more than its estimated 2020 mineral earnings. By 2050, annual earnings amount to USD 2.6 billion from copper, USD 66 million from lead, USD 104 million from manganese, and USD 1.1 billion from zinc. The share of zinc-related earnings increases from 23% to 29% between 2020 and 2050, while lead's share of earnings falls from 6.0% to 1.7%. Total mineral gains in 2050 are USD 3.2 billion per year in the high recycling scenario and USD 5.3 billion per year in the low recycling scenario. Total

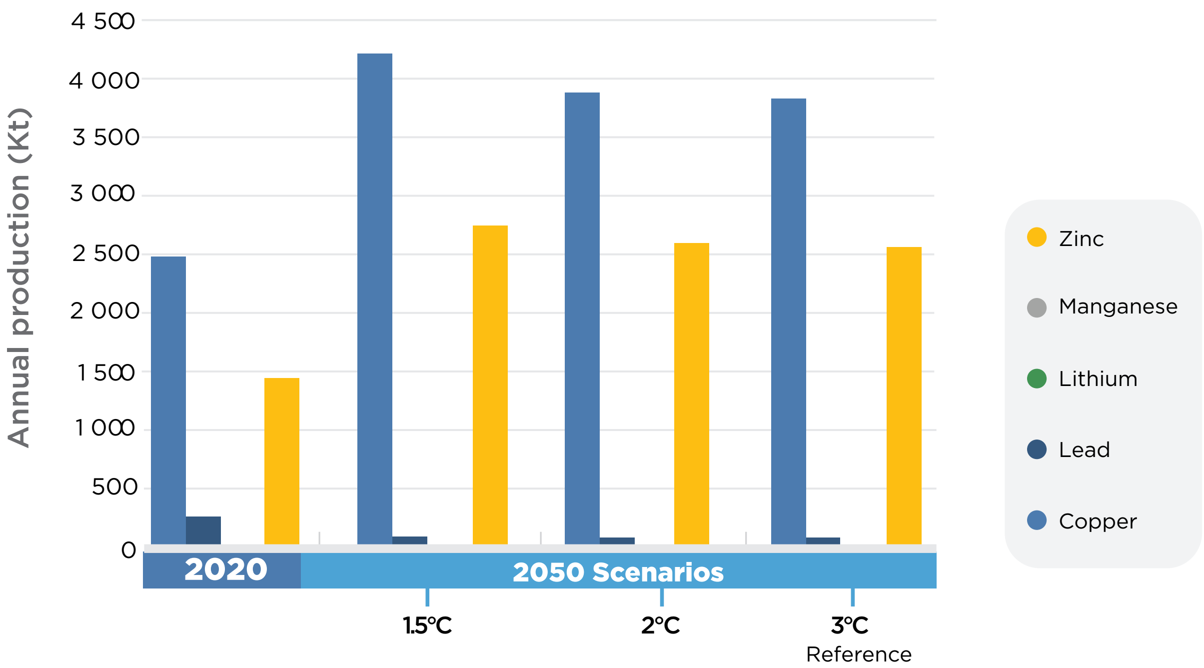
mineral revenues under the reference scenario (3.0°C) in 2050 are USD 3.6 billion per year, of which USD 2.4 billion come from copper, USD 59 million from lead, USD 102 million from manganese and USD 1.1 million from zinc.

2.4.2.6 Peru

Peru currently produces copper, lead, and zinc, and does not produce significant amounts of lithium or manganese. Peru's currently known copper and lead resources are sufficient to sustain production in the 1.5°C scenario until at least 2050. According to the production projections in this analysis, Peru would exhaust its currently known zinc resources by 2038, unless new resources are discovered. This is not considered in the analysis of production or economic benefits presented in this section. However, in Annex B the impacts of limiting the forecasted production of the countries in the resource limit as a sensitivity analysis.

Peru's share of the world copper market increases between 2020 and 2050, while its share of the lead and zinc markets decreases over the same period. In 2019, Peru was estimated to be the world's second largest copper producer. It currently has a 12% market share in copper, 6% in lead and 12% in zinc. Assuming historical trends continue, its share of the copper market would increase to 13% by 2050. This contrasts with a decrease in market shares to 4.8% for lead and 11.4% for zinc by 2050.

Figure 2.17 - Annual mineral production in Peru in 2050 under low carbon scenarios and the reference case



Comment: Assuming a central recycling scenario
Source: Own elaboration based on results of the Vivid Economics model.

In the 1.5°C scenario, Peru produces 4.2 Mt of copper, 112 kt of lead and 2.7 Mt of zinc annually by 2050. Copper production is 71% higher in 2050 than in 2020, while zinc is 87% higher. In contrast, lead production is 61% less. In the high recycling scenario, Peru produces 3.8 Mt of copper, 67 kt of lead and 1.6 Mt of zinc per year by 2050. This compares to its annual production of 6.1 Mt of copper, 205 kt of lead and 3.0 Mt of zinc under the low recycling scenario. In the central scenario, annual production in 2050 is 3.8 Mt of copper, 99 kt of lead and 2.5 Mt of zinc.

Peru generates USD 14 billion per year in total mineral revenues by 2050 under the 1.5°C scenario, of which 81 % is attributable to copper. This is equivalent to 6.2% of its 2019 GDP, or 70% more than its estimated 2020 mineral earnings. By 2050, annual earnings amount to USD 11 billion from copper, USD 81 million from lead and USD 2.7 billion from zinc. The share of earnings attributable to zinc increases from 17% to 19% between 2020 and 2050, while lead's share of earnings falls from 2.5% to 0.6%. Total mineral gains in 2050 are USD 12 billion per year in the high recycling scenario and USD 19 billion per year in the low recycling scenario. Total mineral revenues under the reference scenario in 2050 are USD 13 billion per year, of which USD 10 billion from copper, USD 72 million from lead and USD 2.4 billion from zinc.

3. Potential socio-environmental opportunities and challenges

This chapter analyzes the potential socio-environmental opportunities and challenges related to an increase in the production of specific minerals (copper, lithium, manganese, lead and zinc) under a 1.5°C scenario, with a 2020 baseline, presented in Section 2.4, to capture the estimated economic benefits of USD 50 billion per year by 2050 (Table 3.1).

Table 3.1 Growth in production under different decarbonization scenarios compared to 2020 production.

Growth in production compared to 2020 (% by weight)							
Year	Scenario	Copper	Lead	Lithium	Manganese	Zinc	Total
2050	3.0°C	54%	62%	990%	28%	74%	56%
	2.0°C	57%	-62 %	1016%	30%	76%	59%
	1.5°C	70%	-58%	1102%	31%	86%	72%

Comments: The results displayed are for the central recycling scenario
Source: Own elaboration based on results of the Vivid Economics model.

To this end, we developed a socio-environmental framework to evaluate and prioritize these opportunities and challenges, seeking to include the likely positive and negative impacts associated with mining operations in Argentina, Bolivia, Brazil, Chile, Mexico, and Peru. The following sections detail the socio-environmental factors identified for the assessment framework (section 3.1), then present the most relevant opportunities and challenges using the analysis framework (section 3.2), and provide recommendations specific to the socio-environmental factors (section 3.3), finally discussing their implementation in chapter 0.

3.1 Socio-environmental framework

To develop the socio-environmental framework, we analyzed sustainability reports, carbon footprint reports of mining companies and general and mining-specific environmental, social and governance (ESG) frameworks to identify the socio-environmental factors that cut across mining operations[9]. Subsequently, the assumptions identified were validated and complemented by means of surveys and interviews with experts in the field (see online questionnaire and interviews section "Environmental and social opportunities and challenges of select metals in LAC countries"). In addition, perspectives were obtained on the importance of the impacts and their relevance in the short and long term. The results are framed in heat maps of challenges and opportunities that will allow the identification of policies and strategies to be implemented in LAC countries related to the relevant group of metals. It should be noted that these socio-environmental factors were a basis for exploring the two types of impact, both as opportunities and challenges. To compensate for those factors that were not considered, respondents were asked, based on their experience, to add them to the heat maps and elaborate their responses on them.

3.1.1 Environmental factors

This study considered a baseline of seven environmental factors relevant to the five minerals in the countries selected for analysis. These environmental factors are defined in Table 3.2.

Table 3.2 - Definition of analyzed environmental factors

Environmental factors	Definition
Greenhouse gases (GHG)	GHGs that are emitted in the extraction and processing of minerals. Mostly CO_2eq; CH_4 originating mainly from carbon mining; N_2O and F-gases are minor gases emitted.
Air quality	Refers to the concentration of pollutants in the air near the mining operation. It includes dust and dust emissions that are perceived by nearby populations associated with mining operations.
Water management	This involves the quality and management of the water resource from input to output, everything that has to do with wastewater discharges, as well as water supply processes.

[7] Among the documents reviewed, the following stand out: Folchi, 2005; True Footprint, 2019; Allianz, 2018; Church and Crawford, 2018; SASB, 2018; Responsible Mining Foundation, 2019; World Economic Forum, 2015; Murray & Roberts, 2018; El Dorado Gold, 2018; Rocky Mountain Institute, 2019; SRK Exploration Services, 2019; Baker McKenzie, 2019; Fitch Ratings, 2020; Dufey, 2020; International Council on Mining and Metals, 2015a; United Nations, 2011; among others.

Management of tailings and hazardous materials	This is where mining environmental management typically focuses on addressing concerns about the impact of surface tailings disposal in the form of tailings and waste rock. Includes tailings management.
Environmental impact and impact on biodiversity	Potential environmental contamination from mining operations and damage to biodiversity that sustains economies, provides food, fuel, building materials and fresh water, and helps mitigate the impacts of climate change and natural disasters. Includes direct impacts from the establishment of operations, as well as indirect impacts outside the mining operations.
Energy management	Energy management involves the processes associated with the purchase and use of energy; it also considers energy efficiency in the different steps of mining (extraction, purification, refining and refining).
Physical impacts of climate change	It is a holistic factor that includes elements of the above. This includes elements such as changes in temperature, floods due to torrential rains, droughts, fires, decrease in the productivity of agricultural areas, which are associated with climate change.

3.1.2 Social factors

This study considers six social factors relevant to the five minerals in the countries selected for analysis[10]. The social factors are broadly defined in Table 3.3.

Table 3.3 - Definition of social factors analyzed

Social factors	Definition
Employee health and safety conditions	This factor considers everything that has to do with the safety and health of employees in their work in the mining industry. It includes the management of health and safety risks on the administrative side, working conditions in mining activities and company support in case of accidents.
Security	This includes both asset safety and mine site safety. It is associated with the safety of employees' residences outside the mining activity, as well as with the perceived impacts on the safety conditions of neighboring populations (increase in domestic violence, alcoholism, robberies).

[10] Among the studies reviewed, the following stand out: Folchi, 2015; International Council on Mining and Metals, 2020; Pont Vidal, 2008.

Human rights	This refers to the role that States and companies play in ensuring that the inherent rights of all human beings, without distinction, are respected and protected. Among others, it highlights the right to life and liberty, freedom from slavery and torture, freedom of opinion, freedom of transit, the right to education, the right to work, the right to drinking water, and the right to a safe environment.
Indigenous communities	Relations with peoples who are considered indigenous (...), regardless of their legal status and retain some or all of their own social, economic, cultural and political institutions (International Labor Organization, 1989).
Community relations	This factor includes social management, conflict management, dialog with local communities, including special strategies to include gender, and the ability to reach agreements with these communities to improve the social environment.
Labor relations	This factor includes everything related to the terms of employment among workers in the mining companies. Includes salary, benefits, employment, grievance procedures and union relations. The complaints relate to addressing violations of existing rights and entitlements, ranging from threats or harassment, to underpayment of wages, refusal to grant rest periods, weekly rest days or holidays, discrimination or underpayment of bonuses or other entitlements.

3.2 Socio-environmental opportunities and challenges

As mentioned in the previous section, using the socio-environmental factors framework, we developed heat maps for opportunities and challenges in these dimensions, in the context of a commitment to decarbonize and keep global temperature below 1.5°C, and a potential significant growth in mining activities in LAC.

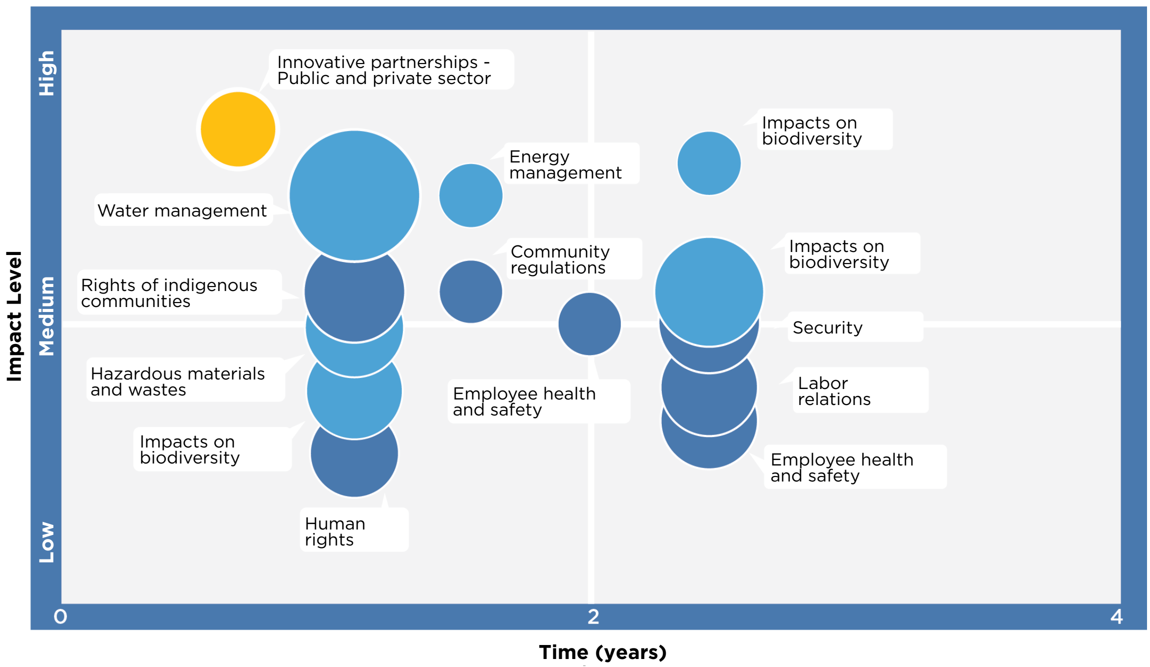
For the preparation of the heat maps, more than 40 case studies related to the minerals lithium, manganese, copper, zinc and lead were analyzed in the five Latin American countries within the scope of the project: Argentina, Bolivia, Brazil, Chile, Mexico, and Peru. The following were identified: i) the opportunities that mining operations have generated and have the potential to continue generating; and, ii) the challenges that mining operations face in socio-environmental terms, taking into account the expected growth (presented in section 2.4), summarized in Table 3.1.

The assumptions established in the maps were confirmed and adapted, based on the vision provided by experts from different sectors with experience in the minerals and countries in the scope of the project, through interviews and online surveys[11]; to whom the expected growth of the relevant minerals was presented as an introduction to start the interview. Based on the triangulation of interviews, reports and knowledge of the team, the heat maps shown below were generated [12].

3.2.1 Socio-environmental opportunities (positive impacts) identified for LAC

The main opportunities mentioned by each of the interviewees, in terms of level of impact and priority over time, are presented in the heat map below. The size of the bubble represents the degree of relevance of the factor for the interviewees; in green the environmental factors are presented, in blue the social factors and in yellow the most relevant factors added during the interviews. For the purpose of this report we do not present an exhaustive discussion of each factor, but rather a brief presentation of each one of them, with the understanding that all the factors presented are of utmost importance for the industry and it will be possible to deepen the individual analysis of each one in future research.

Figure 3.1 - Heat map of opportunities (positive impacts) of mining operations, considering low carbon scenarios.



Comment: The environmental factors are displayed in green, the social factors in blue and the most relevant factors added by the interviewees in yellow
Source: Authors' own elaboration

[11] See Annex C - Online questionnaire and interviews "Environmental and social opportunities and challenges of select metals in LAC countries".
[12] For more information on the construction of heat maps, see Annex C 2.2.

Water management is seen as a great opportunity due to the practices that, historically, mining companies have developed by improving water supply with the communities, while at the same time ensuring the supply for their operations. The Chilean experience in water desalination and watershed remediation processes should be highlighted. According to the Chilean Copper Commission, more and more mining companies are joining the construction of desalination plants or using seawater directly to address water limitations, to the extent that it is technically and economically feasible (Comisión Chilena del Cobre, 2016). In scenarios of increased copper production, this may be indicative of the potential increase in new desalination plants and the inclusion of these types of projects, which contribute to obtaining the necessary social license to operate. Generally, local communities tend to perceive new mining projects as a threat where water is scarce, because it competes with their productive activities and basic needs. Materializing the opportunity begins with reducing or eliminating pressure on local water sources and comprehensive management that considers the health and quality of the water source and the needs of the area.

Innovative alliances are perceived as a high impact opportunity due to the encouragement that mining companies in Latin America have given to the association of different areas of interest: companies and communities; and companies-academia, for the benefit of the community[13]. For example, education centers and capacity building programs for women and men in the community. Mention was also made of the associative relationships between the value chain of mining operations and the advantages of improving traceability and transparency of impacts through integrated management systems that include the value chain. In addition, public-private partnerships have been a mechanism for a more efficient use of local taxes from mining companies, ensuring that investments have a positive impact at the local level and are aligned with the needs of the communities[14].

Energy management opportunities are mentioned as mechanisms through which mining operations have been able to reduce their carbon emissions, while at the same time promoting initiatives to green their energy supply with renewable energy. A regulatory framework that enables renewable distributed energy generation helps more of these opportunities to materialize, particularly in off-grid areas. Energy efficiency was identified as another opportunity applicable to the minerals considered in this

[13] It is worth mentioning the study carried out between ECLAC and the Catholic Pontifical University of Chile ("Climate Change Adaptation Map of the Metropolitan Region Basin Project") with the purpose of providing information to implement climate change resilience and adaptation policies. The report reveals that climate change is substantially affecting water availability in the basin. Therefore, under this new context, all stakeholders would end up competing for the resource, which would be expressed, among other things, through the Water Use Rights market (ECLAC, 2019).
[14] Initiatives such as the Extractive Industries Transparency Initiative, which presents the social contract as a key aspect, can be an example of this.

study. For example, the implementation of energy efficiency measures in the lithium refining process, where most of the energy is used (efficient pumping and electrolysis equipment), especially relevant for Chile and Argentina. For other minerals, such as copper, manganese, and lead, energy efficiency measures provide benefits throughout the production chain because for these metals energy use is similar in their extraction, purification and refining; zinc, on the other hand, uses most of the energy in purification and refining (Nuss, 2014). It should be noted that the most commonly used energy efficiency measures in mining operations focus on measures that improve the efficiency of the vehicles involved in the operations, as well as in their driving pattern; followed by the use of frequency variators in electric motors, the latter related to fans, pumps, conveyor belts, grinding and separation equipment, among other equipment used in mining processes (Montagú el at, 2019).

In the social dimension, the perspective of safeguarding the **rights of indigenous communities** was identified as an opportunity that mining companies have been adopting, particularly due to the adherence of the companies to international initiatives that contemplate this priority aspect. They also highlight sustainability frameworks that include the protection of indigenous communities in their due diligence processes, which contribute to obtaining the social license.

Tailings and hazardous materials management is identified as an opportunity because tailings are inherently associated with mining operations and, therefore, are those that have historically been included in management systems for evaluation and monitoring. It highlights the type of tailings involved, for example, copper mining is a major source of acid mine drainage (AMD), which occurs when copper sulfides oxidize and mix with water. Additionally, copper is associated with the radioactive heavy metals uranium, thorium and radium, which can be leached by acid mine drainage (AMD). In other cases mentioned by the people interviewed, the importance of proper management of mining waste is that its lack of management is related to the occurrence of accidents (poor tailings management), water pollution, soil contamination and negative impacts on biodiversity [15].

Respondents suggested that one of the ways to realize the opportunity to reduce tailings and hazardous material is through finding valuable utility in waste and implementing principles of **circular economy.** It is essential to seek **alliances** between the mining companies themselves and between other industries that generate similar waste in order to invest in technologies and research and develop technologies to treat the waste and find alternative uses for these materials. Respondents also highlighted the importance of increasing traceability, monitoring and compliance, and raising standards.

[15] For more information see Global Tailings Management Standard, in Annex E.2.

Regarding **environmental impacts and biodiversity,** this aspect is maintained in the short and medium term; in this sense, it is recognized that mining operations inherently affect biodiversity at multiple spatial scales. However, opportunities have been identified through the implementation of **environmental sustainability plans** and commitments made by mining companies to clean up their surroundings. To guarantee a sustainable impact, it is necessary to think in the long term, to work with local organizations that can implement long term biodiversity monitoring systems, that there are differentiated periodic evaluations for places with high biodiversity value and that contain quantitative elements to compare the progress and scope of the interventions that are performed. These proposals, combined with environmental legislation, can encourage better **mine closure** management and provide for native species recovery near projects.

A case was identified where the mining company implemented a waste and watershed remediation plan to capture the mineral oxides present from previous operations. These initiatives are important to recover soil, restore the ecosystem and mitigate the impacts of **climate change.**

Actions to protect **human rights** are also deemed relevant opportunities in the short term because, through due diligence processes requested by investors and clients with international capital, some mining companies, especially those associated with the International Council on Mining and Metals (ICMM), have incorporated guidelines that help them to know if they are complying with their responsibilities in this area (International Council on Mining and Metals, 2012), through their regulatory frameworks and social investments.

Security opportunities include the efforts made by mining companies to prevent theft and control unauthorized access to work areas. This factor is included in the social investment plans that have historically been developed by mining companies, such plans contain strategies to address social issues related to the safety of the surrounding communities; for example, actions to prevent alcoholism and drug use, as well as to prevent domestic violence.

Labor relations are seen as a medium-term opportunity because the people interviewed mentioned lessons learned in this area. One of the most commented examples is that employees of mining operations are the letter of introduction of mining companies in the surrounding communities and, therefore, the welfare of these personnel is key to avoid potential social conflicts in time. It is worth highlighting the case of Mexico, where mining operations have historically had a high potential for union conflicts, arising from disagreements in the safety and health conditions of employees, in addition to conflicts generated among the trade associations themselves.

In the context of the previous paragraph, employee **health and safety** conditions, when incorporated into **integrated management systems,** are considered a medium-term opportunity. Successful measures implemented include health initiatives, enforcement and transparency in the data provided in terms of accidents and fatalities in mining operations, as well as supervised monitoring of on-site measures, such as: standards for explosives used in mining, equipment fire protection systems, improved cap lamp technology and controls, improvements in ventilation systems, installation of blast-proof walls to seal areas, regional support systems in seismically active mines, hydraulic struts, and other forms of active roof support. Strategies for improving health and safety conditions aim to reduce work-related fatalities while simultaneously increasing the efficiency of operations.

Among the results of the online survey, he highlighted the recommendation that companies should be motivated to carry out security campaigns out of conviction and not out of obligation. In this sense, it is mentioned that it is necessary to increase the scope and have comprehensive programs that include security management towards the communities and the dissemination of security programs for them. It is also suggested to include behavioral elements as an important piece to benefit from security.

A long term challenge related to the perception of mining companies is worth highlighting: **the cultural transition to improve public perception,** since in some countries projects have been cancelled as a result of socio-environmental pressures. One of the interviewees suggested, in this regard, avoiding misinformation and providing specific third-party opinions on the quality or performance of projects.

Finally, according to the results of the online survey, the most relevant opportunities in the socio-environmental dimensions were identified for the five metals in the scope of this study[16].

[16] Of the 33 people who answered the survey in Spanish and English, the section on opportunities and challenges was nourished by the responses of 19 people; the methodology to find the most relevant factors shown in this table was to choose the one with more than 50% of selection, only, in the "Very relevant" category.

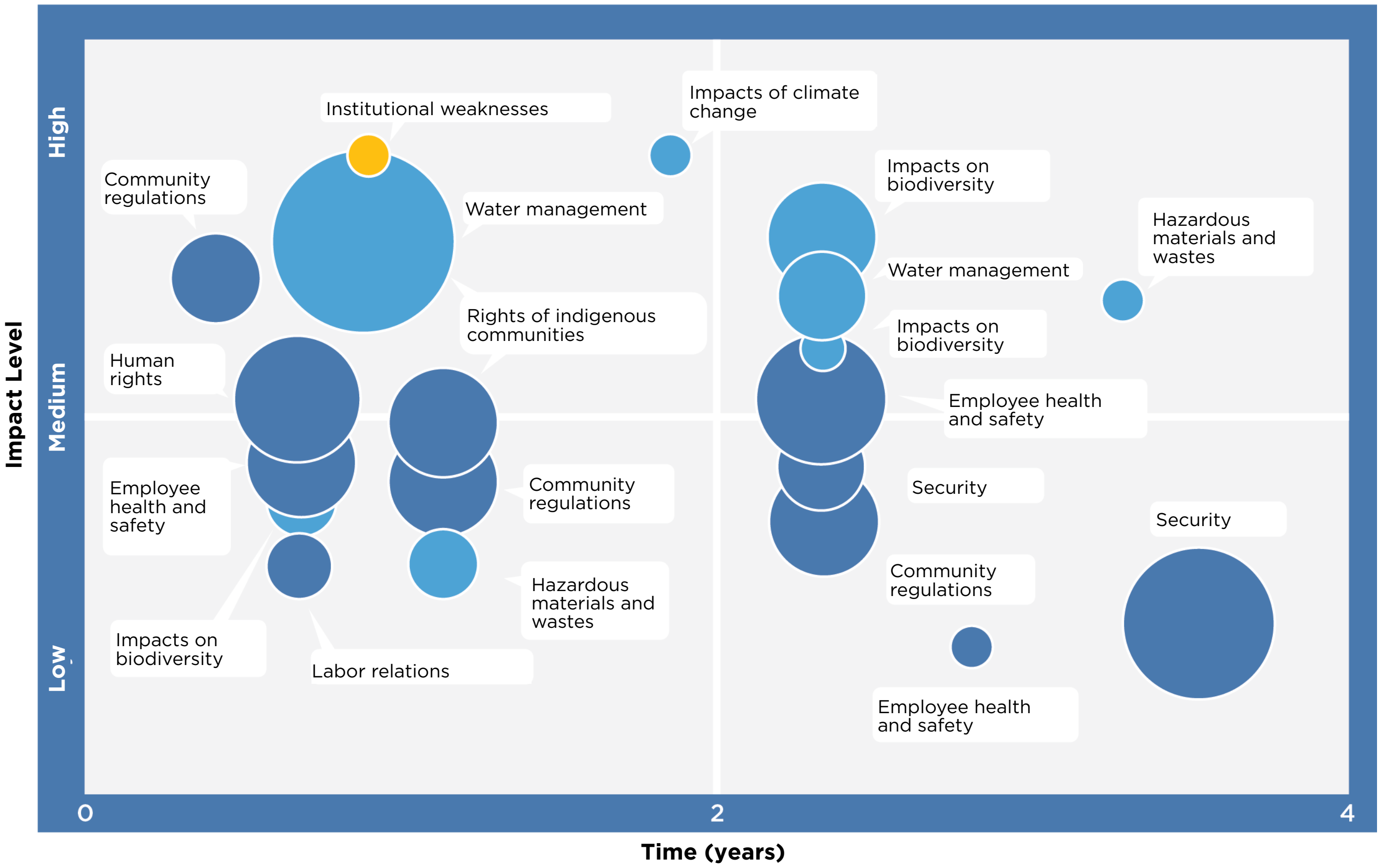
Table 3.4 - Most relevant opportunities by mineral from the online survey

Opportunities		Copper	Lithium	Manganese	Lead	Zinc
Environmental factors	Greenhouse gases (GHG)	✓	✓			
Environmental factors	Air quality					
Environmental factors	Water management	✓	✓		✓	✓
Environmental factors	Waste and hazardous material management		✓			
Environmental factors	Environmental impact and biodiversity					
Environmental factors	Energy management			✓		
Environmental factors	Physical impacts of climate change			✓		✓
Social factors	Employee health and safety conditions	✓	✓	✓	✓	✓
Social factors	Security					
Social factors	Human rights					
Social factors	Indigenous communities					✓
Social factors	Community relations		✓		✓	✓
Social factors	Labor relations					✓

3.2.2 Socio-environmental challenges (negative impacts) identified for LAC

The challenges most frequently mentioned by the people interviewed, considering the scenarios of low carbon emissions and, therefore, a growth in mineral production in the different countries, are presented in the map below; the size of the bubble represents the relevance in terms of level of impact and priority over time. The most relevant factors added by respondents are shown in yellow, environmental factors in green and social factors in blue.

Figure 3.2 - Heat map of challenges (negative impacts) of mining operations, considering low carbon scenarios



Comment: The environmental factors are displayed in green, the social factors in blue and the most relevant factors added by the interviewees in yellow
Source: Authors' own elaboration

Water management is identified as a high impact challenge in the short term, due to the large amount of water that is perceived to be used in mining operations. For example, the consumption used for lithium production operations, where the ratio is 500,000 gallons consumed per ton of lithium produced. In some areas, this high consumption has a great impact on local agriculture, modifying social processes by causing communities to obtain water or graze animals in different or more distant places than they are used to. This water challenge is also related to the release of chemicals through leaching or spills that harm communities and food sources.

Based on the above, it can be inferred that the challenges in water management are largely related to community relations issues, which, upon perceiving these changes and relating them to mining operations, generate social conflicts that jeopardize the continuity of operations and generate reputational damage.

In the area of **community relations,** there is a challenge that is becoming more and more relevant in mining operations. On the one hand, communities are exposed to more information on the potential impacts that mining operations can generate and, on the other hand, they have greater power to pressure companies to address socio-environmental issues. One of the key aspects mentioned was land use and land tenure, where concessions granted to mining projects are often perceived as an invasion and threat to their territories, which has been the cause of protests and conflicts with mining operations due to threats to the human rights of the surrounding populations, including indigenous peoples and peasants.

The above highlights the challenge for mining companies in obtaining **social license** in the areas where they start from explorations to operations, to ensure a favorable social environment, as well as to achieve a shared vision of the territory, since, in areas with mining activities, in many cases, communities do not have direct benefits from mining revenues or have limited access to the State, which generates pressures from communities on mining companies to obtain compensation (ECLAC, 2019). Mechanisms that have historically yielded positive results include ongoing, inclusive and transparent dialogue processes with communities. Likewise, the issue of community relations is linked to the challenge of **human rights** violations due to the hiring of private security, use of government security forces and, in some cases, paramilitary forces that attack the population without due diligence processes.

Some interviewees mentioned as a recurring theme the **institutional weaknesses** in their countries to i) promote community relations, through adequate social impact assessment processes, public consultation and transparency in mining concessions; and ii) demand compliance with socio-environmental regulations from small and medium scale mining companies. This issue is relevant, for instance, in Bolivia, due to the informal

conditions of small and medium-sized mining cooperatives, which cover most of the country's mining operations; they also face fewer requirements in terms of compliance with mining, environmental and social impact regulations. In the case of Mexico, corruption at the local level was mentioned, which requires internal training to identify early signs of corruption, to have mechanisms in place to prevent it from occurring and to create whistle-blowing mechanisms. For Brazil, on the contrary, a perception of environmental over-regulation was mentioned, where the problem is due to the lack of adequate supervision. In addition, the people interviewed mentioned that organized crime and security is the challenge with the greatest impact on any mining operation, in relation to institutional weaknesses.

The adoption of GHG reduction strategies by investor guidelines is mentioned as a high impact challenge and in the short term because the mining sector is estimated to be responsible for 4 to 7% of global emissions (Delevingne et al, 2020). These emissions can be direct or indirect, i.e., they come directly from the fossil fuels (mostly diesel) used in operations or from the energy consumed for their activities. In addition, drilling and blasting operations required for mining also emit CO^2.

From the information provided by the experts, we deduce that zinc and lead do not have much opportunity to reduce their GHG impact, naturally related to energy management. While the minerals with the greatest opportunities are copper and lithium, these opportunities are focused on changes in the transportation of cargo and transport of minerals and fuels for the machinery used in the operations. Experts mentioned the best practices of implementing combustion filters for all vehicles used in mining operations or switching to electric vehicles, as one mining company in Peru has considered for the transportation of its workers. In the case of copper, one opportunity identified to reduce the GHG impact of the operation is to improve the processes in mills, crushers and crushers, and ventilation.

To date, investors have been the most active in knowing where they have their capital and, according to those interviewed, they are the ones moving the mining industry towards sustainability, recognizing that the risks associated with not considering sustainability aspects are very high[17]. Interviewees highlight examples of global tailings storage and management standards and investor agreements. (More information on the adoption of corporate strategies is discussed in the next chapter).

[17] (Delevingne et al, 2020) also agrees that several large mining companies have installed their own sustainability committees, indicating that mining is joining the wave of corporate sustainability reporting and activity. He mentions that reporting emissions and understanding decarbonization pathways are the first steps in setting targets and taking action.

The rights of indigenous communities are particularly addressed because of their status as specific subjects of law; however, one of the main challenges is the difference in definitions between countries. In Mexico, *indigenous peoples* are defined as "those who descend from populations that inhabited the current territory of the country at the beginning of colonization and who preserve their own social, economic, cultural and political institutions or part of them" and indigenous communities as "those that form a social, economic and cultural unit, settled in a territory and that recognize their own authorities, in accordance with their customs and traditions". In Peru, the Public Consultation Law defines them as "those who recognize themselves as such, maintain their own culture, are in possession of an area of land, and form part of the Peruvian State in accordance with the Constitution. These include indigenous peoples in isolation or in a situation of initial contact".

In Mexico and Peru and other Latin American countries, legal battles have been waged in order to obtain injunctions against mining concessions claiming that the State transgresses ancestral territories under the protection of these definitions (Villegas, 2016). The people interviewed mentioned that real costs to cover social considerations should be included in the feasibility budgets for operations; for example, social impact studies and costs associated with improving the perception and relationship with the communities, which are evaluated through the Social Investment Plan. It should be noted that, in some countries, this Social Investment Plan is part of the local environmental processing.

Occupational health and safety. The relevance of this challenge is high because when there is no adequate management, the life and safety of employees in their professional work is put at risk and it can also have direct impacts on biodiversity. One of the examples most commented on by the people interviewed was the breach of the Corrego do Feijão tailings dam in Brazil of the mining company Vale S.A., in 2019 (section 4.3.1), with human and environmental consequences. The alternatives mentioned to minimize the risks that mining operations face range from increasing information to employees to understand the risks to which they are exposed, making use of policies against alcohol and drug abuse through spontaneous testing, and inclusive education programs, to the introduction of labor and environmental safety standards for the entire production process, certified and recognized with national and international distinctions.

Environmental and biodiversity impacts. They are considered challenges with different levels of impact in the short and medium term, as they can affect biodiversity and cause environmental impacts throughout the life cycle of a project, both directly and indirectly. In general, direct impacts are more easily identifiable and can include land clearing activities, opening of open-pit operations, direct discharges into bodies of water. In the

case of indirect impacts, these can result from environmental or social changes induced by mining operations (International Council on Mining and Metals, 2017). For example, infrastructure development associated with mining may attract human populations and cause new threats or exacerbate pre-existing threats, such as overexploitation (e.g., hunting, fishing), invasive species, and loss of habitat for other land uses. Cumulative impacts occur when multiple mines cause more biodiversity loss than the sum of individual mines.

Labor relations, although considered a low-impact challenge, are mentioned as a priority issue by the people interviewed. The main challenge lies in the fact that in LAC countries there have been social and labor movements involving mining company workers that have led to the formation of organized labor unions recognized by national legislation. Relations with labor unions are especially important to listen to and address workers' concerns and maintaining an open channel of dialogue is vital to avoid precarious labor relations, which, as mentioned, are a problem throughout the LAC region. This issue is especially important in the transition to formality of small and medium-sized mining cooperatives, since some legislations protect the right to union association and collective bargaining.

Finally, for the issue of **mining regulation,** as a challenge, the disparity in which regulations are applied in small and medium-sized operations (cooperatives) and the operations of large mining companies is observed. In the case of countries such as Brazil, according to those interviewed, the main issue is not the lack of regulation, but the fact that it cannot be applied to the ever-growing illegal mining sector. In the case of Mexico, it is mentioned that regulation is lax and there is a failure in supervision, which promotes cases of corruption. For countries such as Chile, it refers to the ability to comply with new regulations, for example, the recently discussed Glaciers Law, which aims to prohibit mining activity in areas surrounding glaciers, including permafrost and periglacial zones.

Finally, according to the results of the online survey, the most relevant challenges in the socio-environmental dimensions for minerals were identified in the scope of this study[18].

[18] Of the 33 people who answered the survey in Spanish and English, the section on opportunities and challenges was nourished by the responses of 19 people; the methodology to find the most relevant factors presented in the table was to choose the one with more than 50% of selection, only in the "Very relevant" category.

Table 3.5 - Most relevant challenges by mineral from the online survey

Challenges		Copper	Lithium	Manganese	Lead	Zinc
Environmental factors	Greenhouse gases (GHG)					
	Air quality					
	Water management	✓	✓		✓	✓
	Waste and hazardous material management		✓			
	Environmental impact and biodiversity			✓		
	Energy management	✓	✓			
	Physical impacts of climate change					
Social factors	Employee health and safety conditions	✓	✓	✓	✓	✓
	Security					
	Human rights					
	Indigenous communities					
	Community relations	✓	✓	✓	✓	✓
	Labor relations	✓	✓	✓	✓	✓

3.3 Maximizing opportunities and addressing challenges related to mining in a low carbon transition scenario

From the interviews and online surveys, it was confirmed that there are particularities depending on the mineral, the country where the mining operations are developed, and the size of the companies that carry out such operations. The following is a summary to be taken into account as a context for the adoption of policies and strategies.

Mineral: copper

Main producing countries in the scope of the project: Chile, Mexico, and Peru

Significant socio-environmental impacts identified by the people interviewed. Considered a non-ferrous base metal. In copper mining, the main production processes are classified as: open pit mine, subway mine, concentrator, smelter, refinery, LX-SX-EW leaching, and the services area (Comisión Chilena del Cobre, 2019).

GHG emissions. Since it is estimated that copper emits around 600 kg CO2 per ton of copper concentrate extracted and processed, it is one of the metals with the highest GHG emissions, as well as manganese and zinc (Norgate, 2010). Copper, of all metals, is also considered to have the highest aggregate potential for harm to human and environmental health (Nuss, 2014).

Water management: Chile is one of the countries with the largest investments in seawater desalination processes, making them a high impact factor related to energy management for extraction and pumping to operations.

Mineral: lithium

Main producing countries in the scope of the project: Argentina, Bolivia, and Chile

Significant socio-environmental impacts identified by the people interviewed. It is a metal that has served as an input for production processes and, for decades, has been in high demand for the manufacture of lithium-ion batteries. In countries such as Argentina and Chile, lithium is extracted through the evaporation of brine in free and confined aquifers containing this mineral, it may go through a chemical process of separation from other minerals and processes in drying plants, until it becomes a finished product (IDB, 2019).

Water management: The largest problem is water: approximately 500,000 gallons per ton of lithium. The release of chemicals through leaching, spills or atmospheric emissions can harm communities, ecosystems and food production. This issue is particularly significant for the markets of Argentina, Chile, and Bolivia, as they form the lithium triangle, where an increase in production would be expected in a low carbon scenario.

Environmental and biodiversity impacts. In the case of the area known as the lithium triangle, the impact of lithium extraction is known to inevitably damage the soil and pollute the air.

Institutional weaknesses. The specific case of Bolivia is highlighted, where an increase in production of around 800% was estimated, the social and environmental impact generated by the informal conditions of small and medium mining cooperatives, which cover most of the mining operations in the country, as well as the politicization of policy implementation. In the case of Mexico, social conflicts over lithium extraction are perceived to be influenced by political movements outside the control of mining companies' performance. In the case of Argentina, where the low emissions scenario is associated with a lithium growth of approximately 1100%, this mineral does not have the legal restrictions on ownership that it has in Chile and Bolivia, so the procedure for obtaining permits for exploration and exploitation does not vary greatly with respect to other minerals. It is important to note that in this country the mining property corresponds to each of the provinces. In this country there are no restrictions on the amount of water that companies can extract from the salt flat or the amount of lithium or brine they produce, so companies operating in this territory extract with virtually no restrictions (Jerez Henríquez, 2018).

Mineral: manganese

Main producing countries in the scope of the project: Brazil

Significant socio-environmental impacts identified by the people interviewed. The two most relevant impacts mentioned are:

Air quality. It is extracted in open pit mines, with documented consequences on the health of nearby communities (Duka et al., 2011). According to World Health Organization data, the daily intake of airborne Mn by the general population in areas without Mn-emitting industries is less than 2 μg/day. In areas with major smelting facilities, intake may increase to 4-6 μg/day, and in areas associated with ferro- or silico-manganese industries, it may be as high as 10 μg/day, with maximum values exceeding 200 μg/day. According to the people interviewed, these values have been little studied/measured in Latin America. From the surveys we were able to obtain two types of recommendations to take advantage of the opportunity to reduce negative air quality impacts: with technology and with measurement.

On the one hand, the technological management allows better operation of the blasting, transport, and smelting processes. Greater use of humidification is proposed to reduce negative impacts to air quality. It is also proposed to raise awareness of the mitigation potential by controlling the speed of the equipment in order to reduce the concentration of harmful gases. In addition, taxes should be inversely proportional to the age of the equipment, seeking a renewal of the technologies present in the mining industry in the short and medium term.

Environmental and biodiversity impacts: As a result, new mining operations are taking place mostly in the Amazon, far from population centers. Environmental impacts are the most relevant of attention for new manganese mining sites. They also face another problem: the high occurrence of illegal mining, due to the price of the mineral[19].

Mineral: lead

Main producing countries in the scope of the project: Bolivia, Peru, and Mexico

Significant socio-environmental impacts identified by the people interviewed. The most relevant impact mentioned, especially for the area of operation, are the institutional weaknesses, due to which mining companies face longer delays and increased costs in the development of socio-environmental baselines (processing).

Mineral: zinc

Main producing countries in the scope of the project: Bolivia, Peru, and Mexico

Notable socio-environmental impacts identified by the people interviewed: water management and climate change. Mining companies face water and climate-change adaptation issues in areas considered vulnerable to either drought or flooding. This issue is associated with community relations, as mining operations are perceived as direct competition for water consumption. This situation is particular to Peru and Mexico. There are also reports of contamination of aquifers in Brazil by deep subway extraction of zinc[20].

Derived from the factors identified in Table 3.6 and based on expert responses, the following is a synthesis of recommendations to take advantage of opportunities

[19] Illegal mining has also been identified in Peru, and is linked to three factors: (i) the sustained rise in the international price of the mineral, in this case gold, which made this activity increasingly attractive and profitable despite the open risk conditions generated by operating illegally; (ii) the lack of adequate employment, both in rural and urban areas, which causes part of the population to opt for an activity that generates significant income; and (iii) the institutional weakness of the State in its different instances, national and subnational, which translates into a limited capacity for control and oversight of the territories (Proética, 2019).
[20] Other studies suggest that zinc production is concentrated in areas where water stress is already high. Combined with climate change, this is estimated to worsen in the coming decades (Delevingne et al., 2020).

and address the socio-environmental challenges most perceived as relevant: **water management, employee health and safety, community relations, and labor.**

Table 3.6 - Recommendations for taking advantage of the opportunities and address the socio-environmental challenges most perceived as relevant

Recommendations for taking advantage of opportunities and address the socio-environmental challenges that are perceived to be most relevant	
Water management	• Monitoring and compliance with regulations in each country • Implementation of passive water treatment systems • Motivate and promote water reuse, recognizing innovative initiatives • Adequate watershed management, including stakeholder management and control of water supply according to the needs of the area • Include the installation of water treatment plants in sustainability and social investment plans • Promote technology replacement campaigns that disseminate its effects and the impact of technological innovation among industries
Employee health and safety conditions	• Turn occupational safety into safety, through management systems/ implementation of international standards • Implement "zero tolerance" policies and other efficient control measures in the long term. • Reinforce health and safety programs and management systems.
Community relations	• Generate approaches with the communities and the implementation of permanent discussion and listening forums to identify real activities that can be used by the community • Promote campaigns to include communities in the workforce, directly or indirectly • Implement good neighbor policy • Promote and guide teamwork with communities • Exchange experiences and provide friendly and useful technologies to the environment • Interact with communities from the exploration or early development stages of a mining area
Labor relations	• Assertive relations with trade union groups and fair wage policies • Continuous training programs to promote access to technologies • Implement labor conflict prevention policies. • Promote the updating and strengthen the supervision of regulations in each country. • Implement campaigns to improve the quality of life of employees and work environments • Implement permanent listening mechanisms

By identifying the socio-environmental factors most relevant to mining operations and the particularities of each mineral in different countries, it is difficult to find a single solution to maximize benefits and meet the challenges of burgeoning mining operations. The interrelationship between socio-environmental factors was highlighted in the narrative by all interviewees. This suggests it is necessary to analyze these factors not individually, but in their country context and in their relationships with other factors.

As mentioned in section 2, increased production of minerals such as copper and lithium will have a significant impact on the markets of Chile, Peru, and Mexico if the world seeks to achieve the 1.5°C scenario, which implies an evolution towards sustainable finance that guarantees capital flows to low carbon projects aligned with the 1.5°C science. This would mean an accelerated shift towards the adoption of new mechanisms such as initiatives, standards, and taxonomies that provide the tools and information necessary for banks, institutional investors (pension funds and insurers) and asset managers to have a clear direction on where and how capital flows should go in a low carbon economy. Although there is currently no global consensus on a conceptual framework for sustainable finance that defines, among other things, its taxonomy, standards, and verification and control mechanisms, an organic convergence toward the adoption of the ESG conceptual framework in the financial system, led by the EU Action Plan - Sustainable Finance[21], in particular the components of ESG reporting and *Supply Chain Due Diligence*, is beginning to be evidenced.

The potential implications of this market trend toward adopting socio-environmental standards for the mining sector in Latin America are: first, increased pressure to adopt socio-environmental standards from financial investors (international and local) toward mining companies and, at the same time, increased pressure from customers of mining companies who will demand products that meet specific socio-environmental criteria. Additionally, the adoption of ESG standards contributes to projects reducing operational shutdowns (specific examples in section 4.3.1) or increasing their challenges due to the lack of social and environmental licenses that result in strikes that negatively impact project cash flows and profitability. Adopting ESG standards in the LAC region would therefore help create more favorable market conditions to attract more investment to the region and, at the same time, enhance social benefits. However, in the interviews we found that the trend toward adopting ESG standards requires specific contextualization in the context of Latin America and the Caribbean (LAC). It has been seen that the way of understanding ESG is different in LAC than in other regions. In particular, there is a certain delay in implementing ESG standards in LAC compared to other regions such as North America, Europe and East Asia[22]. Market pressures from investors, clients,

[21] More information in the following link.
[22] More information in the following link.

and regulation toward adopting ESG best practices in LAC are lower relative to other regions. This may explain why they are understood differently and managed with less urgency.

That said, the 1.5°C scenario represents a major opportunity for Latin America (USD 50 billion annually by 2050) to supply the minerals needed for a low carbon economy, but it could anticipate new trends in socio-environmental requirements from customers and their investors who will demand sustainable products to gain a possible competitive advantage. The following section will explore different angles to accelerate the adoption of socio-environmental standards in mining companies in Latin America.

Beyond this area, there are other strategic measures that can be derived from the implementation of these standards, but which merit a study in their own right (and it is therefore recommended that their applicability and value to the industry be studied in more detail). These include:

- Promote the link between the mining industry and the mining equipment, technology and services innovation ecosystem (METS)[23]. The above in search of solutions to solve socio-environmental and productivity challenges, reduce maintenance costs, and increase mine life (Ruiz, 2018). As far as possible, integrate local domestic services and content into these solutions (ensuring that it is sufficiently competitive) (UNDP, 2018).

- Encourage the development and investment of associative infrastructure, allowing services to be provided more than one company and more than one mine. Associative infrastructure aims to reduce costs and environmental footprint by sharing common infrastructure, and is applicable for rail lines, hubs, power transmission line, roads, desalination plants, pipelines, and ports (CESCO and Spencer Stuart, 2018; IDB, 2020).

- To deepen the understanding of circular economy opportunities applicable to mining, starting with the type of infrastructure for metallurgical processing that will increase the recycling rate. This also involves promoting the use of resource labeling from recycling processes to allow comparison between the economic and environmental attributes of different products. Finally, keep in mind that market access for irreparable and non-recyclable products should be more strictly regulated (Rasiewicz et al., 2020). Notwithstanding the above, even with highly ambitious recycling rates, primary production will still be necessary to meet the demand for these minerals and provide a significant decarbonization scenario.

[23] The experience of BHP's Expande program stands out. It is worth highlighting BHP's experience in promoting programs such as Expande, which calls for innovation challenges to solve some of its main socio-environmental problems.

- Ensure a fiscal regime that, on the one hand, is stable over time (resulting in a predictable regulatory framework) and, on the other hand, is flexible in order to respond to the cyclical nature of the commodities and minerals market (UNDP, 2018; Smith and Davis, 2020).

- Consider that the adoption of corporate strategies through the implementation of ESG frameworks or adherence to sustainability initiatives is the option with the greatest growth potential for mining operations. These strategies, depending on the framework chosen, may include: i) taking advantage of new technologies to make better use of energy, reduce GHG emissions, and reduce pollutants. For example, through the supply of energy using renewable sources in mining projects; ii) strategies to combat deforestation that may be caused by a mining operation in a new and forested site, avoiding a loss in the natural capacity of the ecosystem to reduce CO2 emissions; iii) estimating a cost of GHG generated to measure and compare the impact of reducing emissions and participation objectives of mining companies in Latin American countries with emissions markets.

4. Recommendations and strategies to harness the advantages of growing demand for sustainable mining in the framework of a low carbon transition

Meeting the challenges of a low carbon transition implies a considerable increase in demand for critical minerals (section 2.3), in order to provide the technologies to limit the global temperature increase to 1.5°C. By 2050, LAC countries are expected to produce between 2% and 12% more minerals annually in the 1.5°C scenario compared to 2020. Within this scenario, the minerals that will benefit the most from growing demand will be copper and lithium; annual demand for copper is expected to more than double the current level, while demand for lithium will be more than ten times higher.

This increased demand entails a series of benefits for the region, such as higher revenues estimated at USD 50 billion, increased economic activity associated with jobs and accelerated demand for local services and technological capabilities. However, these benefits can only be reaped by LAC countries whose mining industries can provide a supply consistent with responsible sourcing (from a socio-environmental perspective) (section 3.2).

In particular, this is the expectation of the financial sector and clients of mining companies, which are imposing greater pressure to adopt socio-environmental standards. For example, there is beginning to be evidence of an organic convergence towards the adoption of the ESG conceptual framework in the financial system, led by

the EU Action Plan-Sustainable Finance[24], in particular the components of ESG reporting and supply chain due diligence.

There is a wide range of areas in which industry and public policy can collaborate to consolidate a mining production supply consistent with responsible sourcing. These are presented below[25]:

- **Institutional framework and mining development:** to generate a more solid sectoral institutional framework (ministries, services and public companies) by analyzing how each of the actors involved relate to each other. In this way, we will be able to better direct the efforts for sustainable development in the sector. Moreover, consider the management of information and improvement of transparency among each actor involved.

- **Citizen participation and territorial development:** promoting dialogue and joint development of productive activities. Deepen the understanding and learning from those experiences in which mining companies have shared part of the benefits with the local community, in order to strengthen the relationship with them and guarantee the social license[26]. It is essential to understand to what extent this does not imply a transactional company-community relationship, and to what extent it is actually achieved to address an efficient project development in the pre-investment stage and consistent with clear socio-environmental standards.

- **Indigenous peoples**: work together with local indigenous communities, identifying their rights and identity in accordance with their social, economic, cultural, and political institutions.

- **Associative infrastructure:** associative infrastructure aims to reduce costs and environmental footprint by sharing common infrastructure, and is applicable for rail lines, hubs, power transmission line, roads, desalination plants, pipelines, and ports (CESCO and Spencer Stuart, 2018). The aim is to promote the development and investment of associative infrastructure, allowing services to be provided to more than one company and more than one mine.

- **Labor relations and gender equity:** ensuring appropriate conditions to ensure health, occupational safety, gender equity and opportunities for occupational development.

- **Human capital and productivity:** to have the conditions to train and improve human capital so that it can participate in and take advantage of technological change.

[24] For more information visit the following link.
[25] Most of these areas are the bases from which some governments in the region are leading strategies to modernize their mining industries. This is the case of Chile, through its National Mining Policy to 2050.
[26] See, for example, Government of Australia, 2020, chapters 4, 5 and 6.

• **The value chain and innovation**: promoting the mining industry's link with the mining equipment, technology and services innovation ecosystem (METS)[27]. The above in the search for solutions to solve socio-environmental, productivity, maintenance cost reduction, and mine life extension challenges (Ruiz, 2018).

•**Taxation and public investment:** ensure a tax regime that, on the one hand, has a stable tax structure over time (resulting in a predictable regulatory framework) and, on the other hand, is flexible in order to respond to the cyclical nature of the commodities and minerals market (UNDP, 2018). It is essential that this revenue be directed to public investments that contribute to consolidating a competitive supply of minerals consistent with responsible sourcing.

•**Green mining:** developing a mining activity that prioritizes the efficient use of water resources and the minimization of mining environmental liabilities, as well as emissions management and biodiversity protection. In particular, it is important to deepen the understanding of circular economy opportunities applicable to mining, with the aim of reducing the extraction of new minerals. This involves a new type of metallurgical processing infrastructure to increase the recycling rate[28] , as well as promoting the use of resource labeling from recycling processes to allow comparison between the attributes of different products (Rasiewicz et al., 2020).

• **Small and medium mining:** Establish development policies especially oriented to assist small and medium mining in their productivity and sustainable development challenges.

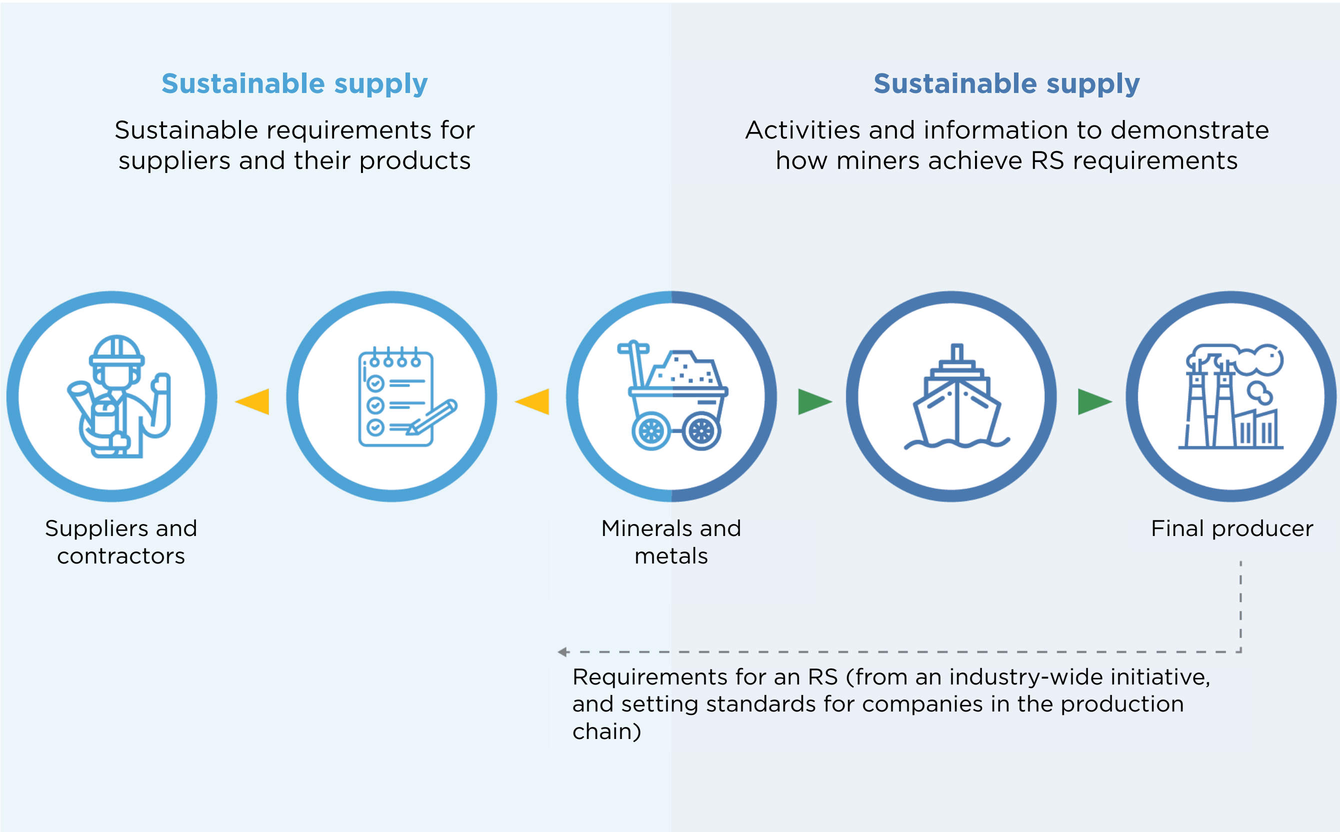
Importance of voluntary sustainability initiatives (VSI)

Voluntary sustainability initiatives (VSIs) contribute to responsible sourcing by complementing, aligning and, in some cases, reinforcing government regulations and increasing transparency in the mining sector. Several initiatives have emerged seeking to improve the social and environmental traceability of mining, which are having positive effects along the value chain. In this context, the emergence of voluntary sustainability initiatives (VSI)[29] has made a significant contribution to improving standards in mining companies and, in general, in the extractive industries[30]. These initiatives generally fall

[27] Highlights the experience of BHP's Expande program.
[28] Notwithstanding the above, even with highly ambitious recycling rates, primary production will still be necessary to meet the demand for these minerals and provide a significant decarbonization scenario.
[29] "These approaches range from offering guiding principles, due diligence templates, industry standards and standardized reporting practices" (Farooki, 2020, p. 3).
[30] The United Nations Forum for Sustainability Standards defines voluntary initiatives: "Voluntary sustainability standards are standards specifying requirements that producers, traders, manufacturers, retailers or service providers may be asked to meet, relating to a wide range of sustainability metrics, including respect for basic human rights, worker health and safety, environmental impacts, community relations, land-use planning and others". See more details in the following link .

under the definition of Responsible Sourcing (RS). RS does not have an internationally accepted definition, but can be understood as the management of sustainable development in the supply or procurement of a product (International Council on Mining & Metals, 2015b). Figure 4.1 depicts the scope of RS in the production chain in the mining industry considering: the supply of products and services for the mining industry (yellow arrows), the delivery of information by the mining company to the end customer certifying that the agreed standards are met (green arrows), and the interaction between end customers and the rest of the production chain in the demand for responsible standards (dotted gray arrow).

Figure 4.1 - Responsible sourcing throughout the chain of producing a product



Source: International Council on Mining & Metals, 2015

In order for mining in LAC to move toward a socio-environmentally sustainable supply, coordinated efforts are required among different stakeholders: public policies, the private sector, and civil society. Regulation, customers, and investors can positively influence the effective adoption of socio-environmental standards by mining companies.

- **Regulation:** refers to any administrative or normative requirement from local, regional, national or international sectorial institutions by which the mining company or its productive activities must be governed.

- **Customers:** any actor along the production chain that uses as input the material extracted, recycled or refined by the mining company until it reaches the final customer.
- **Investors:** stakeholders who have committed financial resources to mining projects or companies and, therefore, have a direct interest in the good performance of the business and the mitigation of risks associated with their activities, whether required by regulations, clients or the investor's own mandate.

These three actors, together with civil society, which is directly harmed by the socio-environmental externalities of mining, are depicted in Figure 4.2[31].

Figure 4.2 - Stakeholders relevant in implementing voluntary sustainability initiatives

Source: Authors' own elaboration

The improvement of the socio-environmental standards with which mining companies operate is governed by two levels: a minimum floor (local regulation), and a ceiling (alignment to voluntary standards). Both levels are presented in Figure 4.3, and are increasing the expectation of good socio-environmental practices for mining. Each of them is described below:

- **On the first level (minimum floor):** Governments are responsible for establishing regulations that combine economic development objectives with social promotion

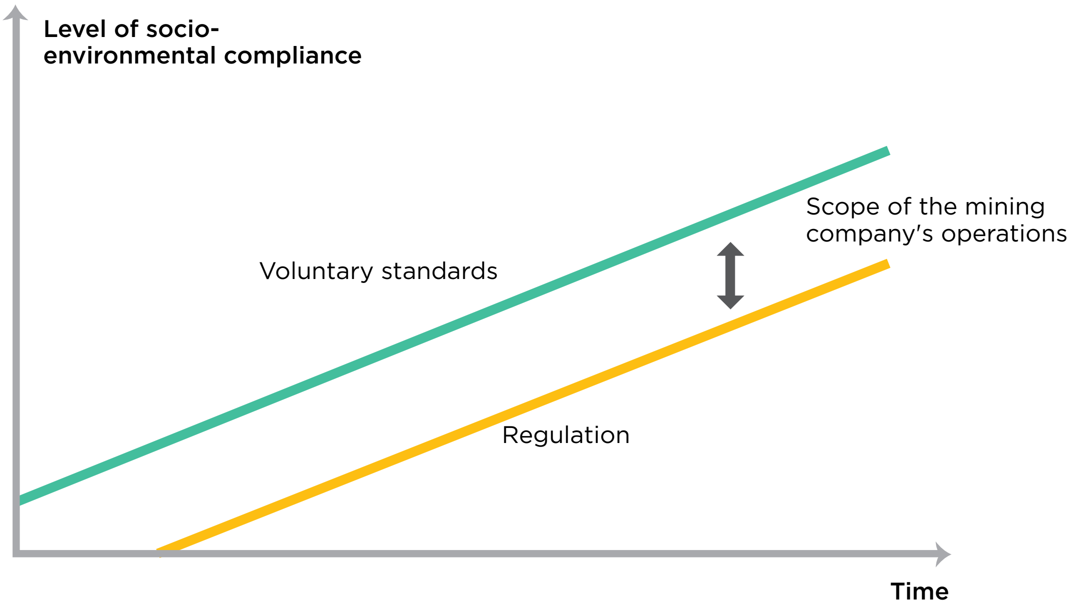
[31] The stakeholders that will be analyzed under the theoretical framework presented are highlighted in green and civil society, as a group affected by the negative externalities of mining, is highlighted in red.

and environmental protection. To this end, regulatory systems must be capable of influencing operations, which will occur to the extent that countries have strong institutions with adequate resources to implement and monitor regulations and, if circumstances so require, to oversee and sanction non-compliance. On the other hand, regulations will be distinguished according to how prescriptive they are, i.e., how precise are the indications as to how the desired level of compliance is to be achieved. It is important to note that international agreements such as conventions or free trade agreements, and therefore the expectations of relevant trade intermediaries, also influence the level of ambition of local regulation. Governments must work with the mining sector to make the application of sustainable practices the basis of operations, even beyond the requirements of Environmental Impact Assessment Systems. In addition, it is important that local regulation guarantees a robust and known *rule of law*, the absence of which could hinder project development[32].

- **On the second level (roof):** There are actors in the value chain, both upstream in project financing (investors) and downstream in the demand for materials (customers). Both can demand social and environmental performance from mining companies over and above local regulations, for which they have tools such as certified audits, traceability and contract compliance reporting in the supply chain. There is already evidence of interest in investment with socio-environmental criteria[33]. Mining projects often rely on international investment for exploration and development of operations. This strategic (upstream) position of financiers gives them a significant role in encouraging responsible mining practices that require compliance with certain environmental and social standards (German Environment Agency, 2020). This results in the risk classification to evaluate the financing[34]. On the other hand, mining customers (downstream) are subject to regulations in their home countries, voluntary commitments, and the scrutiny of their end customers, which obliges them to strengthen the traceability of responsible procurement systems. These types of initiatives are market-based instruments that seek to make socio-environmental aspects transparent throughout the supply chain and are therefore subject to market forces and preferences.

[32] For example, lithium, a very important element for the construction of batteries that would allow significant energy storage, has legal restrictions for its exploitation in Chile. See La Tercera newspaper, Pulso supplement (October 11, 2020) La oportunidad perdida del litio?, which indicates that, despite the availability of reserves in the country, production has dropped from 38% of the world's supply to 23% in four years. Available at the following link. It is also worth emphasizing the risks to project development that could be triggered by uncertainties caused by the regulatory framework (for instance, associated with discretion in the environmental assessment of projects).
[33] In 2019, global sustainable investments exceeded USD 30 billion, a 68% increase since 2014 and a tenfold increase since 2004, revealing that investors present a growing societal concern for the negative effects that human activity is having on the planet and people (Pennini, 2020).
[34] Over the next 15 years, more than $1 trillion will need to be invested in the metals needed for the energy transition and to meet the demand for decarbonization, which is almost double what has been invested over the past 15 years.

Figure 4.3 - Level of socio-environmental compliance



Source: Authors' own elaboration

The relationship between both requirements generates a virtuous circle in which regulation is updated and improved through the experience of voluntary standards, operating as a natural laboratory. In summary, both levels reveal the need for joint and coordinated work between the different stakeholders to ensure that mining becomes a full contributor to the economic, social and environmental development to which the inhabitants of the region aspire (Hund et al., 2020).

For the preparation of this chapter, we have used the literature available and conducted interviews with experts in mining activity, regulation and promotion of standards, whose vision has been complementary to the findings of the literature, particularly in relation to which are the drivers of behavioral changes in companies for the adoption of standards in socio-environmental matters. All experts consulted had access to the projections detailed in Chapter 2.

Different initiatives from both the industry and multilateral organizations have been deemed relevant references for responsible development in the mining industry.

These include: the *Climate-Smart Mining initiative*[35] (from the World Bank); the principles established by the work *Mineral Resource Governance in the 21st Century*[36](from UNEP, which highlights the importance of having a social license to operate); as well as texts from the International Council on Mining and Metals (ICMM) and the Intergovernmental Forum on Mining, Minerals and Sustainable Development (IGF).

The recommendations in the following sections are limited to accelerating the adoption of standards and traceability schemes for responsible mining.

4.1 Public policy - regulation and promotion

4.1.1 Description of the measure and how it can have an impact on accelerating the effective adoption of socio-environmental management and reporting systems

The State plays an important role in ensuring that productive activities, particularly in the mining industry, improve their standards in social and environmental matters, among other things. This role is complementary to that played by other stakeholders, such as communities, civil society as a whole, investors, workers or the destination markets of the products.

In a context of increasing demand for critical minerals for the transition to a low carbon economy, environmental assessment systems in LAC will face increased requests for project approval, and governments will have to respond to the growing demands of communities for respect for their livelihoods, including environmental protection. As presented in the introduction to the chapter, **voluntary standards are complementary to government regulations**. The latter set the **minimum requirements for the actions of companies, while the promotion of voluntary standards complements regulatory efforts and, at the same time, serves as examples that lead to new regulations** and thus improve the environmental and social performance of mining companies, contributing to social welfare as a whole. In this sense, it is necessary to nurture this relationship by disseminating evidence of the positive impacts resulting from the adoption of responsible practices.

Since mining is an activity defined by well-defined projects, the gateway for most of the socio-environmental considerations is constituted by the Environmental

[35] For more information on this project, please click on the following link.
[36] Available at the following link.
[37] These are complemented by the institutional framework for environmental oversight and the environmental courts.

Impact Assessment Systems (SEIA)[37]. In these, projects are subject to scrutiny by the government as a whole (not by a single sector) and are checked for compliance with current regulations on various matters, including significant community effects and environmental impacts. In the latter case, the resolutions approving the projects establish risk management, adaptation, mitigation, compensation and recovery measures[38] associated with well-defined impacts related to water, air, soil, waste management, and impacts on biodiversity, among the most significant. In the social case, measures related to impacts on traditional ways of life, modification of social systems, cultural impacts, mobility and displacement of people or populations, etc., are established. The Environmental Impact Assessment Systems establish minimum standards that all projects must meet in relation to environmental and social impacts, but do not cover or satisfactorily mitigate all of them, nor do they take into account the synergistic effects that several different projects may have in a relatively restricted territory[39]. Evidence of this is the conflict that mining activity continues to show in the region and the opposition that many projects face from communities and civil society.

In fact, some important elements of the social sphere are not even covered by the SEIA[40] and must be referred to other regulatory systems. Such is the case of respect for human rights, which is based on countries' adherence to the United Nations Charter of Human Rights and its local application (United Nations, 1948), or due diligence standards.

In a similar vein, **international treaties establish minimum levels of requirements that governments translate into national legislation that can affect mining**. For instance the Aarhus Treaty in Europe defines rights of access to information, participation and environmental justice, establishing the basis on which adhering governments require agents to ensure compliance with the rights enshrined in the treaty. In the case of LAC, the Escazú Agreement is inspired by the Aarhus Treaty to define minimum standards of access rights in environmental matters[41]. These types of international instruments serve as major **enabling frameworks for the channeling of these sustainability standards within companies**, and pave the way for greater transparency of information in the hands of the private sector.

[38] See, for example, Reglamento del Sistema de Evaluación de Impacto Ambiental (Chile), DS. 40/2013; Title III, paragraph 2,°, article 18, subparagraph i) (Mitigation, Remediation and Compensation Measures Plan).
[39] See, for example, Hervé and Insunza, 2019, p. 5.
[40] This is because EIAs or EISs only evaluate the project's own impacts. Since the intervention will cause effects beyond these impacts, there are always unresolved elements. In cases of violation of human rights, there are elements that go beyond the scope of the project itself.
[41] At the time of writing this report, the Escazú Agreement had not yet entered into force, as only 9 of the 11 required ratifications had been received. Argentina ratified the agreement, but had not yet deposited the instrument at the United Nations. Mexico announced the ratification of the agreement on November 5, 2020.

Similarly, treaties associated with hazardous substances, such as Basel, Stockholm and Minamata[42] or free trade agreements, have effects on mining activity, although these effects take time to reach implementation[43]. In the case of Chile, these treaties have been important in capacity building, particularly in the management of hazardous substances and in the preparation of the mining site closure law[44].

In addition to regulation, companies can adopt voluntary standards in a number of areas, including social and environmental, over and above what is required by regulation. For their part, governments can play a positive role in promoting these voluntary standards, beyond the minimum legal requirements. However, it is recognized that the most important driver of long term behavioral change is regulation, i.e., the legal obligation for companies to comply with specific standards[45] Hofmann et al, 2018).

The complementarity between regulation and voluntary standards can be achieved in two main ways. On the one hand, where regulation is weak, voluntary schemes can fill regulatory gaps by improving the relationship between the company and the communities and making it easier to obtain a social license to operate. The example of multinational companies applying the standards of their home countries in jurisdictions with less demanding legislation is an example of this type of substitution. On the other hand, the implementation of voluntary standards has led to their subsequent adoption as legal requirements, improving local regulation, and leveling the playing field for all actors (not only companies that voluntarily adopt best practices and invest in community relations and environmental protection, but these become a compliance floor for all).
In this sense, voluntary standards serve as laboratories of best practices, where governments can observe the best experiences in order to formulate effective regulation.

In any case, governments should pay attention to the disparate reality of large companies in relation to small and medium-sized ones. The latter have difficulty in establishing more robust management systems and often find it difficult to make the transition to best practices. However, the lack of compliance with standards is not a problem exclusive to smaller companies, as evidenced by the examples of large companies that have not managed to transfer transparency practices, legal compliance beyond the minimum and respect for local cultures and practices to their organizational

[42] Treaty regulating the presence of Mercury in the environment. Among other provisions, it prohibits primary mercury mining.
[43] In many cases, these treaties establish general provisions that require the enactment of special laws at the national level for their implementation.
[44] Chilean Ministry of Mining, personal communication (November 2020). The Mining Site Closure Law, No. 20,551, was enacted in November 2011.
[45] This statement emerged from several interviews with experts in the mining sector and in the promotion of standards. Regulation is recognized as the irreplaceable framework from which to build performance systems with improved standards.

culture. These difficulties can be addressed by generating a clear diagnosis of the capabilities of local companies to cope with the demands of implementing voluntary standards.

For a reference case study to exemplify public policy, see Annex D1: Participatory Environmental Monitoring and Surveillance Committees in Peru.

4.1.2 Discussion and recommendations - Public policy

The regulation of mining activity requires a whole-of-government approach and not just one sector. The multiplicity of interests, factors, impacts (positive and negative) requires that several ministries and agencies be involved in the approval and monitoring of projects, to ensure compliance standards in social and environmental matters in line with the country's development objectives and to promote regulatory coherence (for example, so that the regulation of one sector does not go against the regulation of another).

The basis for compliance with standards will continue to be regulation. It is recognized that clear and stable regulation is the best instrument for attracting investment. Regulation must be sufficient, robust, and enforceable to ensure minimum standards, including in the case of small and medium-sized companies.

Admitting that regulations are not able to cover all the problems, complementarity with voluntary standards is not only desirable but necessary. This complementarity is achieved through a dialogue between governments, communities and companies (where other stakeholders may also be involved). Additionally, voluntary standards practice can be a vehicle for regulatory improvement efforts (Potts et al, 2018). Lastly, **over-regulation can be unfeasible**, **particularly if the country does not have the means to adequately monitor and control it**. Experience reveals that governments play an important role in promoting voluntary standards, even above the legal minimums. In this sense, there is still ample capacity for action by multilateral institutions to contribute to strengthening the institutional framework for social and environmental oversight by the State, generating capacities for effective monitoring systems (for instance, monitoring and oversight committees) and providing resources to strengthen monitoring and oversight systems.

In the same vein, and given the multiplicity of existing standards, governments can support their convergence in order to facilitate compliance and improve company performance[46]. They can support the generation of evidence on the impacts of the different schemes (if they effectively lead to social and environmental improvements

[46]In this regard, it is interesting to learn about the experience of Copper Mark in the case of copper mining, as an effort to unify standards and facilitate the task of compliance and reporting for companies.

in the mining industry considering that many of these schemes certify on prescriptive standards and do not measure results) and in improving transparency. To do so, they must cooperate with businesses and multilateral financial organizations (Mori Junior and Ali, 2016). In this regard, "governments can use voluntary standards as platforms for dialogue with industry members, (…) to build trust and act as tools to broaden support for policy initiatives on responsible business conduct". (Church, and Crawford, 2018).

Transparency, stakeholder participation, monitoring and evaluation mechanisms, interoperability, independent audits, sanctions for non-compliance, focus on local development, training and capacity building are cited as key attributes for standards (Mori Junior and Ali, 2016).

The strength of national institutions is a key element in implementing standards and their oversight (whether regulated or voluntary). The stronger the governments and institutions, the better the capacity to enforce regulations and promote good practices among companies. In terms of enforcement, there are graded approaches to the type of sanctions that governments can apply: reprimand, support to the company for compliance[47], monetary sanction, loss of license to operate. Since the aim of the policies is to adopt the best possible standards, the use of sanctions should be left as a last resort (necessary in severe or serious cases), ensuring that the systems lead to compliance. In a complementary sense, governments can analyze the convenience of granting financial assistance to smaller mining companies to improve their compliance with standards.

The reality of countries can be disparate in relation to the ability to regulate and enforce standards. Voluntary initiatives and international agreements can partly address situations where countries lack all the means to require high standard social and environmental practices, particularly when multinational companies bring the standards of their parent companies to the countries where they have significant operations, even in the absence of sufficient local regulation. The role of other stakeholders such as communities, civil society and the international press can play a decisive role in pressuring companies to comply with high social and environmental standards.

The case of the Participatory Environmental Monitoring and Surveillance Committees (CMVAP) is an example of how a non-binding initiative initiated in a tripartite effort (State, community and company) can lead to a binding regulation that improves the social and environmental standards with which companies, in this case mining companies, develop their activities. An important element is the participation of at least three relevant stakeholders for the establishment and consolidation of this initiative: the government, the communities and the companies. They may be joined by other institutions of civil society or academia.

[47] See, for example, (OECD, 2019, p. 47).

The CMVAPs have had a varied performance, from instances that have had little impact to some that have transcended the initial mandate, reaching achievements in favor of the community beyond mere monitoring. The difference in performance is mainly explained by the greater or lesser degree of involvement of local communities, the training of their members and their degree of formalization; and by the support of institutions with competencies in monitoring matters (Ménard, 2011, pp. 48, 49). To a lesser extent, financing problems and the communication strategy that the committees maintain with the community have an influence. Governments can support the management of the committees, as has been the case in some municipalities that have become directly involved in them or have made municipal infrastructure available to them. In the case of governments, agency support has been beneficial in the direct management of committees and has shown a real interest of the central government in their work (Ménard, 2011, pp. 32 and 33).

The fact that these committees have been successful in fulfilling their specific mission does not ensure the end of conflict in the mining sector. The limited nature of environmental monitoring mainly to variables defined in the environmental impact studies leaves many aspects of the company-community relationship out, where conflicts of great magnitude can occur—and have occurred—even after the enactment of the regulations on the committees.

In line with what was identified in Chapter 3, the high level of conflict experienced in LAC in relation to mining projects shows the urgent need to make progress in improving practices by companies and in protecting communities, particularly human rights defenders in environmental matters. The adoption of the Escazú agreement by some countries in the region entails a step forward in this regard, since the agreement recognizes the need to strengthen the rights of these stakeholders, particularly when it establishes that: "Each party shall take appropriate, effective and timely measures to prevent, investigate and punish attacks, threats or intimidation that environmental human rights defenders may suffer in the exercise of the rights covered by this agreement" (United Nations, 2018).

This indicates the need to continue with programs and initiatives that promote understanding between the parties, improve mutual trust and ensure the social protection of the communities and the environmental integrity of their territories (Table 3.6).

An effective improvement of standards will generate additional attractiveness for investments and a differentiating attribute for the target markets. For governments, promoting high-level performance in mining improves investment targets and results in benefits for communities and enhanced environmental protection. This means that high-performance mining sector, including medium and small companies, becomes an asset

for the country as a whole. Although most of the effort to improve performance will come from the companies themselves, governments must use the instruments at their disposal, whether regulatory or voluntary, to promote the continuous improvement of the industries operating in their territories, particularly mining companies.

In this line, the main recommendations to achieve the above are summarized:

1. To achieve an evolution in regulation in coherence with the lessons learned from the local implementation of voluntary standards by supporting the generation of evidence on the impacts of the different voluntary standards and on the improvement of transparency.

2. Develop a robust oversight capacity on the part of the State to ensure enforceable minimum standards, and the application of clear sanctions when necessary. This can be achieved by reinforcing the state's social and environmental oversight institutions, building capacity to empower affected parties/complainants to monitor, and providing resources to strengthen monitoring and surveillance systems, including new traceability solutions.

3. Promote the signing of international agreements that serve as enabling frameworks for greater transparency of information through instances where consensus is generated around these agreements and applied to improve the region's minimum socio-environmental standards.

4. Design regulations that consider the limitations of small and medium-sized companies through a clear diagnosis of the capacities of local companies to meet the demands of implementing voluntary standards and best socio-environmental practices.

4.2 Responsible commodities: downstream demand

4.2.1 Description of the measure and how it can have an impact on accelerating the adoption of socio-environmental management and reporting systems

At present, the scopes of responsibility are not limited only to the internal operation of a company, but also to practices carried out along the entire value chain of a product (Grimm et al, 2014); it is the companies further down the value chain that are most exposed to end customers. These companies are often in a position of power and

possess resources to establish sophisticated supply chain governance mechanisms (Hofmann et al, 2018). Thus, for example, Mitsubishi Materials integrated responsible procurement criteria into its corporate social responsibility policy in 2014, developing a framework for addressing issues linked to conflict minerals and educating its suppliers about internal corporate social responsibility policy[48].

Companies are motivated to source materials with a lower socio-environmental impact for two main reasons: to comply with local regulations and not to be exposed to public scrutiny. Buyers of minerals and metals are subject to a large number of laws in several of the countries in which they operate when acquiring these minerals, forcing them to raise the standards of their service and product suppliers[49]. On the other hand, the media, non-governmental organizations and international organizations have highlighted the importance of responsible sourcing, which puts at risk the competitiveness of those further down the production chain (and closer to the end customer), affecting the possibility of seeing their operations interrupted by citizen opposition or other organizations (RCS Global, n.d.).

In sectors such as the infrastructure, electronics and automotive industries, the challenge of assessing the provenance of materials used in the manufacture of their products has become established (International Council on Mining & Metals, 2015b). This discussion started based on conflict minerals or 3TG [50], but today it has moved on to other minerals (Farooki, 2020a) such as cobalt where practices that violate human rights have been uncovered[51] , and even other minerals such as copper or aluminum. By way of example, during 2017 Amnesty International analyzed the due diligence processes in the sourcing of minerals from conflict zones[52] by major electric car manufacturers. The report concluded that the measures taken by companies were not sufficient to ensure that their supply chain was free of conflicts against human rights (International Institute for Sustainable Development, 2018).

[48] Other interesting examples are Apple's commitment to transparency in socio-environmental aspects throughout its supply chains and to achieve 100% carbon neutrality by 2030; and the Drive Sustainability initiative, made up of 10 companies in the European automotive industry that seek to manage socio-environmental management throughout their value chain.
[49] An example of these are the Dodd Frank Act Section 1502 in the United States (for 3TG), the EU Conflict Minerals Legislation (for 3TG importers), the French Corporate Surveillance Act and the Modern Slavery Act in the United Kingdom (RCS Global Group, n.d.).
[50] Conflict minerals are those whose systematic exploitation and trade in a conflict context contribute to, benefit from or result in the materialization of serious human rights violations, violations of international humanitarian law or violations amounting to crimes under international law.
[51] For example, reports published by Amnesty International or The Washington Post that linked cobalt to child labor in Congo (Amnesty International, 2016) (Amnesty International, 2017) (Frankel, 2016).
[52] Conflict minerals are minerals whose systematic extraction and trade contribute to human rights violations in the country of extraction and surrounding areas.

This has triggered a discussion on how to clean up the supply chain associated with a product, and the term "responsible sourcing" (RS) has been coined to describe the efforts put into that line. The International Council on Mining and Metals (ICMM) states that there is no internationally accepted definition for RS, although some institutions have their own definitions, such as the International Chamber of Commerce, which defines RS as "a voluntary commitment by companies to take social and environmental considerations into account when managing their relationships with suppliers". On the other hand, the British Standards Institution (BSI) has developed a responsible sourcing industry certification scheme standard for construction products (BS 8902: 2009) which defines responsible sourcing as "the management of sustainable development in the supply or procurement of a product".

The above combines two important dimensions of RS: the first is the management of a company's internal business operations and the monitoring of supply chains. The second focuses on collecting data and information, monitoring conditions at the location/origin of minerals and documenting the process from source to smelter/fabrication (Farooki, 2020b). The RS consists of four levels of commitment for a company that has adopted this type of practice:

1. **Commitment:** the company recognizes and commits to respect the RS agenda, and commits to respect international conventions on RS.

2. **Strategy:** the company formulates operational and commercial strategy, with identified initiatives, to follow the principles it has signed up to.

3. **Implementation:** the company implements the identified initiatives. Several RS approaches directly address the implementation phase, providing due diligence measures, monitoring, and evaluation documents, reporting templates, etc.

4. **Reporting and auditing:** last stage for the adoption of RS practices. It considers company reporting, the use of a reporting template that adheres to a specific standard, and third-party auditing and certification.

RS is triggered by those who make up the end-user market in conjunction with other stakeholders such as non-governmental organizations (Susan van den Brink, 2019). RS provides assurance to stakeholders throughout the supply chain: manufacturers and retailers obtain information on a product's reliability and safety conditions, while consumers receive information on the sustainability efforts made during the product's life cycle. The process itself can be complex, involving a range of global stakeholders across supply chains and sectors (Intergovernmental Forum on Mining, Minerals, Metals and Sustainable Development, 2019).

As a consequence, various voluntary consumer standards and coalitions have emerged to ensure that the purchase of their materials has met high socio-environmental criteria, which has even given rise to concerns about the potential dilution of their effectiveness (GIZ, 2018). Today, it is estimated that there are over 160 voluntary standards focused on mining, which are in addition to government regulations applied to mining companies and consumers of materials (Dufey, 2020). This has given rise to the discussion of **how different standards can work together efficiently, without duplicating efforts and recognizing** each other (GIZ, 2018) independent of industry, value chain stakeholders, company size, etc[53]. For this it is important that there are instances where consensus can be generated among the different parties in order to recognize trends and synergies between different standards available in the market.

Today, companies downstream in the value chain are increasingly demanding more information from their suppliers in terms of provenance (mines of origin) and production methods (RCS Global Group, n.d.)**. To achieve robust traceability, monitoring and reporting systems are required throughout the value chain. This implies the coordination and harmonization of the market, from consumers around the variables and standards they will demand for their products, to suppliers and those who make up the value chain,** in order to be able to monitor and report these variables and adapt their production processes to meet the requirements of their customers.

In this regard, the potential of Blockchain technology in product traceability applications in the supply chain has been discussed given the security delivered by the technology. Along these lines, initiatives such as the *Responsible Sourcing Blockchain Network* have been developed to deliver monitoring services in the production chain of various products (RCS Global Group, n.d.), and guidelines on the use of Blockchain for traceability in supply chains (developed by the *Responsible Mining Initiative, RMI*) (Responsible Minerals Initiative, 2020). Other concrete actions that demand can take is to **fund third-party certification organizations,** thereby reducing upstream compliance costs for suppliers, while at the same time ensuring the reliability of certification.

With the differentiation of the origin of the different materials that make up the value chain, new spaces could open up for **stakeholders such as refiners or smelters that specialize in working with minerals of a responsible origin**. This would ensure that the materials used have not been mixed with materials from operations failing to meet minimum socio-environmental criteria. In order to encourage the generation of these businesses, it is necessary to **identify the companies that could offer these services in the medium and long term, and support them through the creation of funds and capacities** for the consolidation of this service.

[53] The above is encompassed in the term "interoperability", which is defined as: [...] the degree to which diverse systems, organizations and individuals can work together to achieve a common goal·

On the demand side, the greatest challenges faced consist of defining a consensus among all the stakeholders that make up the value chain (regardless of the risk or exposure in which they find themselves) about the data to be requested from their suppliers. This happens because downstream stakeholders in the value chain require information from refiners, traders or mining companies according to their own needs, which will be different from the information required by other buyers. As an example, the Responsible Jewelry Council, which was created in 2005 through the collaboration of 14 companies in the jewelry sector, developed a single standard for the jewelry market, which greatly facilitates the implementation of socio-environmental measures throughout the production chain. At present, this council has more than 1100 companies and has developed two standards: a code of practice and a voluntary Chain of Custody standard (Dufey, 2020).

On the supply side, there is also no industry-accepted standard for mineral control. In addition, specific technical barriers are identified for this sector associated with: data entry and management of each of the variables, transformation of paper-based processes to digital platforms, complex aggregation points (especially for mineral mixtures), high costs due to computer processing for data management and that the appropriate technologies to track the product are not properly developed[54]. In this sense, **the coordination and interoperability of standards is fundamental,** with which to promote learning between different standards and to direct efforts to establish certification tools and indicators together that can be applied to more than one standard (GIZ, 2018). To generate this, it is necessary to **promote the use of flexible standards that recognize the synergies that exist with other instruments** of "good practices", and to promote instances of discussion and the generation of agreements to converge in common agreements. and to **promote instances of discussion and the generation of agreements** to converge in common agreements.

It should be noted that responsible sourcing practices have been initiated as voluntary efforts by companies to comply with socio-environmental standards that are stricter than existing regulations and meet the requirements of end customers. Even so, these practices are increasingly moving closer toward becoming mandatory regulatory requirements such as *EU Conflict Minerals Regulation* and *London Metal Exchange Responsible Sourcing* requirements (Farooki, 2020).

[54] An example of this is The Copper Mark standard, which seeks to homologate different existing standards in order to reach a common floor in terms of responsible production.

4.2.2 Reference case study to exemplify measurement: Responsible supply chain of the London Metal Exchange (LME)

The London Metal Exchange (LME) is the world's largest trading platform for metals (mostly non-ferrous metals). During 2019, USD 13.5 billion was transacted, and to date it has 550 accredited deposits distributed in 34 international points to facilitate the physical transaction of minerals (London Metal Exchange, 2020).

During 2017, the LME surveyed 350 metals producers about the responsible sourcing standards to which they adhered in their production processes. This process came about after civil society campaigned for improved transparency requirements on mineral sourcing, in particular about child labor with cobalt from the Democratic Republic of Congo (Institute of Chartered Accountants in England and Wales, 2020).

In April 2019, the LME published a "Responsible Supply Chain Guidance" based on the OECD Due Diligence Guidance (OECD, 2016), being the first step to engage in Responsible Metal Sourcing. In implementing this initiative, the LME has stated that it expects that by 2024, all member brands will be compliant with the Responsible Supply Chain (London Metal Exchange, 2019a).
With this initiative, the LME ensures that any user purchasing metal from one of its warehouses will obtain a product that meets the LME's responsible sourcing criteria. For this purpose, companies wishing to trade products on the LME must have a "Red Flag Assessment" (RFA), which will allow them to prove that producers comply with minimum responsible sourcing criteria. In addition, production companies will be required to comply with ISO14001 and OHSAS 18001/ISO 45001 (or equivalent) standards to demonstrate that environmental and health management mechanisms are being implemented correctly.

The initiative also seeks to integrate small and artisanal mining companies in the process of transparency and management of their socio-environmental risks, meaning the LME has sought to avoid discriminatory criteria between large and small mining companies (London Metal Exchange, 2020). To this end, it seeks to provide a risk assessment model that is suitable for both types of producers, given that larger producers have greater legal and administrative resources. For this reason, the timeframe for small producers to adapt their processes was set at 2022 to commit to the different standards, and 2023 to comply with them (London Metal Exchange, 2020).

One of the main challenges has been to standardize the large number of existing standards in order to unify the same requirements when auditing a company participating in the LME. To this end, the LME has defined the objective it seeks in the socio-environmental practices of its participants, but has left to the discretion of the producers how to accredit these practices (which can be using standards, external auditors, etc.) The objective of this is to standardize the vast majority of existing standards, giving producers the flexibility to use the tools that best suit their context (depending on the size of the producer, social context, regulatory context, practices they are already using, etc.).

Producers (whether or not they display red flags) who wish to follow an industry standard can adopt an internal or external standard aligned with the OECD ("track A"). On the other hand, producers who do not identify red flags in their initial assessment can complete a standard LME RFA model form, which can then be externally audited ("track B") or reviewed and published by the LME ("track C") (London Metal Exchange, 2019b). This flexibility around compliance pathways will ensure that companies sourcing from conflict zones are not preemptively penalized because they are considered higher risk. However, regardless of the pathway selected, all producers will be required to carry out an alarm assessment, and to address any problems identified as a result.

Additionally, the LME has allocated an initial contribution of USD 2 billion, from fines levied on the LME market, to charitable initiatives in the responsible sourcing sector (London Metal Exchange, 2020).

At present, of the South American countries that trade on the LME, Chile has 13 companies approved to trade on this platform. Peru, on the other hand, has two companies that are approved to trade on the LME, while Brazil has only one company that trades on the London Metal Exchange (London Metal Exchange - Approved-brands, 2020).

The LME has stated that its role is to appropriately balance the different views of market stakeholders. In this sense, feedback from civil society organizations has been considered and, at the same time, the opinions of producers who have asked for more achievable deadlines to adapt their processes to these new requirements have been respected (LME, n.d.). This has helped to generate a consensus in the market, supporting the adoption of socio-environmental requirements by production companies, unifying criteria on the demand side and helping not to discriminate against the different market players in the process of implementing these practices[55].

[55] For a list of companies traded on the LME, click here.

4.2.3 Discussion and recommendations

Demand has been one of the main drivers for the development of standards and practices to "clean up" a mineral's production chain. In this process, it has been the stakeholders that are closer to the final customer who have pushed for the incorporation of better production practices by upstream stakeholders.
The implementation of this type of standards presents a series of **major challenges regarding the coordination of the value chain** in order to ensure that the necessary requirements are met by each of the stakeholders involved in the production process. To this end, it is important that **the standards used are in accordance with the capabilities of the extracting companies, considering that within this market there are smaller companies with more limited resources to implement these practices**.

On the other hand, it is important to establish clear objectives regarding the demands to be made on companies, and to allow flexible mechanisms so that they can comply with the requirements imposed. Each company responds to different internal processes and contexts, meaning the possibility of standardizing existing efforts, or those yet to be made, is important so as not to generate greater pressure and avoid duplication of efforts. In this sense, the voluntary program created by *The Copper Mark* or the adhesion system used by the LME allows the use of standard equivalencies that are aligned by the same objective. In addition, they are standards that operate in other activities within the value chain, so as to reach the end customer with better information.

In the case studied, it can be seen that addressing the challenges identified above is easier when there is an intermediary (in this case the LME), which is impartial and knows the reality of the parties (supply and demand). This allowed for greater coordination and agreement by all parties to become involved in a market that is more committed to socio-environmental issues.

In addition, it can be seen how demand can incorporate mechanisms to encourage the adoption of standards, such as the USD 2 billion LME fund for RS projects, or the incorporation of RS criteria in public procurement processes by the state or state-owned companies, which could help to generate a track record of the use of these practices in the region. To achieve this, it will be necessary to generate financial instruments to reduce price uncertainty in RS processes and to generate capacities at the level of state-owned companies for the implementation of these criteria. Other actions that could be taken are the contracting of external auditing entities that can serve as certifiers, which facilitates the transition process to the adoption of responsible practices.

It is worth noting the challenges this market will face in the future. At present, it has been sought that all participants in this market comply with a minimum of established

criteria. In the future, it will also be possible to compare the performance of different producers with respect to other criteria, such as, for example, commitments related to emissions management and process efficiency.

As a summary, from the information gathered it can be distinguished that the main recommendations in terms of demand are as follows:

1. Promote the **harmonization and interoperability** of current standards through agreement instances in mining clients for the convergence of standards.

2. Promote the implementation of reliable **monitoring, reporting and independent verification** systems along the entire production chain through financial support and capacity building for the adoption of standards and independent verification.

3. Generate a **precedent of "responsible sourcing"** in public procurement processes for products derived from mining by state-owned companies in the region. This can be achieved through the generation of financial instruments to reduce price uncertainty in responsible sourcing processes and the generation of capacities at the level of state-owned companies for the implementation of these responsible sourcing criteria.

4. Move towards **traceability in the origin of inputs** for refineries and smelters, so that in the long term they can focus exclusively on responsibly sourced minerals. This can be achieved by applying for international funds or generating demand-side funds for the adoption of standards by service providers. It is also crucial to identify companies that could take on this role in the medium and long term, and determine gaps to incorporate minerals with socio-environmental responsibility criteria and support the establishment of goals to move towards an exclusively responsible operation.

4.3 Corporate governance and the financial market: investor requirements

4.3.1 Description of the measure and how it can have an impact on accelerating the adoption of socio-environmental management and reporting systems

The high levels of emissions and socio-environmental externalities associated with the mining industry are increasingly high priority issues for investors (Sanderson and Hume, 2019). They are a key player in the promotion of sustainability criteria in mining through the requirements they can impose on the operations they finance, either by their mandate or by regulations that affect investors and are passed on to their clients.

In order for the sector to meet sustained demand for minerals and metals over time, it must be able to incorporate investor demands for proper management and reporting of socio-environmental challenges and opportunities (Responsible Mining Foundation and Columbia Center on Sustainable Development, 2020). This will allow us to move toward sustainable mining and anticipate the negative financial consequences of poor management of these dimensions.

For example, Newmont Mining[56] had to withdraw from its USD 5 billion "Conga" copper and gold project in Peru in 2016 due to civil society opposition. In Peru alone, it is estimated that between 2010 and 2014, USD 62 billion of the country's GDP was lost due to projects paralyzed by socio-environmental conflicts (Palomino et al, 2015).

Tahoe Resources[57] shares, on the other hand, were down 28% on the Toronto Stock Exchange and more than 33 % on the New York Stock Exchange in 2017, after in July of that year the Guatemalan Supreme Court suspended its operating license to "Escobal", the third largest silver mine in the world (Jamasmie, 2017). This suspension was due to the fact that the surrounding communities were not consulted in the project installation process.

As a last case, one has that after the tailings collapse in January 2019 in Brumadinho, which ended in 250 deaths, Vale suffered a USD 19 billion loss in market value in just one day, and as of October 2019, its share price still reflected a 26% annual devaluation (Laier, 2019).

The above cases suggest that sustainable development in the industry is imperative. The rise of investors demanding socio-environmental engagement beyond regulation is not simply an altruistic trend[58], although those companies that fail to demand it could face severe financial and reputational consequences (Deloitte Insights, 2020). **It is crucial for mining companies to manage the adverse socio-environmental effects associated with mining sites and the financial risk they may pose in** order to attract investors in the long term.

An increase in socio-environmental requirements, in addition to being fundamental in reducing investor risk, could result in increased competition among companies for financing. At this point, it will require companies to go beyond mandatory compliance with local regulation[59] and demonstrate to investors that they are adopting good practices under voluntary sustainability standards (Pennini, 2020).

[56] One of the world's largest gold miners and the only one currently maintained in the S&P 500 index, as of November 2020.
[57] It currently belongs to Pan American Silver, a company that acquired Tahoe Minerals in 2018.
[58] As of 2019, global investments with sustainability criteria reached USD 30 million billion, up 68% from 2014 and tenfold since 2004. (Pennini, 2020).
[59] Such as requirements for local environmental impact assessment systems.

To ensure the adoption of sustainability and responsible mining standards, investors can take concrete actions to mobilize the industry. Depending on the type of investor, different types of measures can be taken to effectively engage with mining companies and their corporate governance.

For example, shareholders can become more involved with corporate governance in order to persuade towards the adoption of responsible criteria and practices, and *proxy voting*, which corresponds to voting on shareholder meeting resolutions, and voting against proposals that do not meet investment expectations. Shareholders' and partners' resolutions also apply, corresponding to a request from a group of shareholders to the rest, in order to submit a proposal for the company to resolve certain environmental or social issues in a certain way.

On the other hand, institutions such as credit agencies could deliver a worse risk categorization for the company. The different groups of investors can take actions such as providing worse credit rates, voting against board members for failure to comply with socio-environmental and/or climate commitments, or even warning of the possibility of divestment in the company if the socio-environmental issues that mining companies are required to comply with are not managed.

In this sense, corporate governance in the mining sector plays a key role in the adoption of investment requirements and has a proactive role in the integration of socio-environmental criteria, leaving a clear vision of how the various challenges they face can be turned into opportunities (Berkouwer, 2020). For this commitment to be credible and accepted by investors, the standards must be adopted within the companies' business strategy and not as isolated events associated with an area of corporate social responsibility (Deloitte Insights, 2020).

Mining associations, in particular the International Council on Mining and Metals (ICMM), are taking the lead[60] in linking mining corporate governance with the integration of sustainability requirements for participation in its group of member companies. ICMM was the first industry body to commit to the United Nations Guiding Principles on Business and Human Rights in 2018 (International Council on Mining and Metals, 2018) and looks to its members to lead and be a role model for the rest of the industry. Within their requirements, they seek to maximize the benefits of mining and metals production for local communities and minimize negative impacts to effectively manage the socio-environmental challenges of mining (Pennini, 2020).

[60] ICMM represents 28 of the world's leading mining companies, which manage nearly 650 assets in more than 50 countries and account for almost half of the world's iron ore and copper production and a quarter of all mining products. In addition, they represent 36 regional and commodity associations.

The socio-environmental challenges associated with extractive sectors such as mining translate into **risks that investors must proactively manage through the governance of mining companies**. The high level of economic resources that must be mobilized for the sustained demand for metals involved in the transition to a low carbon economy places investors as one of the main actors in the responsibility of aligning their businesses with stricter socio-environmental requirements. This will allow them to reduce their investment risks and the harmful effects of mining operations on the environment and society.

It is worth mentioning an innovative mechanism in the United Kingdom, whereby individual investors buy shares in companies (with poor social and environmental practices) and transfer their shareholder power to an NGO (ShareAction in the UK) to represent them at the Annual General Meeting of Shareholders and thus exert pressure for the adoption of ESG standards. To the extent that the NGO groups more shares of individual investors, the more power they have at the Annual General Meeting of Shareholders.
ShareAction is a leading organization in giving a voice to those wishing to invest their securities as well as their assets. ShareAction seeks to leverage Shareholder Activism in order to accelerate the transition of companies to adopt ESG standards. ShareAction leverages its influence as shareholders at the Annual General Meeting of Shareholders, and its voting power as a mechanism to put ESG issues on the agenda in front of the company's board of directors.

As an example, ShareAction filed shareholder resolutions with BP and Shell in 2009, demanding that these companies stop investing in tar sands. Since then, Shell has sold all of its oil sands assets. ShareAction employs tactics supported by civil society and investment industry partners to drive climate ambition and action in large companies. These tactics include detailed analysis and research of these large companies' progress toward transitioning to a low carbon economy ,and then incorporating challenging questions at Annual General Meetings and tabling shareholder resolutions to encourage the adoption of ESG standards.

For reference case study to exemplify corporate governance see Annex D.2
Global Tailings Management Standard for the Mining Industry (PRI, UNEP FI, ICMM involvement)

4.3.2 Discussion and recommendations

Investors play a key role in contributing to the development of standards that reflect the sustainability performance expectations they have for their clients. The mining and tailings safety initiative for investors is an example of how different stakeholders in the

financial sector can coordinate around common goals and define actions to be taken in the event of non-compliance.

The experience of how investors have been actively involved in demanding the tailings management standard is a precedent for how they can address other socio-environmental challenges. For this, it is essential that they understand the challenges, opportunities and risks faced by the mining industry, and collaborate in initiatives that allow **to unify the criteria and requirements to be requested from companies.**

For example, there are initiatives such as the United Nations-Convened Net-Zero Asset Owner Alliance, corresponding to a group of 30 institutional investors with USD 5 billion under management[61] with a mandate to transition their investment portfolios to net-zero GHG emissions by 2050. They are committed to fulfilling this duty through comprehensive management of socio-environmental and governance challenges, through advocacy and intervention in the design of public policies and/or standards, and binding action with corporations and industries.

In addition, the role of investors in accelerating the adoption of sustainability practices in mining may be enhanced by future regulations for the financial sector that require them to exert influence on their investment niches or better assess and report on socio-environmental risks. An example of this is the UK's requirement for the financial sector, along with all other sectors of the economy, to disclose risks and challenges related to sustainability and climate change in line with the Task Force on Climate-related Financial Disclosures (TCFD)[62] in an action plan towards 2025 (HM Treasury, 2020). Efforts to standardize these socio-environmental metrics, specifically ESG, are also presented in the European Union's non-financial reporting regulation[63].

It is worth mentioning that in order to fulfill this role effectively, the involvement of the different types of investors must be proactive. However, shareholders tend to be "reactive", getting involved in socio-environmental issues when problems are already emerging and evident, rather than anticipating them. Other stakeholders with longer investment horizons, such as pension funds, although they have the interest and proactivity to manage these challenges, hardly have the capacity to address each type of challenge in a granular manner. In this sense, it will be necessary for investors' expectations to converge with the concrete actions they can take to engage mining companies in promoting sustainable mining.

[61] More information is available at the following link.
[62] While many investors have increasingly sought to integrate socio-environmental and governance criteria into their investment decisions, many often report that one of the biggest obstacles to these initiatives is the lack of consistent and reliable data to know where to target efforts and to measure, analyze and track progress. The TCFD was established to help address these issues in a systematized way (ESG Today, 2020).
[63] More information is available at the following link.

Based on the above, the proactivity of the corporate governance of mining companies in making transparent and disclosing their efforts in socio-environmental matters, adopting voluntary management initiatives on these challenges as part of the business, and actively participating in the creation of new standards or agreements on responsible practices at the corporate governance level will be highly relevant. Those companies managing to include socio-environmental criteria within their business models are the ones that will be most prepared to respond effectively to investors' expectations (Deloitte, 2020).

Whether or not they are driven by regulations that accelerate their actions, investors have the capacity for sustainability initiatives to permeate the myriad of socio-environmental challenges embedded in mining. Its role in binding mining companies can be carried out through collaboration with the drawing-up or promotion of standards, clarity in the demands on mining clients, and the definition of measures to be implemented as consequences if the requested socio-environmental criteria are not met. Therefore, to promote the adoption of standards, it is recommended to proactively engage investors to identify socio-environmental risks and adopt standards to mitigate them, through capacity building for investors so that they are aware of existing standards and market trends, in addition to promoting regulation of the financial sector around new requirements for the assessment and reporting of socio-environmental risks. At the same time, it is recommended that investors collaborate in the development and promotion of standards through dialogue and consensus building.

5. Conclusions and recommendations

The transition to a low carbon economy has a large economic potential for mining in LAC estimated at more than USD 50 billion annually by 2050 (equivalent to Uruguay's nominal GDP in 2020). It is suggested to adopt socio-environmental standards so that LAC can create the market conditions necessary to attract more investment and obtain the social and environmental license that will allow the region to capture the major benefits of increased demand for minerals. The adoption of ESG standards contributes to reducing the operational risk perceived by investors, paused or cancelled projects (section 4.3.1), strikes due to lack of social and environmental licenses that have negative outcomes for cash flows and project profitability. Additionally, in a 1.5-2.0°C scenario, traditional finance will evolve to sustainable finance where the adoption of ESG standards will be instrumental to ensure the flow of capital to sustainable projects. Although we believe that the global trend of ESG standards is lagging in LAC (section 3.3), there is still time to catch up.

In a 1.5°C scenario and a 2.0°C scenario, more energy will be produced from renewable sources such as wind and solar, while most vehicles run on electricity or green hydrogen. The electrification of the passenger vehicle fleet is much faster in the low carbon scenarios than in the reference case (3.0°C). These transitions also require extensive upgrades to power grids, particularly to improve energy storage and distribution infrastructure, as well as to expand electric vehicle charging infrastructure. Mineral demand is higher in the low carbon scenarios than in the reference case (3.0°C), and demand is significantly higher in the 1.5°C scenario than in the 2.0°C scenario. Copper and lithium are the minerals most likely to benefit from a low carbon transition. Global copper demand is expected to more than double from 2020 to 2050, when low carbon technologies will demand 32% of total copper. In the case of lithium, it is the mineral that exhibits the highest growth by 2050, with an increase of 1100%, reaching a total lithium demand of 1.1 Mt in 2050, which comes mainly from low carbon technologies (94%), highlighting that the different low carbon technologies require more metals relative to conventional technologies.

By 2050, the focal countries in this study will produce 990% more lithium, 74% more zinc, 54% more copper, 28% more manganese and 62% less lead in the 1.5°C scenario than in 2020. The differences between the decarbonization scenarios (1.5°C, 2.0°C and 3.0°C) are much smaller relative to the expected increase between 2020 and 2050. For example, between the 2°C and 1.5°C scenario, lithium increases by only 8%, while between 2020 and 2050 this increases by 990%. This highlights that reaching the decarbonization targets of the 2016 Paris Agreement (equivalent to a 4°C scenario) requires increasing global metal production significantly. Therefore, the great opportunity for LAC is real just by reaching the goals of the 2016 Paris agreement, which evolve to be more ambitious with the new trends of zero carbon by 2050.

Copper producers are most likely to benefit from more aggressive decarbonization in the 1.5°C scenario. By 2050, the focal countries will gain USD 50 billion per year from the production of key minerals, with USD 43 billion (86%) coming from copper where Chile and Peru have the greatest potential. The highest profit growth rate is in Argentina, with an annual growth rate of 5.2% due to the benefits of lithium and copper, foreseeing the opportunity for Argentina to benefit from the growth in the demand for metals.

To meet the goals of the Paris agreement, projected mineral consumption will need to increase significantly in the coming years. This, in a context where the mining industry faces socio-environmental pressure due to the impacts of mining and increasing scrutiny from demand and investors, which, combined with regulation, forces it to increase the pace of effective adoption of better socio-environmental standards in its production processes in order to participate in supplying that demand.

Cross-cutting country issues related to mining required for decarbonization include water management, employee health and safety conditions, labor relations and community relations. However, it should be noted that each mineral and each country has its own particularities.

The adoption of socio-environmental standards in mining companies in LAC promoted by public policy is identified as a good strategy that can be complemented with other alternatives that should be evaluated:

- Promote the link between the mining industry and the mining equipment, technology and services innovation ecosystem (METS)[64].

- Encourage the development and investment of associative infrastructure that allows providing services to more than one company and more than one mine.

[64] The experience of BHP's Expande program stands out.

- To deepen the understanding of the circular economy opportunities applicable to mining, starting with the type of infrastructure for metallurgical processing that allows increasing the recycling rate.

- Ensure a fiscal regime that, on the one hand, is stable over time (resulting in a predictable regulatory framework) and, on the other hand, is flexible in order to respond to the cyclical nature of the commodity and mineral market (UNDP, 2018; Smith and Davis, 2020).

- Consider that the adoption of corporate strategies through the implementation of ESG frameworks or adherence to sustainability initiatives is the option with the greatest growth potential for mining operations.

- Deepen the understanding and learning from those experiences where mining companies have shared part of the benefits with the local community, in order to strengthen the relationship with them and guarantee the social license[65].

We identify in this report that the biggest challenge is how the mining industry in LAC will accelerate the adoption and reporting of socio-environmental standards in order to maintain or increase its market share. If this does not occur, there is a risk that sources of capital and mining customers will divert their attention to other mining markets where there is perceived to be less risk. Actual adherence to these standards can be an opportunity to differentiate products in the global marketplace and can represent a desire to contribute to good corporate governance and sustainable development.

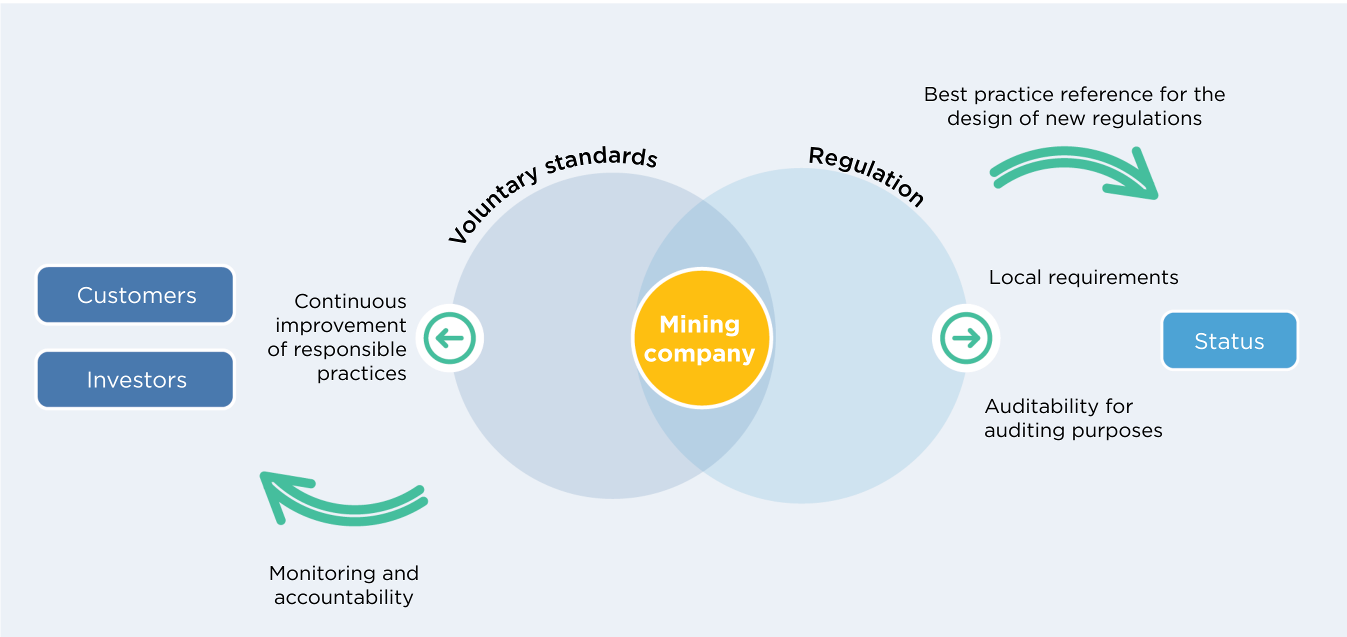
However, this situation could change under a different scenario in which major sources of capital and dominant clients neglect the socio-environmental attributes of mining, and do not allow the consolidation of a responsible value chain in the materials necessary for a low carbon transition. For example, in the face of a greater influence of national development banks of large emerging economies[66], without interest in the socio-environmental traceability of raw materials, or in intermediary clients who do not perceive the need for product differentiation on the part of more sophisticated end consumers, the above scenario could develop. Even so, the authors of this report consider this scenario unlikely, given the socio-environmental risks (greater conflict and environmental impact) that would end up restricting supply and increasing prices, making products developed under these criteria less competitive.

In the regulatory arena, an effective way to address the challenges and opportunities that open up in mining for a low carbon transition scenario is the adoption of both voluntary (arising from voluntary standards to which companies subscribe) and

[65] See, for example, Government of Australia, 2020, chapters 4, 5 and 6.
[66] For example, more interested in promoting national industries than in the socio-environmental traceability of the raw materials used by those industries.

mandatory (arising from regulation) responsible practices. In this regard, the laws governing the operation of mining facilities are framed in a virtuous circle together with voluntary standards, where the regulation defines a floor for the obligations to which mining operations must adhere, and the voluntary standards support the weaker edges of the regulation, playing the role of a natural laboratory for the implementation and subsequent enforcement of new, stricter regulations (see Figure 5 1). It has been observed that adherence to international treaties and exchange agreements favors the adoption of better performance standards, so it is recommended that governments support discussion forums on these agreements and, ideally, advance in the ratification and national implementation of these agreements. Accordingly, the "minimum floor" of local regulation is strengthened in coherence with the increase of the "ceiling" defined by voluntary standards, bearing in mind the industry's capacity to adopt best practices, promoting the **evolution of local regulation in coherence with the lessons learned from the local implementation of voluntary standards**. It is therefore recommended that **governments support the generation of evidence of the impacts that voluntary standards have on the practices of mining companies in improving their social and environmental performance.**

Figure 5.1 - Relationship between stakeholders and voluntary and mandatory production standards (regulation)



Source: Authors' own elaboration

Regarding the role of demand in articulating the value chain based on responsible sourcing (RS), manufacturers of low carbon transition technologies are closer to the end-customer, so they are exposed to greater market interest in making an AR-based product available. This makes them stakeholders with a fundamental role in **promoting the harmonization and interoperability of the large number of standards in force,** so that on the one hand they reflect the expectations of end customers, and on the other hand they encourage the adoption of these practices by the mining industry. To this end, it will be necessary to generate instances in accordance with the sectoral level, industry or demand segment, and promote the use of standards that facilitate the homologation of efforts already made within the companies, always considering the particularities of large companies in relation to medium and small ones.

These efforts need to be complemented by **investors who are in a position to have a proactive involvement in the corporate governance** of some mining companies, to make transparent and disclose their efforts in socio-environmental matters, actively participating in the creation of regulations and new standards. The use of Monitoring, Reporting and Verification (MRV) systems will also be important to differentiate the origin of a product, which could also **open spaces for new stakeholders such as refiners or smelters exclusively dedicated to minerals from a responsible origin,** who can **prove that their entire production complies with socio-environmental standards and has not been mixed with other materials from less rigorous operations** in their processes. For this purpose, it would be essential to identify the companies that could take on this role in the medium and long term, as well as the existing gaps for operating entirely with responsible products. In addition, these stakeholders may be motivated to apply for international funds or to generate new funds for the consolidation of this market/service.

Finally, the importance of establishing tools to encourage the adoption of socio-environmental practices and standards in all mining companies (regardless of their size) is emphasized. The implementation of monitoring, traceability and reporting systems requires significant resources and it is important to establish how these initiatives will be financed. In this sense, the State has an important role to play in providing incentives for the adoption of responsible practices, partially covering implementation costs and establishing spaces to showcase the industry's progress at the national and international level, including the use of innovative technologies that support monitoring, reporting and verification systems and compliance with standards.

Additionally, **an RS culture can be generated in public procurement processes for products or services by the State.** For its part, the demand side can also participate, for example, in the contracting of external auditing entities that can verify that the established criteria are being met, which lends credibility to the process and covers the verification costs associated with the implementation of responsible practices.

LAC is in a highly privileged position with its abundant mineral resources needed in a low carbon economy. Adopting best practices and socio-environmental standards will help realize social and economic benefits without compromising the environment. It also contributes to attract more investment by reducing the operational risk perceived by investors, reducing the risk of pauses or cancellation of projects by having the necessary social and environmental license to operate. It will depend on the correct articulation between government, mining companies, the financial sector and clients to create prosperity in the region by accelerating the adoption of ESG standards.

A. Detailed methodology

Demand-driven modeling

General Description

This section sets out the methodology for estimating low carbon demand scenarios for each of the five focus minerals (copper, lead, lithium, manganese, and zinc). The analysis consists of four steps, as illustrated in Figure 1:

1. Estimate the demand for energy technologies in the 3°C, 1.5°C and 2°C scenarios. This analysis uses the TIMES Integrated Assessment Model (TIAM) to estimate the change in demand for energy technologies in low carbon scenarios compared to the 3°C reference case.

5. Determine mineral intensities for energy technologies and select technologies. To convert the demand for energy technologies into corresponding demand figures for the focus minerals, the analysis uses the mineral intensities of those technologies. These are obtained from previous literature and analysis.

6. Estimate total mineral demand in 2030 and 2050. Using the results of the previous two steps, the analysis estimates the total demand for the focus minerals in the two scenarios in 2030 and 2050, by sector (such as power generation, passenger vehicles, freight vehicles, and stationary storage).

7. Estimate the demand for extracted minerals in 2030 and 2050. This step develops low, central and high recycling scenarios for each mineral to reflect the high level of uncertainty associated with the circular economy aspect. These recycled content estimates are applied to the total demand estimates to produce estimates of mined demand in 2030 and 2050 for each mineral of interest, by sector.

Figure 1 Summary of the demand modeling approach

1 Technology outputs	+	2 Mineral intensities	=	3 Mineral demand	→	4 Mined demand
Renewables capacity additions (GW)		Tonne per GW wind, solar, geothermal, etc.		Demand from renewables infrastructure		Recycling scenarios, reuse assumptions
CCS (GW and km pipe)		ton per GW and tonne per km pipe		Demand from CCS infrastructure		
Number of EVs		kg per EV		Demand from EVs		
Number of EV chargers		kg per charger		Demand form ICE vehicles		
Stationary battery storage capacity additions (GW)		ton per GW stationary battery storage		Demand from stationary battery storage		

Source: Vivid Economics

Estimated demand for energy technologies below the 1.5°C and 2.0°C pathways

TIAM Overview

The technological results of this analysis are generated using Imperial College's TIMES Integrated Assessment Model (TIAM). TIAM is a multi-regional, least-cost optimization model of the entire energy system. The model captures the entire energy chain from the extraction of fossil fuels from reserves to energy use in the demand sectors. There are five demand sectors: agriculture, commercial buildings, residential buildings, transportation, and industry. Within each of these demand sectors, energy demand is broken down into demand for different energy services such as heating and lighting in the residential sector, transportation kilometers in the transportation sector or tons of steel in industry. These can be supplied by different technologies, which in turn consume different fuels (such as coal, gas, biomass, and electricity). The model is divided into 15 regions, and allows trading of fuel and carbon permits between regions. The model can choose between different technological options to satisfy the given energy service demand. The objective function of the model is to minimize the total discounted energy system cost over the time horizon subject to a given climate constraint (e.g., a constraint on CO2 emissions or an exogenous carbon cost).

Energy system data such as technology costs, construction constraints, resource supply curves and annual resource availability are additional model inputs. The TIAM model used is the version of the ETSAP-TIAM model of the Grantham Institute of Imperial College London, which is developed and maintained by the Energy Technology Systems Analysis Program (ETSAP) of the International Energy Agency (IEA)[67.] The structure and functionality of ETSAP-TIAM is reported in peer-reviewed scientific journals (Loulou and Lambriet, 2007; Remme and Blesl, 2008). ETSAP-TIAM has been adopted and developed by several academic modeling groups around the world and is featured in a number of peer-reviewed intercomparison studies of mitigation models for stringent climate change targets, including the Stanford Energy Modeling Forum studies 22 and 27[68].

Temperature scenarios

This analysis includes two low carbon scenarios, a 1.5°C and a 2.0°C scenario, and an initial 3.0°C scenario. The temperature scenarios are characterized by carbon budgets. Carbon budgets define the amount of carbon that can be emitted into the atmosphere to limit global warming to a certain temperature with a certain probability. In each of its recent assessments and special reports on climate change, the IPCC has published estimated carbon budgets for staying below 1.5°C and 2°C warming with 50% and 66% probability. Here, the carbon budgets associated with staying below 1.5°C and 2°C warming with a 50% probability are used. Therefore, carbon budgets of approximately 1500 Gt CO_2 and 580 Gt CO_2 are used for the 2°C and 1.5°C scenarios, respectively (IPCC, 2018). The carbon budget of the reference scenario is about 3,300 Gt CO2 and assumes that the current NDC commitments are implemented.

Model output processing

TIAM production requires processing before we can use it to estimate mineral demand using mineral intensities. This is for three reasons:

1. **First, many TIAM outputs come in units that do not match the mineral intensities in the literature**. For example, transport productions are expressed in billions of kilometers per vehicle, while mineral intensities in the literature are given in kg of mineral per vehicle. To convert transportation outputs to units of millions of vehicles, this methodology uses average annual mileage figures from the literature for each vehicle type. Outputs in billions of vehicle kilometers are then divided by the assumed annual mileage to obtain units of millions of vehicles.

[67] For more information on the model, such as the technologies included, see the following link.
[68] ᵗSee EMF 22 and EMF 27.

2. Second, TIAM results do not consider the required replacement of technologies once they reach the end of their useful life. For example, TIAM indicates the amount of GW of onshore wind energy needed in each year to meet electricity demand in each region; however, it does not provide the total amount of capacity additions needed to meet existing demand and replace windmills that are retired that same year. The methodology uses lifetime therefore estimates for each technology from the literature and uses them to calculate the required replacements per year per technology.

3. Third, not all low carbon technologies of interest for this work are directly included in TIAM. This applies to fixed storage and electric vehicle chargers. To calculate stationary storage, this analysis is based on results from Carbon Tracker and the Grantham Institute, assuming that 0.25 GW of storage is required to support each GW of variable generation capacity (wind, solar and ocean) once the penetration of variable generation exceeds 20b% market share[69]. For electric vehicle chargers, the assumptions, based on data from IEA (2019), are that each personal electric vehicle is coupled with a private charger and a 0.1 public charger (IEA, 2019) and that approximately one-third of public chargers are fast chargers. According to data from Shenzhen, the first city to implement an all-electric bus fleet, each fast charger serves approximately 3 buses (Lin et al., 2019). Finally, using the European Automobile Manufacturers Association's projections of the number of charging stations and electric vehicles needed to meet the EU's heavy-duty vehicle CO_2 emissions standard in 2030, this analysis estimates that 1.45 fast chargers per truck (including public and private chargers) are needed (European Automobile Manufacturers Association, 2020).

Determining mineral intensities and technology coverage

Mineral intensities and total demand estimation

To estimate the total mineral demand for each of the selected technologies, this analysis applies the mineral intensities from the literature to the TIAM outputs processed. These mineral intensities are compiled from an extensive literature search covering academic articles, industry reports, and government publications. Some of these mineral intensities are taken directly from the literature, while others require conversions and scaling to suit the needs of this analysis. In particular, mineral intensities for automotive electric vehicles exist for all minerals, however, mineral intensities for all other types of electric vehicles (two- and three-wheel electric vehicles, bus electric vehicles, commercial truck electric vehicles, medium truck electric vehicles, heavy electric vehicles) in TIAM are not always available in the literature. When these data points are missing, the analysis scales the automobile EV (electric vehicle) estimates by the ratio of the weight of the other type of EV to the weight of the automobile EV.

[69] For more information visit the following link.

There are two factors that could affect mineral intensities over time: substitution by less mineral-intensive products and innovation. TIAM optimizes the use of technologies within a given carbon budget and cost pathway, which means that the scenarios we use already incorporate the former through differences in technology deployment. The latter, innovation in technologies, must be captured outside TIAM. This is captured by implementing dynamic market shares of battery technologies, as described below. The analysis assumes that all growth in stationary storage demand is met by chemical battery technologies. It should be noted that hydrogen and fuel cells are not major components of the scenarios considered here. While the scenarios rely to some extent on hydrogen in industry, it does not feature significantly in the decarbonization of the transportation sector due to relatively higher costs.

The mineral intensities of electric vehicles and stationary storage could change considerably over the next 30 years and the analysis reflects this through dynamic mineral intensities for these technologies. The mineral intensity of electric vehicles and stationary storage is highly dependent on the market shares of different battery biochemicals. There are likely to be major changes in these market shares. To account for this, the analysis draws on previous work by Vivid Economics that forecasted the market share of each of the major battery chemistries. These market share projections are combined with the mineral intensity of each battery chemistry (in tons of mineral per GW) to calculate a representative battery intensity for each mineral. Market share projections are estimated separately for electric vehicles and stationary storage batteries, so different representative intensities are calculated for these two battery applications. The representative EV battery chemistry is then multiplied by the assumed battery size per TIAM vehicle type to obtain a mineral intensity per vehicle. It is not necessary to convert the representative chemical composition of the stationary storage battery to new units, since the demand for stationary storage is given in units of GW.

Technology coverage

The technologies covered in this analysis are:

- Passenger and freight vehicles (EVs, BEVs, hydrogen, etc.): these are key determinants of battery demand, which are important for all focus minerals.

- Electric vehicle chargers (slow and fast chargers): these do not contribute significantly to focus mineral demand, but as they are important for the deployment of electric vehicles, these are included.

- CCS pipelines: source of copper and manganese demand.

- Power generation (wind, solar, nuclear, nuclear, hydro, etc.): these are important determinants of demand for copper, lead, manganese and zinc.

- Electricity transmission and distribution infrastructure: an important determinant of copper demand[70].

Estimated total mineral demand

The mineral intensities of different technologies are applied to the corresponding TIAM production over technology growth to estimate total mineral demand growth. This step calculates the total demand for the focus minerals by multiplying the TIAM outputs processed (e.g., GW of aggregate offshore wind capacity) with the mineral intensity of that technology (e.g., ~10,000 tons of copper/GW). The results are estimates of total global demand in 2030 and 2050, for the three scenarios (1.5°C, 2°C and 3°C) and broken down by sector (e.g., energy, passenger vehicles, freight vehicles, stationary storage and others).

Estimated demand for extracted minerals

To reach at an estimate of extracted mineral demand, this analysis subtracts the portion of demand satisfied by recycled content from the total estimated mineral demand, based on three recycling scenarios. It is important to evaluate mined demand under various recycling rate scenarios because the recycling rate could change significantly over the next 30 years, which could have a large impact on mined demand. We considered three future recycling scenarios to reflect that there are significant ranges in potential end-of-life recycling rates for each of the five focus minerals (Table 1). The first is a "low" scenario where recycling is assumed to remain constant at today's levels. The second is a "central" scenario in which the overall recycled content increases to be consistent with current EU end-of-life recycling rates, which tend to be high compared to the rest of the world (Mathieux et al., 2017). The third is a "high" recycling scenario where the overall recycled content increases to a level that is consistent with end-of-life recycling rates of 100%. See Box 1 for definitions of recycling rates used here.

[70] Electricity transmission and distribution (T&D) infrastructure will only be considered for copper demand due to the lack of mineral intensity estimates in the literature for manganese, zinc and lead (lithium is not used in any component of T&D infrastructure).

Table 1 Recycling scenarios by mineral

Mineral	Current recycling rate	Projected recycling rate in 2050 by scenario		
		Low	Central	High
Copper	35%	35%	55%	59%
Lead	54%	54%	75%	85%
Lithium	0%	0%	20%	39%
Manganese	12%	12%	37%	60%
Zinc	25%	25%	31%	60%

Note: For a definition of the initial recycling rate, see Box 1.
Source: Authors' own elaboration

Box 1: Recycling rate definitions

There are two recycling rates relevant to this study:

1. Initial recycling rate (also called recycled content [RC]). This rate is calculated from the amount of scrap metal recycled at end-of-life (EOL) divided by the total amount of metal produced. This is the rate we use in our analysis to indicate the amount of total mineral demand that is met by recycling.

2. End-of-life recycling rate (EOL-RR). This rate indicates the amount of metal recycled from EOL scrap divided by the amount of metal available for recycling (the total amount of EOL scrap).

For the mineral demand of batteries in stationary storage, the analysis also considers the market for second life batteries. When electric vehicle batteries reach the end of their useful life in the transportation sector, they are likely to continue to be used in the stationary storage sector, where battery specifications are less stringent. While this market for second-life batteries has not yet developed, this market is expected to grow significantly as the deployment of electric vehicles increases (Engel et al., 2019). To account for this expected change, this analysis assumes that reused batteries meet 50% of the demand for lithium, manganese, and copper from stationary storage by 2050, increasing linearly from the current market share of zero (Hund et al., 2020). This assumption is the same for all temperature and recycling scenarios. This analysis does not consider the impact of a second-life battery market to meet the demand for transportation storage, as there is currently little evidence that this can be done on a commercial level (Hund et al., 2020).

Considerations

This analysis does not consider the price effects of changing technology input costs. One factor that will contribute to the demand for energy technologies in the future is the cost of their basic inputs, which are likely to increase below the 1.5°C and 2°C scenarios. However, these price effects are not directly considered in this study. For some minerals, such as copper, it is reasonable to assume that demand for many energy technologies will not be significantly affected by increases in the price of copper, since this input tends to account for a small proportion of the total price. However, for other minerals such as lithium, battery demand could have a significant impact on the price of the mineral. This effect is partially explored through recycling scenarios. A higher price would be consistent with the high recycling scenario, as a high price would incentivize more collecting and innovation to improve lithium recycling. Higher recycling rates would lead to a reduction in demand for mined lithium. However, this does not seize the potential for a higher price to lead to the substitution of lithium for other minerals in batteries. To fully explore the effect of higher prices on demand would require constructing a long term demand curve for each mineral, which is beyond the scope of this study.

Supply-oriented modeling

The mineral supply model calculates the annual mineral production of Latin American countries required to meet global demand projections, as well as the resulting earnings. The analysis consists of four steps:

1. Estimate the future market share of each country producing a mineral. This step forecasts the future production of each country until 2050 based on historical production trends. Each country's share of the total production projection is used as our market share projection.

2. Calculate the implicit production for each country given the global demand in all demand scenarios if production were not constrained by resources ("unconstrained" scenario). This scenario does not limit the future production of countries by currently known resources. Each country's production is composed of its projected market share in Step (1), multiplied by the global demand under each temperature and recycling scenario, which are outputs of the demand model.

3. Calculate the implicit production for each country given the global demand in the demand scenarios if production were constrained by currently known resources ("constrained" scenario). In this scenario, countries gradually deplete their currently known resources through their production. It uses the market shares calculated in Step (1) to determine "unconstrained" production as in Step (3) above, but continually checks whether cumulative production implies that a country exhausts its currently known resources. If so, production drops to zero for that country. The "production gap" left by the depleted country is covered by other countries, in proportion to their market shares.

4. Estimate the producer surplus for the focal LAC countries. Producer surplus is a measure of the amount of monetary benefit a producer receives for supplying a given quantity of product. This involves projecting the price of each mineral and the likely profit margin for the producers of each mineral.

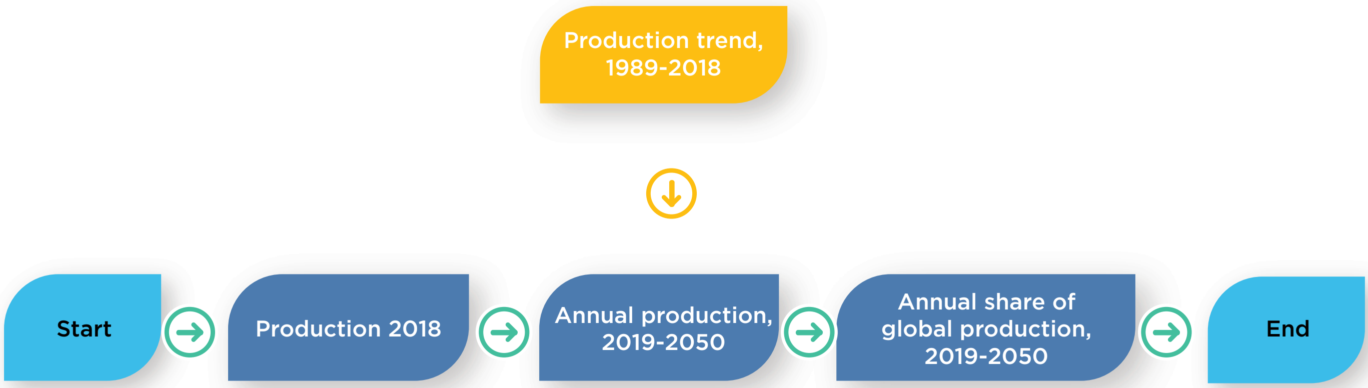
The remainder of this section sets out these steps in more detail.

Estimated future market shares

To obtain each country's future market share, the supply model projects each country's future production using historical trends and finds its share of total production. The first step is to calculate the trend in production growth using country-level data on production over the past 30 years. This includes all producers, not just producers in Latin America and the Caribbean. For each country, we used the historical production growth trend to estimate annual production through 2050. Finally, we express each country's projected production as a share of the total projected global production in that year to obtain the market share. The absolute production estimate from the market share calculation is not used in the following steps; it is only used here to determine future market shares.

The underlying assumption of this approach is that historical trends in countries' long term production patterns are likely to continue advancing. The market share projection does not reflect the historical market share trend, but rather the historical production trend. Countries have limited control over their own market share. As most countries have several producers of each mineral, there are likely to be many different priorities and challenges. In addition, a country's market share is determined by the production of all other producing countries, which the country is unlikely to be able to affect. In contrast, each producer has much more control over its own production, meaning the production figure is much more likely to reflect the unique objectives and challenges of each producing country than the market share.

Figure 2 Steps to calculate market shares for each country



Source: Vivid Economics

Mineral production

There are two scenarios for future mineral production, one in which production is not constrained by resources, and one in which a country that has exhausted its mineral resources stops producing. These approaches are based on two opposing theories in the academic literature: the "marginal cost" and "fixed shares" theories, respectively. The following sections detail these two scenarios and their academic basis.

Unrestricted supply scenario

In the unrestricted scenario, a country's annual production is equal to its market share of global demand in that year. This approach uses the market share determined as described in Section 0, and multiplies it by global demand in a given year to find each country's production. It does not compare a country's cumulative production with currently known resources.

The "marginal cost" theory is that the boundary between valuable rock (ore) and invaluable rock (waste rock) changes with commodity prices and production costs and, therefore, the amount of recoverable resource is not fixed. Consequently, research shows that resource estimates continually grow in response to demand and production. Looking at historical data, copper resources have consistently matched production growth in the past, implying that there are always more resources remaining than current estimates indicate. Companies do not delineate complete mineralized systems, but drill parts of them to bring them into production. They then use the revenues to drill more parts of the system over time, as well as to discover new deposits, increasing reserves and resources[71]. It is therefore unlikely that current resource estimates will be binding in the future. Rather than resource depletion, research in line with the "marginal cost" theory suggests that environmental, social and governance factors are likely to be the main source of risk in the supply of metals and minerals in the coming decades[72].

Restricted supply scenario

In the restricted scenario, a country that has exhausted its mineral resources will not be able to continue supplying that mineral. To implement this constraint, an iterative model is run through the following steps for each year, illustrated in Figure 3:

1. Calculate the theoretical production in each country by multiplying its share of global production and global demand.

2. Calculate the cumulative production of each country.
   a. If cumulative production exceeds resources, actual production is equal to the remaining resource in that year.
      i. Calculate the "output gap", defined as the difference between the country's theoretical and actual annual production.
   b. If cumulative production does not exceed resources, actual production equals theoretical production.
   c. If resource data are not available[73], it is assumed that both resources and actual production are equal to theoretical production. This means countries cannot increase production beyond the historical trend.

3. Determine the global output gap by summing the output gap in all countries.
   a. If the overall production gap is greater than zero, allocate the production gap to the remaining countries based on their market shares (excluding the country whose resources are depleted and countries where resource data are not available).
      i. Add the assigned gap to the theoretical output for these countries and repeat steps 1 to 3.

[71] See more details in the following link.
[72] See more details in the following link.
[73] Resource data are not available for some small producer countries.

4. If the overall output gap is zero, supply and demand are in equilibrium and the model stops.

The "fixed-stock" theory underlying this scenario is that the amount of recoverable resource is finite, and continued extraction will likely cause the world to experience increasing mineral scarcity over the next century. Since the formation of mineral deposits occurs on geological time scales that are much slower than the rate of resource extraction, this theory suggests that the world will eventually exhaust all available resources. Historical data show that world demand for minerals has steadily increased as more countries develop, especially for minerals such as copper, which are key to the industrialization process[74]. The theory suggests that all known resources will eventually become "stock-in-use" due to continued growth in demand and, as a result, almost complete recycling of metals will be required[75]. The "fixed stock" theory is often contrasted with the "marginal cost" theory, which has given rise to intense debate in the literature[76]. While the "fixed stock" theory largely ignores the influence of non-physical factors, it is still relevant as it emphasizes the resource limits faced by individual producers. This is especially useful for identifying countries with current production rates that may not be sustainable in the long term due to relatively small resources.

Choice of scenario

Although the constrained and unconstrained scenarios have theoretical support in the literature, the unconstrained scenario appears to produce more realistic estimates of future production. The constrained scenario essentially ignores exploration by assuming that resources do not increase over time. It also assumes that producers will maintain (and often increase) production rates until their resources are fully depleted, although production is likely to decline as resources are depleted. More importantly, the constrained scenario suggests that when producers have exhausted their resources, other producers can quickly increase production to fill the resulting production gap. This is unrealistic, given the lead times required to increase production from existing mines and develop new mines. Therefore, the final report presents the results of the supply model (production and producer surplus for LAC countries) for the unconstrained scenario, with the results of the constrained scenario provided as a sensitivity analysis.

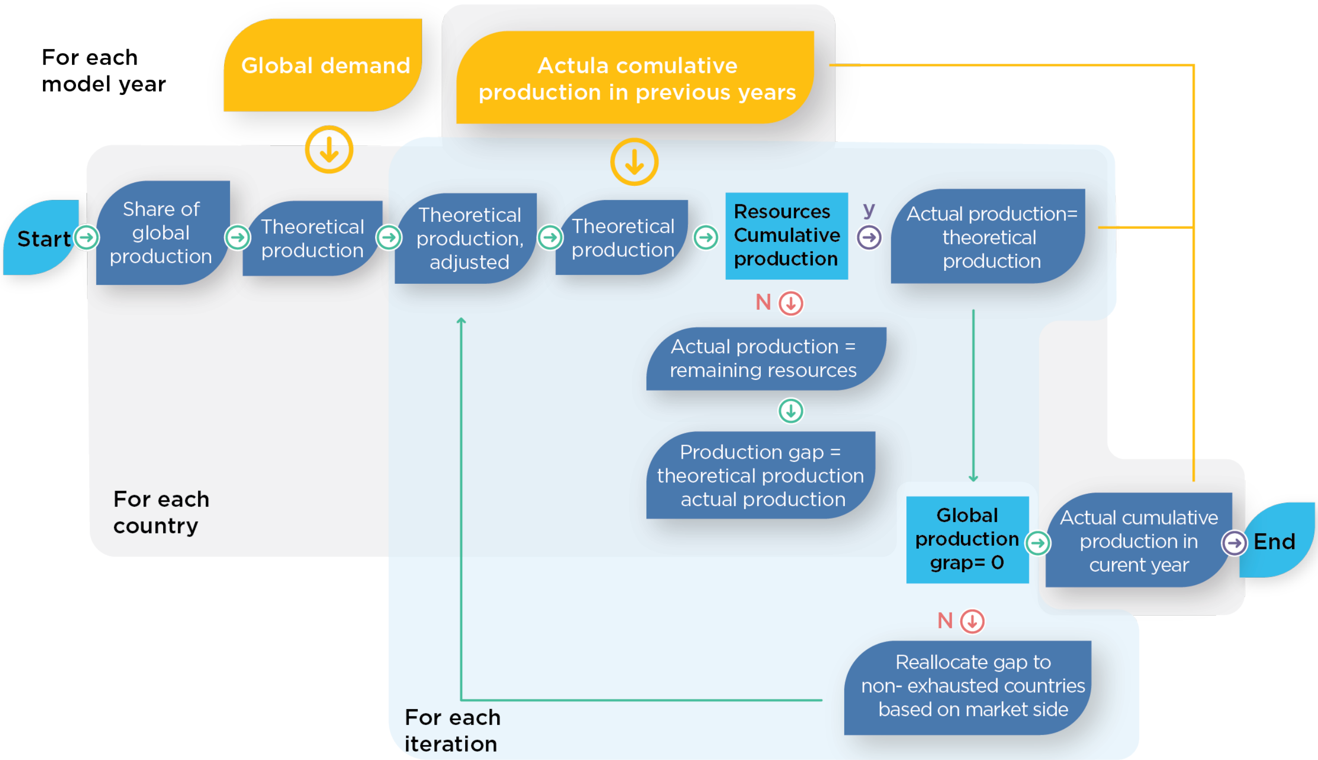
[74] See more details in the following link.
[75] This is a general implication of the theory, as the exact recycling rate will depend on the demand and availability of resources. Recycling rates are provided for the three recycling scenarios.
[76] See more details in the following link.

Choice of scenario by mineral

Mineral	Source	Alloy
Copper	Dicken, C.L., Dunlap, Pamela, Parks, H.L., Hammarstrom, J.M., and Zientek, M.L., 2016, *Spatial database for a global assessment of undiscovered copper resources*: U.S. Geological Survey Scientific Investigations Report 2010-5090-Z, 29 p., and GIS data	http://dx.doi.org/10.3133/sir20105090Z
Lead	Mudd, G. M., Jowitt, S. M., & Werner, T. T. (2017). *The world's lead-zinc mineral resources: Scarcity, data, issues and opportunities.* Ore Geology Reviews, 80, 1160-1190	https://doi.org/10.1016/j.oregeorev.2016.08.010
Lithium	U.S. Geological Survey, Mineral Commodity Summaries 2019	https://www.usgs.gov/centers/nmic/mineral-commodity-summaries
Manganese	Cannon, W.F., Kimball, B.E., and Corathers, L.A., 2017, *Manganese,* chapter L of: Schulz, K.J., DeYoung, J.H., Jr, Seal, R.R., II, and Bradley, D.C., eds,*Critical mineral resources of the United States-Economic and environmental geology and prospects for future supply*: U.S. Geological Survey Professional Paper 1802, p. L1–L28	https://doi.org/10.3133/pp1802L
Zinc	Mudd, G. M., Jowitt, S. M., & Werner, T. T. (2017). *The world's lead-zinc mineral resources: Scarcity, data, issues and opportunities.* Ore Geology Reviews, 80, 1160-1190	https://doi.org/10.1016/j.oregeorev.2016.08.010

Source: Vivid Economics

Figure 3 Steps to calculate the production of minerals in the limited supply scenario



Source: Vivid Economics

Earnings

Profit is the product of production, the mineral price and the expected profit margin for that Mineral. Profits are equivalent to the concept of producer surplus, which describes the benefits a producer derives from production. Therefore, it is equal to gross income minus direct production costs. In the case of miners, the cost of production is the "total cost of maintenance". This is the cost to miners of maintaining mineral production at the current rate.

Two assumptions underlie the calculation of producer surplus:

1. **There is no clear historical upward or downward trend in long term mineral prices.** A prevailing theory in the literature is that real commodity and metal prices fluctuate in so-called supercycles. Supercycles are long-period cycles that affect a wide range of industrial products and evidence of supercycles has been found for

several metals: copper, nickel, lead, zinc and aluminum[77]. However, it is unclear whether these supercycles are driven by supply or demand dynamics. Furthermore, there does not appear to be a general trend of commodity prices towards positive or negative directional price trends, but rather multiple examples of unexpected shapes, such as the shapes in U[78]. Consequently, this analysis is based on fixed real prices. Over the past 30 years, the prices of the minerals in this study have remained relatively constant. Lithium is the only exception, as prices have increased significantly over the last 10 years. This is consistent with a structural shift in market dynamics over the past two decades, arising largely from the growing demand for lithium batteries in consumer electronics and low carbon technologies[79]. In this report, 2020 prices are used for reported earnings.

2. The profit margin of Latin American producers is broadly consistent with the global average profit margin for each mineral. This assumption is based on the availability of high quality data on global sustained average S&P[80] mining margins. This is the profit margin when profit is measured as gross revenue minus all expenses necessary to sustain current mineral production (the all-in sustaining cost or AISC).

[77] See more details in the following link.
[78] See more details in the following link.
[79] Lithium demand growth rates will almost certainly continue to accelerate over time, as lithium is critical to low carbon technologies such as electric vehicles and stationary storage batteries. See for example the following World Bank (2020) and European Union (2013) Our forecasts indicate that by 2050, lithium demand will be approximately 10 times higher in the 1.5°C scenario than at baseline.
[80] See more details in the following link.

B. Limited supply sensitivity

To test the potential stress of future growth in demand for mineral resources, the analysis included a sensitivity analysis in which countries' production was constrained by currently known resources. This "resource-constrained" model assumes that countries' resources are fixed at their current level, assuming that no further mineral exploration will take place. The resource-constrained model calculates the cumulative production of all relevant countries in the world. This ensures that the model captures when one country exhausts its resources, and other countries need to increase production to cover the resulting shortfall.

The "unconstrained" approach that forms the core of the above supply-side analysis and this "constrained" sensitivity reflect two contrasting approaches in the literature. The "resource-constrained" model reflects the fixed-stock paradigm, while the "unconstrained" model used in previous sections reflects the marginal cost paradigm. The marginal cost paradigm proposes that the size of extractable resources depends on mineral prices. The cost of mineral production varies among producers, with the marginal producer having the highest production cost. When demand for minerals exceeds supply, the price will increase, which will in turn make the extraction of more expensive resources economically viable. The unconstrained model, used for the above results, reflects this. The fixed-stock paradigm suggests the resource base is fixed and can only be expanded by discovering new resources. The resource-constrained model was developed to implement this approach, assuming that current known resources are fixed. In reality, producers are looking to the future and will seek new resources before current deposits are depleted.

Although currently known global mineral resources are sufficient to meet demand through 2050 in the 1.5°C scenario, some countries' domestic resources would be depleted. This is especially true for countries with a large share of fast-growing mineral markets such as Australia, which would deplete its currently known lithium resources by 2035 under the 1.5°C scenario. In addition, global zinc demand in the 1.5°C scenario

exceeds the known zinc resources of all current zinc producers by the end of the 2040s. If no new resources are discovered in these countries, zinc production from known but previously untapped resources in territories such as Greenland is required to meet world demand. Although the depletion of zinc, lead, and lithium resources initially occurs mainly in countries outside LAC, in the constrained model this forces the focal countries to increase production to cover the resulting deficit, which in turn leads to the depletion of their own resources.

As a result, the resource-limited model suggests that known resources of zinc, lead and lithium in some focal countries are depleted before 2050 under the 1.5°C scenario. Known copper and manganese resources are sufficient to cover production until mid-century. Although lead demand will decrease over time as it is phased out, lead resources are still depleted in Bolivia by 2031 and in Peru by 2048. As explained above, the known zinc resources of current zinc producing countries are insufficient to meet global zinc demand by 2050. Among the countries of interest, zinc resources are depleted in Argentina by 2047, Bolivia by 2028, Brazil by 2042, Chile by 2041, Mexico by 2043 and Peru by 2038. Lithium resources will be depleted in Brazil by 2042 and in Chile by 2050. This is attributable to massive growth in global lithium demand between 2020 and 2050, which means that the resources of the world's two largest lithium producers (Australia and Canada) will be depleted by the end of the 2030s. Manganese resources are not exceeded in any focal country. This is probably explained by the fact that none of the countries of interest produce large quantities of manganese and that manganese resources are generally abundant worldwide.

The key reason for mineral resource depletion in the constrained scenario is the lack of resource growth, and therefore the scenario is unlikely to reflect actual physical scarcity until 2050. The constrained model holds the currently known mineral resources constant, assuming no further exploration. This affects minerals differently. Although copper is produced on much larger scales than any other mineral, copper resources will not be exceeded in any focal country. Counterintuitively, this is probably because the sheer scale of copper production nowadays means that copper mining is often a key sector of a country's economy. This gives producers the incentives and capital to invest in exploration, to secure a large copper resource and sustain production into the future. Since 1950, there have always been sufficient copper resources to maintain production for at least 200 years[80]. Compared to copper, lead and zinc are relatively less valuable minerals, which reduces incentives to invest in exploration. While lithium production is becoming increasingly lucrative, the rapid growth of the lithium market in recent years means that production is likely to exceed resources currently known by 2050. This is because current resources reflect historical exploration, which at the time may not have anticipated such a large magnitude of increases in future lithium demand. It is

[80] See more information in Copper Alliance.

also possible that the extraction of lithium from alternative sources, such as seawater, may become commercially viable in the future, which would dramatically increase the availability of lithium resources. Consequently, the constrained model does not necessarily reflect true physical scarcity, but rather the extent to which producers have engaged in exploration.

C. Interviews and surveys conducted

This study used the following inputs to obtain the views of different stakeholders involved in mining operations:

C.1 On-line questionnaire "Mineral projection scenarios"

This questionnaire was sent out to economists and professionals involved in mineral projection scenarios to capture the driving forces and obstacles to mining growth in each Latin American country relevant to this study. The survey was distributed using SurveyMonkey, targeting a specific distribution list. However, the responses obtained were considered anonymous.

The questions asked are presented below:

ImplementaSur CLIMATE ACTION   CARBON TRUST   :vivideconomics

Leveraging Growth in Minerals and Metals Demand from a Low Carbon Transition

Dear participant:

The organizations ImplementaSur, Vivid Economics and the Carbon Trust are working in consortium to develop a consultancy for the Inter-American Development Bank (IDB) on Latin America's supply projections of strategic minerals for technologies relevant to low carbon development. This includes an analysis of the potential economic, environmental, and social impacts associated with the production of the following minerals: copper, lithium, manganese, lead, and zinc, mainly in Argentina, Brazil, Chile, Bolivia, Peru, and Mexico, in the future.

The data provided in this form are anonymous; it will be treated with strict confidentiality and analyzed exclusively under the scope of this project.

1. Please choose those minerals in which, because of your background and field of activity, you believe you have the most relevant experience.

	Region
Copper	
Lithium	
Manganese	
Lead	
Zinc	
Other (specify mineral and region)	

Projections of supply and demand of selected minerals in LAC - 2030 and 2050 Scenarios

Below you will find questions related to mineral production and supply and demand scenarios in the following years

2. In a scenario of increased production, what do you expect to be the trend for each of the following minerals in selected Latin American countries over the next 10 years?

	Argentina	Brazil	Bolivia	Chile
Copper				
Lithium				
Manganese				
Lead				
Zinc				

3. With respect to the production trend of the minerals presented in the previous section, is there any mineral or country that you would like to highlight or detail?

4. What political, environmental, social, or technological factors would influence the potential for mining production to materialize in different countries/minerals?

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5. In a scenario of increasing production, what do you expect the trend for each of the following minerals in selected Latin American countries to be in a 30-year scenario (2050)?

	Argentina	Brazil	Bolivia	Chile
Copper				
Lithium				
Manganese				
Lead				
Zinc				

6. With respect to the production trend of the minerals presented in the previous section, is there any mineral or country that you would like to highlight or detail?

7. What political, environmental, social, or technological factors would influence the potential for mining production to materialize in different countries/minerals?

8. How do you think the production growth potential of the countries mentioned above compares to production outside of Latin America and the Caribbean? Why?

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9. According to S&P's analysis, global average margins for copper, lead and zinc are around 40% and for lithium around 50%. This is the profit margin when earnings are measured as gross revenue less all expenses necessary to sustain current mine production (ALL-in-sustaining-costs or AISC). What would be a reasonable estimate of the average profit margin of Latin American copper, lead, lithium, magnesium, and zinc producers?

	Average estimate
Copper	
Lithium	
Manganese	
Lead	
Zinc	

Do you have any particular comments regarding the overall average mineral margins?

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10. Do you consider that the profit margin would vary among the countries under study (Argentina, Brazil, Bolivia, Chile, Mexico, and Peru)? Why or why not?

- (●) Yes
- ( ) No

If you believe there is a difference in profit margins between these producing countries, in which countries would you expect the highest profitability and which would be the least profitable?

11. In the long term (up to 2050), what trend would you expect in the real world price (price excluding inflation) of copper, lead, lithium, magnesium, and zinc in a low carbon, below 1.5°C scenario?

	Trend
Copper	
Lithium	
Manganese	
Lead	
Zinc	

Please provide any comments on your assessment of price trends.

12. Finally, please support us in generating gender statistics.

- (●) Female
- ( ) Male
- ( ) I do not wish to share this information

C.2 Online questionnaire and interviews "Environmental and social opportunities and challenges of select metals in LAC countries".

The interviews conducted followed a standard structure that included a round of introductions of the meeting participants, a brief description of the project, the request for authorization to record the interview in order to support in the review of information, the base definitions of the study (what is understood by opportunities and challenges, as well as the socio-environmental factors used), a dynamic to validate and/or adapt the heat maps generated according to the growth projections in mineral production (dynamic conducted through the MURAL platform), and questions regarding the adoption of sustainability standards, the people interviewed are presented in the Case Studies section.

The online survey "Economic, Environmental and Social Opportunities and Challenges of Select Metals in LAC Countries" was developed in English and Spanish using SurveyMonkey and shared with a targeted mailing list. However, the responses obtained were considered anonymous.

In order to know the profile of the responses, the distribution list considered the following categories:

1. Mining companies – Sustainability or operations team participants.
2. Representatives of international associations involved in the development of sustainability standards and reporting of socio-environmental factors for the mining sector
3. Non-governmental organizations that monitor social and environmental issues related to the mining sector
4. Academia
5. Public sector
6. Other

The questions asked are presented below:

Leveraging Growth in Minerals and Metals Demand from a Low Carbon Transition

Dear participant:

The organizations ImplementaSur, Vivid Economics and the Carbon Trust are working in consortium to develop a consultancy for the Inter-American Development Bank (IDB) on Latin America's supply projections of strategic minerals for technologies relevant to low carbon development. This includes an analysis of the potential economic, environmental and social impacts associated with the production of the following minerals: copper, lithium, manganese, lead and zinc, mainly in Argentina, Brazil, Chile, Bolivia, Peru, and Mexico, in the future.

The data provided in this form are anonymous; it will be treated with strict confidentiality and analyzed exclusively under the scope of this project.

1. Please choose those minerals in which, because of your background and field of activity, you believe you have the most relevant experience.

	Region
Copper	
Lithium	
Manganese	
Lead	
Zinc	
Other (specify mineral and region)	

Environmental and social opportunities to 2030

Below are questions related to environmental and social opportunities associated with the production of select minerals in the coming years.

2. In a low carbon transition scenario, it is assumed that the demand for select minerals will behave as follows by 2030:
Copper: approx. 100% increase
Lead: approx. 20% reduction
Lithium: approx. 800% increase
Manganese: approx. 45% increase
Zinc: approx. 30% increase

Considering the above data, what are the most relevant environmental opportunities for mining companies?
Please scroll the bar to the right to view the rest of the minerals.

	Copper	Lithium	Manganese
GHG emissions			
Air quality			
Water management			
Waste management (hazardous materials)			
Biodiversity/ecological impacts			
Energy management			
Physical impact of climate change			

3. Are there any environmental opportunities not considered in the previous section that you would like to mention?

4. Could you share any recommendations to take advantage of environmental opportunities in the following aspects?
Please indicate whether this is a recommendation to be implemented in the next three years or over a longer period.

GHG emissions	
Air quality	
Water management	
Waste management (hazardous materials)	
Biodiversity/ecological impacts	
Energy management	
Physical impact of climate change	

5. In a low carbon transition scenario, it is assumed that the demand for select minerals will behave as follows by 2030:
Copper: approx. 100% increase
Lead: approx. 20% reduction
Lithium: approx. 800% increase
Manganese: approx. 45% increase
Zinc: approx. 30% increase

Considering the above data, what are the most relevant social opportunities for mining companies?
Please scroll the bar to the right to view the rest of the minerals.

	Copper	Lithium	Manganese
Security			
Human rights			
Indigenous peoples			
Community relations			
Labor relations			
Occupational health and safety			

6. Are there any social opportunities not covered in the previous section that you would like to mention?

7. Could you make any recommendations to take advantage of social opportunities in the following aspects?
Please indicate whether this is a recommendation to be implemented in the next three years or over a longer period.

Security	
Human rights	
Indigenous peoples	
Community relations	
Labor relations	
Occupational health and safety	

Environmental and social challenges to 2030

Below are questions related to the environmental and social challenges associated with the production of select minerals in the coming years.

8. In a low carbon transition scenario, it is assumed that the demand for select minerals will behave as follows by 2030:
Copper: approx. 100% increase
Lead: approx. 20% reduction
Lithium: approx. 800% increase
Manganese: approx. 45% increase
Zinc: approx. 30% increase

Considering the above data, what are the most relevant environmental challenges for mining companies?
Please scroll the bar to the right to view the rest of the minerals.

	Copper	Lithium	Manganese
GHG emissions			
Air quality			
Water management			
Waste management (hazardous materials)			
Biodiversity/ecological impacts			
Energy management			
Physical impact of climate change			

9. Are there any environmental challenges not covered in the previous section that you would like to mention?

10. Could you make recommendations to address the environmental challenges in the following aspects?
Please indicate whether this is a recommendation to be implemented in the next three years or over a longer period.

GHG emissions	
Air quality	
Water management	
Waste management (hazardous materials)	
Biodiversity/ecological impacts	
Energy management	
Physical impact of climate change	

11. In a low carbon transition scenario, it is assumed that the demand for select minerals will behave as follows by 2030:
Copper: approx. 100% increase
Lead: approx. 20% reduction
Lithium: approx. 800% increase
Manganese: approx. 45% increase
Zinc: approx. 30% increase

Considering the above data, what are the most relevant social challenges for mining companies?
Please scroll the bar to the right to view the rest of the minerals.

	Copper	Lithium	Manganese
Security			
Human rights			
Indigenous peoples			
Community relations			
Labor relations			
Occupational health and safety			

12. Are there any social challenges not considered in the previous section that you would like to mention?

13. Could you make recommendations to address the social challenges in the following aspects?
Please indicate whether this is a recommendation to be implemented in the next three years or over a longer period.

Security	
Human rights	
Indigenous peoples	
Community relations	
Labor relations	
Occupational health and safety	

---

14. What do you believe to be the main driver for mining companies to implement international sustainability standards and protocols in their operations?

- ● Investors
- ○ National regulations
- ○ Customers
- ○ Other (specify)

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15. What do you think are the most relevant challenges associated with the current practices of international sustainability standards and protocols?

	No opinion	Not relevant	Not very relevant	Moderately relevant	Very relevant
Inconsistency	◉	◉	◉	◉	◉
Not comparable	○	○	○	○	○
Lack of standardization	○	○	○	○	○
Unclear benefits	○	○	○	○	○
Lack of sensitized/trained personnel	○	○	○	○	○
Other (specify)					

16. What specific technical skills are needed to drive the adoption of sustainability standards, and who should be the recipient of these trainings, government, financial sector, personnel in mining companies?

17. Can you mention successful experiences in Latin American and Caribbean countries where mining has generated clear environmental and social benefits?

18. According to the following categories, please choose the option that most closely matches your profile:

- ◉ Mining company - Part of the sustainability or operations team
- ○ International association involved in developing sustainability standards and reporting frameworks
- ○ Non-governmental organization that monitors social and environmental issues related to the mining sector

- Academia
- Public sector
- I prefer not to share this information

Other (specify)

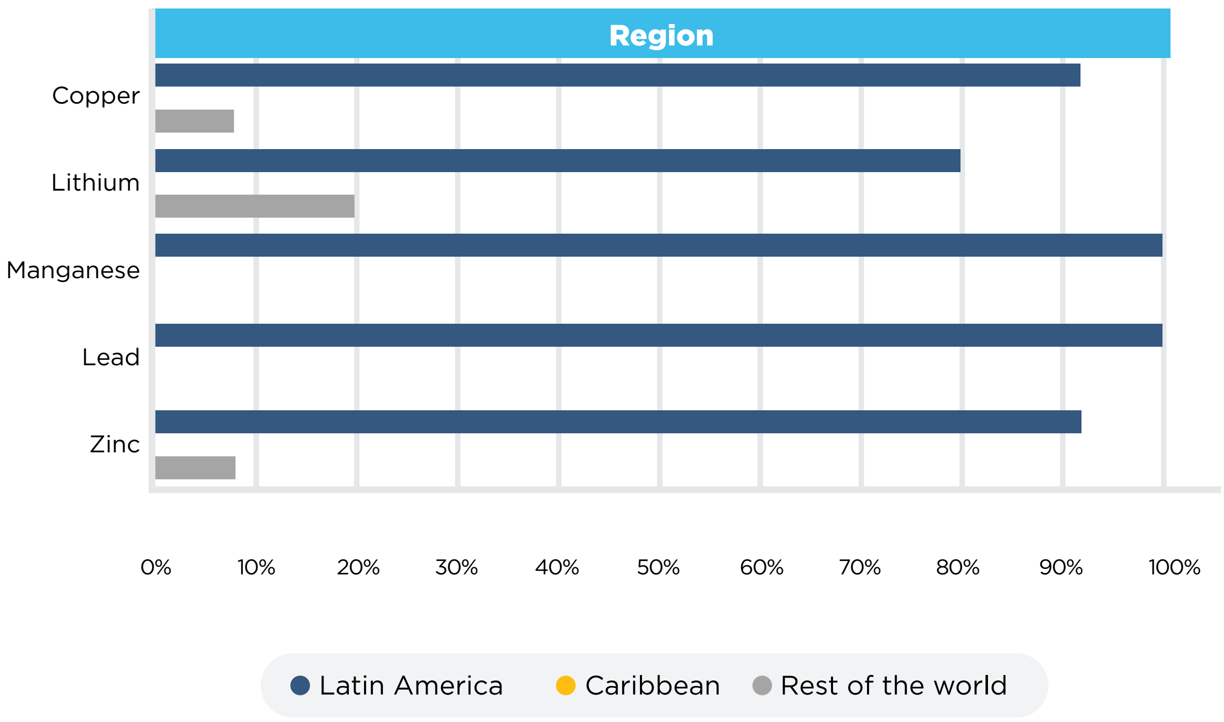
19. Finally, please support us in generating gender statistics.

- (●) Female
- Male
- I do not wish to share this information

Main considerations

The Spanish survey received 28 responses from participants who have experience in mining operations in LAC as well as the rest of the world. The results were used to feed the document and select the most significant impacts depending on each metal.

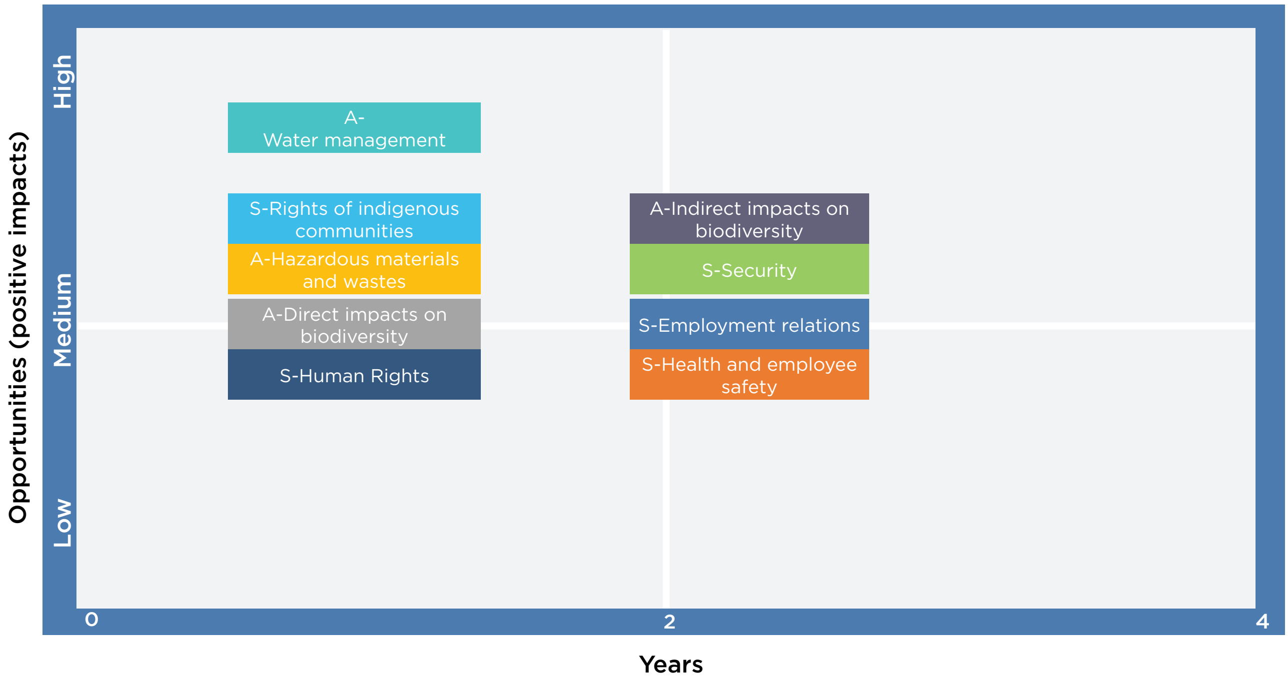
Survey results by mineral experience and region

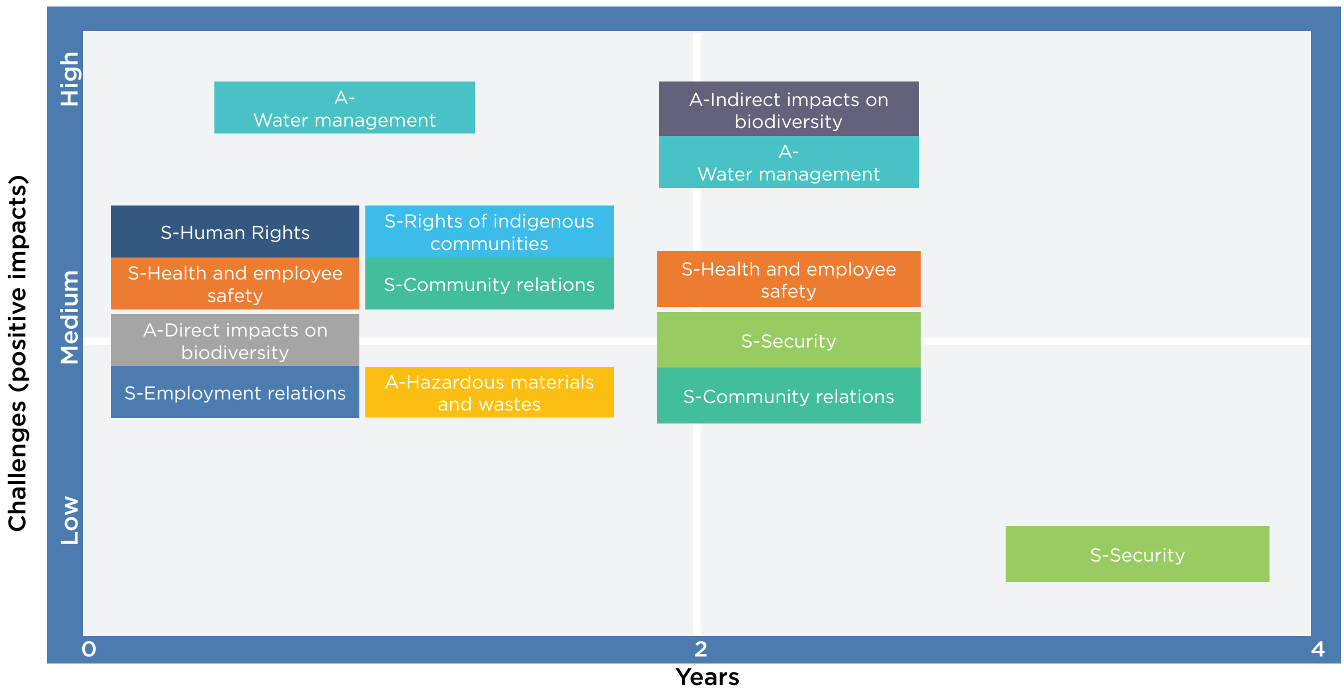


Heat maps developed

The interviews provided insights into the positive and negative impacts of mineral operations, as well as their relevance in the short and long term in relation to the production needed to achieve the 1.5°C target. The interviewees were presented with heat maps of challenges and opportunities constructed with information from 40 case studies related to the minerals lithium, manganese, copper, zinc, and lead in the five Latin American countries within the scope of the project: Argentina, Bolivia, Brazil, Chile, Mexico, and Peru. These maps consider the positive and negative impacts related to mining operations; the maps are presented below.

Heat maps for the opportunities and challenges that mining operations face in the short and medium term





During the interview, dynamics was achieved to obtain the points of view of *how the socio-environmental factors would change for the opportunities and challenges in the mining companies according to the growth projections in mineral production* calculated in this study, and thus validate and/or adapt the heat maps generated (dynamic conducted through the MURAL platform).

The main opportunities and challenges mentioned by each of the interviewees, in terms of impact and relevance over time, are presented in the heat maps below; those recurring factors can be identified by the number of times they were confirmed by the interviewees (repeated boxes). They were also asked to add socio-environmental factors that were not initially considered (boxes without color coding).

Derived from the previous maps, the following tables (Table 4.1 and Table 4.2) summarize the most recurrent opportunities and challenges and their relevance over time. The factors suggested by the people interviewed are also presented.

Table 4.1 - Summary table of the most recurrent opportunities and their relevance over time, considering the 1.5°C growth scenario with 2020 baseline

Impact level of opportunities	Relevance over time		
	Short term	Medium term	Long term
High impact	- Water management - Energy management - Innovative alliances - Circular economy * - Social sustainability plans * - Digitization * - Catalyst for development by sharing socioeconomic benefits * - Social license *	- Best practices in the closure of mining operations * - Integrated management systems* - Promotion of the formality of small and medium-sized mining cooperatives*	- Cultural transition for the improvement of public perception*
Medium impact	- Rights of indigenous communities - Waste and hazardous materials management, including proper tailings management - Impacts on biodiversity - Direct - Human rights	- Impacts on biodiversity - Security - Labor relations - Occupational health and safety - Transfer of technological knowledge* - Energy transition -Mining regulations	Robotics*

Impact level of opportunities	Relevance over time		
	Short term	Medium term	Long term
Low impact	- Cybersecurity*		

(*) Socio-environmental factors added by interviewees

Table 4.2 - Most recurrent challenges and their relevance over time

Level of impact of the challenges	Relevance over time		
	Short term	Medium term	Long term
High impact	- Water management - Community relations - Social license* - Institutional weaknesses* - Adoption of GHG reduction strategies by investor guidelines*	- Impacts on biodiversity - Water management - Cultural transition* - Energy transition*	- Digitization* - Integrated management systems*
Medium impact	- Human rights - Rights of indigenous communities - Occupational health and safety - Impacts on biodiversity - Direct - Labor relations - Mining regulations*	- Occupational health and safety - Security - Community relations - Robotics * - Land use and licensing*	- Circular economy*
Low impact			- Security

(*) Socio-environmental factors added by interviewees

To make it easier for the user to read, heat maps were constructed to display only the most relevant socio-environmental factors, i.e., those that were most frequently mentioned by the people interviewed (Figure D.1 and Figure D.2). Environmental factors are represented in green, social factors in blue and those added by the interviewees in yellow. The content of these maps is detailed in section 3.2.1 and 3.2.2

Figure D. 1 - Map of opportunities (positive impacts) of mining operations, considering low carbon emission scenarios

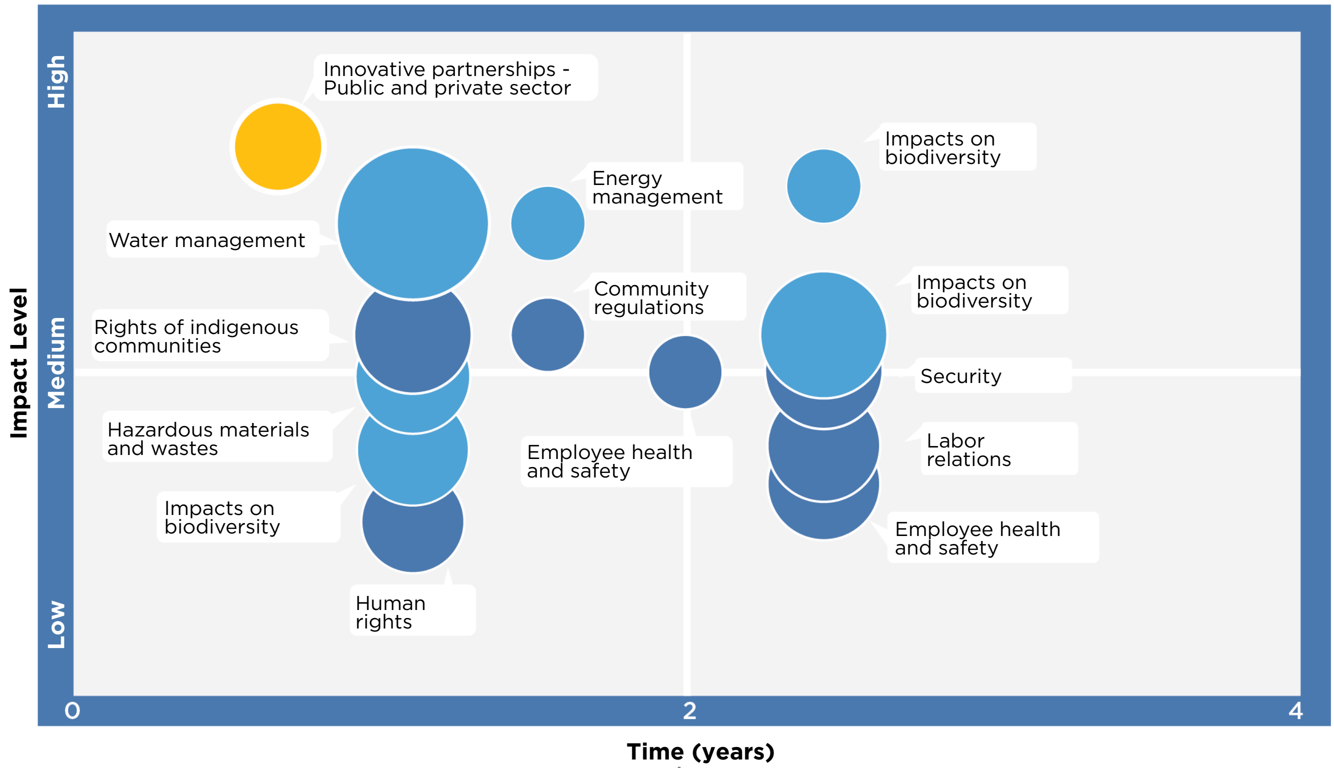
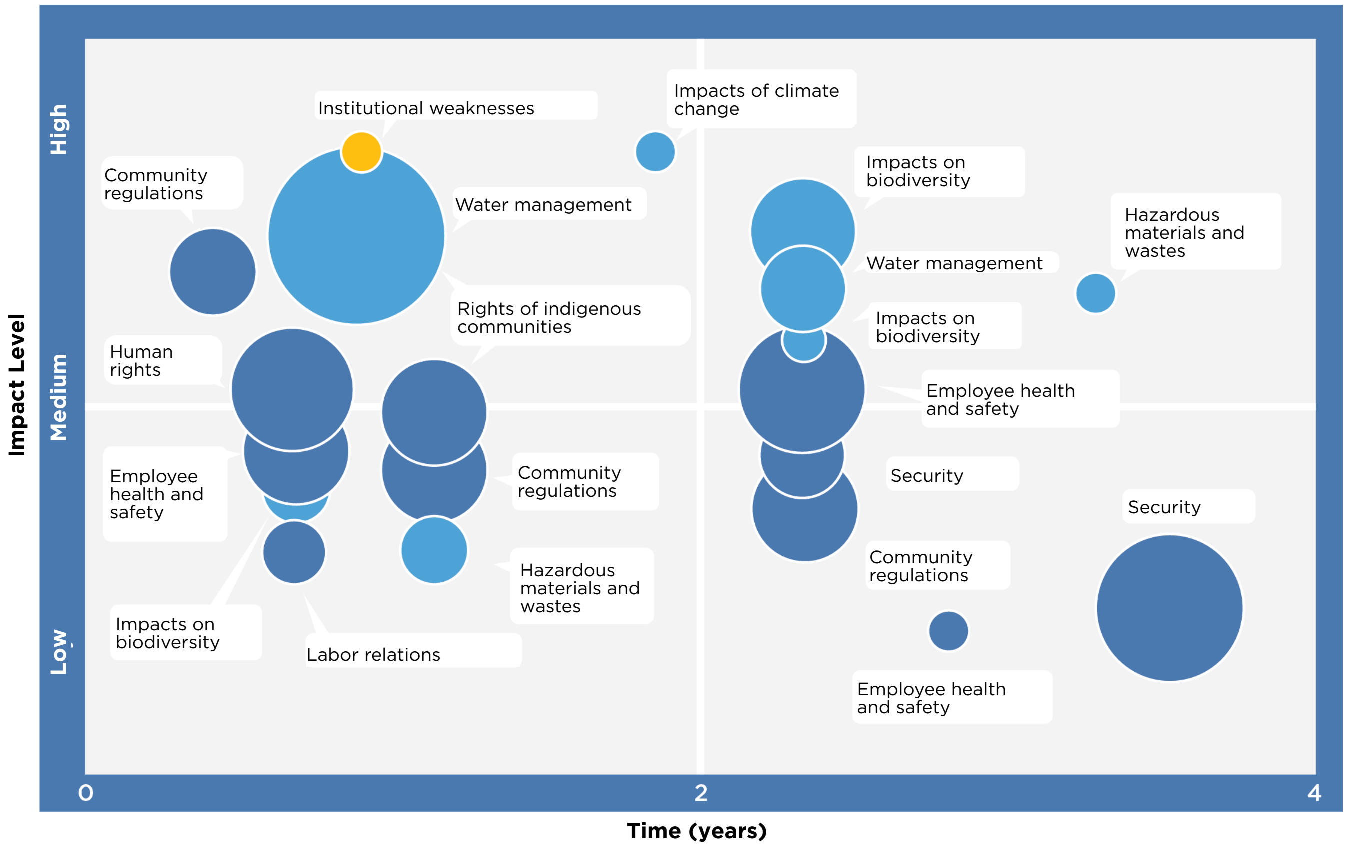


Figure D.2 - Heat map of challenges (negative impacts) of mining operations, considering low carbon scenarios



D.Case studies

D.1 Reference case study to exemplify measurement: Participatory Environmental Monitoring and Surveillance Committees in Peru.

Participatory Environmental Monitoring and Surveillance Committees. According to López Follegatti, the committees "are coordinating bodies that promote the participation of civil society, especially communities, mining companies and the State at all levels, to generate verification mechanisms that contribute to the evaluation of the environmental impacts caused by a certain sector of mining activity" (López Follegati, 2009).

The Committees emerged in the early 2000s, as multi-sectoral technical commissions whose objectives were to propose mechanisms to improve the dissemination of information and citizen participation; and to ensure respect for the company's environmental commitments through involvement in environmental monitoring tasks (Ménard, Guide for the Implementation of Participatory Monitoring and Surveillance Committees, 2011). The first Committees originated in situations of environmental conflict between communities and companies, and arose with the support of local governments (municipalities) or the central government (supervisory agencies or ministries), which gave them a degree of formalization; and in some cases, they arose at the initiative of the company in order to improve the relationship with the community (Ménard, 2011, pp. 5, 10, 17). These commissions brought together the parties (company, community and government agencies) in the search for solutions to the problems arising from mining activities in relation to the communities.

The existence and activity of the committees led to a regulation that governs citizen participation in mining projects, and establishes a formal framework for communities to become involved in environmental monitoring and oversight. In this regard, the ministerial resolution that creates them indicates that the Participatory Environmental Monitoring and Surveillance: "It consists of promoting, in an organized manner, the

participation of the population involved in accessing and generating information related to the environmental aspects of mining activities, after the EIA and EIAsd have been approved, through the monitoring and surveillance of compliance with the obligations of the mining owner" (Article 2, paragraph 2.11).

Even when the Committees lack oversight capacity, if their work is well conducted, they have tangible effects on the activities of companies and oversight bodies, and can promote positive changes in the company's relationship with the community and in environmental protection, even beyond monitoring and surveillance (Pareja, Xavier, & Daitch, 2019). The operation of the committees requires that their members be trained in sampling techniques, and that they dedicate significant time to monitoring and follow-up tasks, which they do on a voluntary basis. This degree of commitment has been an element that has hindered the effective operation of the Committees, which, in some cases, have not been able to become effectively operational (Ménard, 2011, p. 11). In addition to the above, in some cases there is a rotation of committee members, which makes it difficult to build trust (Ménard, 2011, p. 19).

Funding has been a problem for the functioning of the Committees (Ménard, 2011, p. 55). In accordance with the regulations, this can be provided by the companies. On the one hand, the total financing has not come from the companies and some Committees have been able to manage different financial sources, apart from the voluntary contribution of their members. On the other hand, the origin of the funding from an interested party has raised doubts regarding the independence of the committees from the companies and the results of the monitoring. In some cases, the municipalities have helped the committees, not with direct financing, but by contributing resources (such as infrastructure and management). This issue is unresolved and requires an appropriate solution.

D.2 Reference case study to exemplify measurement: Global Tailings Management Standard for the Mining Industry (involvement of PRI, UNEP FI, ICMM)

The series of environmental and social challenges in the mining industry has been exacerbated by recent unfortunate catastrophes, such as the devastating collapse of a tailings dam near the city of Brumadinho in Brazil, owned by the Vale mining company, in January 2019. This fact has served to underline the critical importance

of getting proper disclosure and management of socio-environmental challenges and opportunities right if companies are to attract investment and retain their social license to operate (Sanderson and Hume, 2019).

This section describes the creation of the Global Tailings Management Standard for the Mining Industry and how different types of investors have demanded its adoption by mining companies. The shock of the Brumadinho event led to the creation of an investor initiative called the "Mining and Tailings Safety Initiative for Investors". This initiative is chaired by the Church of England Pension Board and the Swedish National Pension Fund Ethics Council, and is supported by 112 international investors with more than USD 14 billion in assets under management.

Its objective is to enhance understanding and transparency related to the social and financial risks associated with tailings disasters, and to advocate for improved management of them. It has been successful in making investors aware of the catastrophic effects that poor management can have on the community and the environment (Global Tailings Review, 2020).

The initiative seeks to expand the use of a standard that mandates the adoption of decisive and appropriate measures to improve safety and strengthen the management of tailings facilities worldwide (Global Tailings Review, 2020). The Global Tailings Management Standard for the Mining Industry was created in 2020 by the Global Tailings Review, chaired by ICMM, the United Nations Environment Program (UNEP) and the Principles for Responsible Investment (PRI).

The standard was created through a multi-stakeholder process, including affected communities, government authorities, multilateral organizations, mining representatives, and investors. As co-author, PRI represents the latter group, whose signatories globally manage USD 103.4 billion in assets under management. In addition, during the creation of the standard, financial institutions that support smaller mining companies in their development, including the International Finance Corporation (IFC), were consulted to ensure the applicability of this standard to all types of mining operations.

This standard requires operators (and therefore investors) to apply an integrated approach to tailings management, and sets out requirements on six key issues:

1. Communities affected
2. Integrated knowledge base
3. Design, construction, operation, and monitoring of tailings facilities
4. Management and governance
5. Emergency response and long term recovery
6. Public disclosure and access to information

Investors review the public information required by the standard as part of their due diligence, the integration of socio-environmental and governance criteria, and make investment decisions. They expect all mining companies operating tailings facilities to adopt it, as the standard has been developed so that it can be applied by all operators, regardless of their size or geographic location.

Through PRI, financiers are creating investment expectations that can highlight those stakeholders with good tailings management, and take action against companies that do not follow the standard. These include shareholder involvement, proxy voting, stakeholder resolutions and, ultimately, divestment, measures that have been defined in the previous subchapter.

For example, the Norwegian Government Pension Fund withdrew its investments in Vale in the face of a successive tailings failure at its mining operations, topped off by the tragic 2019 accident in Brumadinho "because it is an unacceptable risk that the company contributes to or is itself responsible for serious environmental damage" [sic] (Freitas and Andrade, 2020).

Advancing in adopting the standard is expected to continue in implementation across its three organizations: UNEP will support governments wishing to incorporate this standard into their national or state legislation, PRI will develop investor expectations and guide them on actions to take to support mining companies in applying the standard, and ICMM member companies must comply with the standard as a commitment to belong to this group.

The demand for the adoption of the tailings management standard by mining companies through the various actions that investors can take is a true reflection of the role they play in accelerating the adoption of socio-environmental criteria.

E. Acknowledgments

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No.	Interviewee (Name, position, and area of action)	Profile
1	Alexandra Guaqueta, Global Practice Leader, External Affairs at Rio Tinto, South America	Private sector
2	Alfonso Caso Aguilar, partner - director, Aosocial, Mexico	Others - Consulting
3	Ana María Aranibar Jiménez, Cumbre del Sajama, Bolivia	Others – Consulting
4	Cristian Cifuentes, Strategy and Public Policy Analyst, Chile	Public sector
5	Daniel Lafuente, Sajama Summit, Bolivia	Others – Consulting
6	Dr. Gustavo Lagos, Research Professor, Pontificia Universidad Católica de Chile, Chile	Academia
7	Dr. Stephen Northey, UTS Sydney	Academia
8	Hafren Williams; manager, International Council on Mining and Metals, International	International initiatives
9	Iris Wunderlich; Senior Project Manager Energy, Mining & Sustainability; Chilean-German Chamber of Commerce (CAMCHAL), Chile	Other - Camera
10	Laura Turley, Former Associate at IISD; International Institute for Sustainable Development (former), International	Other
11	Leah Butler; Vice President and Responsible Mining Initiative Leader; Responsible Business Alliance, International	International initiatives
12	María de la Luz Vásquez, Environmental Officer, Ministry of Mining, Chile	Public sector
13	Masuma Farooki; Consulting Director; Minehutte, International	Others - Consulting

No.	Interviewee (Name, position, and area of action)	Profile
14	Nicole Hanson, Sustainability manager, Copper Alliance, International	International initiatives
15	Paul D. Maidstone; Environmental Head, Glencore Zinc, South America	Private sector
16	Prof. Damien Giurco, UTS Sydney	Academia
17	Rinaldo Mancin, Director of Institutional Relations, Instituto Brasileiro de Mineração, Brazil	Public sector
18	Simon Wong, Sustainable Finance Tutor, Cambridge Institute for Sustainable Leadership.	Academia
19	Víctor Pérez, professor of strategic marketing, MBA in Mining, Universidad de Chile, Chile	Academia

F. References

Allianz (2018) ESG Integration Framework. Munich, Germany: Allianz.

Amnesty International (2016) This is what we die for: Human rights abuses in the Democratic Republic of the Congo. London, United Kingdom: Amnesty International.

Amnesty International (2017) Time to Recharge: corporate action and inaction to tackle abuses in cobalt supply chain. London, United Kingdom: Amnesty International.

Australian Government (2020) Working with Indigenous Communities; Leading Practice Sustainable Development Program for the Mining Industry. Canberra: Commonwealth of Australia.

Berkouwer, Chris (2020) The paradox of sustainable investment in mining. Rotterdam, the Netherlands: Robeco.

BID, 2020. From structures to services: the road to better infrastructure in Latin America and the Caribbean. Washington, D.C., U.S.A.

Business & Human Rights Resources Center (2020) Renewable Energy Benchmark - Key Findings Report. London, United Kingdom: Business & Human Rights Resources Center.

CESCO and Spencer Stuart (2020) Mining for Value. Santiago de Chile, Chile: CESCO.

Church, Clare and Alec Crawford (2018) Green Conflict Minerals: The fuels of conflict in the transition to a low carbon economy. Winnipeg, Canada: International Institute for Sustainable Development.

Comisión Chilena del Cobre (2019) Projection of copper production in Chile 2019 -2030. Santiago de Chile, Chile: Chilean Copper Commission.

Comisión Chilena del Cobre (2020) Projection of water consumption in copper mining. Santiago de Chile, Chile: Chilean Copper Commission.

Deloitte (2020) Tracking the trends 2020 - Leading from the front. London, United Kingdom: Deloitte Insights.

Dufey, Annie (2020) Initiatives to make environmental and social aspects transparent in mining supply chains. Santiago de Chile, Chile: United Nations.

Duka, Ykateryna, Svetlana Ilchenko, Mykola Kharytonov and Tetyana Vasylyeva (2011) Impact of open manganese mines on the health of children dwelling in the surrounding area. Emerging health threats journal, 4, 7110. https://doi.org/10.3402/ehtj.v4i0.7110

ECLAC (2019) Mining for a low carbon future: opportunities and challenges for sustainable development. Santiago de Chile, Chile: United Nations.

Engel, Hauke, Patrick Hertzke, y Giulia Siccardo (2019) Second-life EV batteries: The newest value pool in energy storage. Frankfurt, Germany: McKinsey & Company.

European Automobile Manufacturers Association. (2020). A massive increase in truck charging and recharging infrastructure is needed, new data reveals. Brussels, Belgium.

Farooki, Masuma. 2020a. Responsible Sourcing: The Case for Business Competitiveness. Vienna, Austria: Re-Sourcing.

Farooki, Masuma. 2020b. The International Responsible Sourcing Agenda. Vienna, Austria: Re-Sourcing.

Frankel, Todd. "The cobalt pipeline: Tracing the path from deadly hand-dug mines in Congo to consumers' phones." September 30, 2016. The Washington Post.

Freitas, Gerson Jr. and Vinicius Andrade. "Brazil Iron Ore, Power Giants Excluded From Norway's Wealth Fund." Bloomberg. May 13, 2020.

German Environment Agency (2020) Addressing climate change impacts in mining and raw material supply chains. Dessau-Rossblau, Alemania: German Environment Agency.

GIZ (2018) Creating Value Together – Interoperability: Opportunities, Challenges and Ways Forward for Metals, Mineral and Mining Sustainability Standards. Bonn, Germany: Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ).

Global Tailings Review (2020) Global Industry Standard on Tailings Management. London, United Kingdom: Global Tailings Review.

Gordon, Robert, Marlen Bertram, and Thomas Graedel (2006) Metal stocks and sustainability. Proceedings of the National Academy of Sciences, 103 (5) 1209-1214; DOI: 10.1073/pnas.0509498103.

Gordon, Robert, Marlen Bertram, and Thomas Graedel (2007) On the sustainability of metal supplies: A response to Tilton and Lagos. Resources Policy 32(1-2):24-28.

Grimm, Jorg, Joerg Hofstetter and Joseph Sarkis (2014) Critical factors for sub-supplier management: A sustainable food supply chains perspective. International Journal of Production Economics, 152(1), 159–173.

Her Majesty's Treasury (2020) A Roadmap towards mandatory climate-related disclosures. London, United Kingdom: Her Majesty's Treasury.

Hervé, Dominique and Ximena Insunza (2019) Análisis Crítico del Proyecto de Ley que Modifica el Sistema de Evaluación de Impacto Ambiental. Santiago de Chile, Chile: Friedrich Ebert Foundation in Chile.

Hofmann, Hannes, Martin Schleper and Constantin Blome (2018) Conflict Minerals and Supply Chain Due Diligence: An Exploratory Study of Multi-tier Supply Chains. Journal of Business Ethics, Springer, vol. 147(1), pages 115-141, January.

Hund Kristen, Daniele La Porta, Thao Fabregas, Tim Laing and John Drexhage (2020) Minerals for Climate Action: The Mineral Intensity of the Clean Energy Transition. Washington, D.C., U.S.A.: World Bank.

Institute of Chartered Accountants in England and Wales (2020) Responsible sourcing and low carbon metals at the LME. London, United Kingdom: Institute of Chartered Accountants in England and Wales.

Intergovernmental Forum on Mining, Minerals, Metals and Sustainable Development (2019) Do Voluntary Sustainability Initiatives in Mining Advance the SDGs? Ottawa, Canada: Intergovernmental Forum on Mining, Minerals, Metals and Sustainable Development.

Intergovernmental Panel on Climate Change (2018) Special report: Global warming of 1.5°C. Geneva, Switzerland: Intergovernmental Panel on Climate Change.

International Council on Mining and Metals (2012) Voluntary Principles on Security and Human Rights. London, United Kingdom: International Council on Mining and Metals.

International Council on Mining and Metals (2015a) Indigenous peoples and mining. London, United Kingdom: International Council on Mining and Metals.

International Council on Mining and Metals (2015b) Demonstrating value: A guide to responsible sourcing. London, United Kingdom: International Council on Mining and Metals.

International Council on Mining and Metals (2017) Good practice guide for mining and biodiversity. London, United Kingdom: International Council on Mining and Metals.

International Council on Mining and Metals (2018, November 26) ICMM first industry body to commit to UN Guiding Principles on Business and Human Rights [Press release].

International Council on Mining and Metals (2020) Mining and communities. London, United Kingdom: International Council on Mining and Metals.

International Energy Agency (2019) Global EV Outlook 2019. Paris, France.

International Labor Organization (1989) C169 - Indigenous and Tribal Peoples Convention. Geneva, Switzerland: International Labor Organization.

International Lead Association (2015) Lead Recycling Sustainability in Action. London, United Kingdom: International Lead Association.

Jamasmie, Cecilia. "Tahoe Resources forced to halt Escobal mine in Guatemala." July 6, 2017. Mining.

Jameson Jordan, Xin Song and Michael Pecht (2016) Conflict Minerals in Electronic Systems: An Overview and Critique of Legal Initiatives. Sci Eng Ethics. 2016 Oct;22(5):1375-1389

Jerez Henríquez, Bárbara (2018) Socio-environmental impact of lithium extraction in the basins of the high Andean salt flats of the southern cone. Santiago de Chile, Chile: Observatory of Mining Conflicts in Latin America.

Jiang, Kejun, Solomone Fifita, y Katherine Calvin (2018). Mitigation pathways compatible with 1.5 C in the context of sustainable 2 development.

Laier, Paula. "Vale stock plunges after Brazil disaster; $19 billion in market value lost." January 28, 2019. Reuters.

Lindsay Delevingne, Will Glazener, Liesbet Grégoir, and Kimberly Henderson (2020) Climate risk and decarbonization: What every mining CEO needs to know. New York, NY: McKinsey & Company.

Lin Yuping, Zhang, Kai Zhang, Max Zuo-Jun, y Lixin Miao (2019). Charging network planning for electric bus cities: A case study of Shenzhen, China. Sustainability, 11(17), 4713.

London Metal Exchange (2019a, April 23) London Metal Exchange launches consultation on the introduction of responsible sourcing standards [Press release].

London Metal Exchange (2019b, October 25) LME sets out responsible sourcing requirements [Press release]

London Metal Exchange (2020) Guide to the London Metal Exchange. London, United Kingdom: London Metal Exchange.

Lopez, Andrés, Martin Obaya, Paulo Pascuini, Adrián Ramos (2020) Lithium in Argentina: Opportunities and challenges for value chain development. Washington, D.C., U.S.A.: Inter-American Development Bank.

Loulou, Richard and Maryse Labriet (2007) ETSAP-TIAM: the TIMES integrated assessment model Part I: Model structure. CMS 5, 7–40 (2008) https://doi.org/10.1007/s10287-007-0046-z

López Follegatti, Jose Luis (2009) Comités de Monitoreo y Vigilancia Ambiental Participativos. Lima, Peru: Mining and Sustainable Development Dialogue Group.

Mathieux, Fabrice, Fulvio Ardente, and Silvia Bobba (2017) Critical raw materials and the circular economy. Luxembourg, E.U.: European Commission.

Montagú, Haroldo, Gustavo Nadal, Karina Íñiguez and Hilda Dubrovsky (2019) Eficiencia energética en Argentina - Diagnóstico sector minero. Hamburg, Germany: GFA Consulting Group.

Mori Junior, Renzo y Saleem Ali (2016) Designing Sustainability Certification for Greater Impact: Perceptions, expectations and recommendations in sustainability certification schemes. Brisbane, Australia: Center for Social Responsibility in Mining, University of Queensland.

Ménard, Renée (2011) Guide for the Implementation of Participatory Environmental Monitoring and Surveillance Committees. Lima, Peru: Ministry of Energy and Mines, Peru.

Norgate, Terry and Nawshad Haque (2010) Energy and greenhouse gas impacts of mining and mineral processing operations. Journal of Cleaner Production, Volume 18, Issue 3, February 2010, Pages 266-274.

Nuss, Philip y Matthew Eckelman (2014) Life Cycle Assessment of Metals: A Scientific Synthesis. PLoS ONE 9(7): e101298. https://doi.org/10.1371/journal.pone.0101298

OECD (2016) OECD Due Diligence Guidance for Responsible Supply Chains of Minerals from Conflict Affected and High Risk Areas. Paris, France: OECD.

OECD (2018). Economic Survey of Chile 2018. Santiago, Chile: OECD.

OECD (2019) Mining and Green Growth in the EECCA Region. Paris, France: OECD.

Palomino Bonilla, Miguel, Patricia Pérez Malca, Paula Castillo Vera, and Piero Ortiz Chávez (2015) The economic cost of not implementing mining projects due to social conflicts and/or bureaucratic obstacles. Lima, Peru: Peruvian Institute of Economics.

Pareja, Claudio, Andre Xavier, and Sarah Daitch (2019) Participatory Environmental Monitoring Committees in Mining Contexts; Lessons from nine case studies in four Latin American countries. New York, NY, USA: United Nations.

Pennini, Aldo. "The ESG bar has just been raised... Who will get over it?" March 20, 2020. Mining Journal.

Potts, Jason, Matthew Wenban-Smith, Laura Turley, and Matthew Lynch (2018) State of sustainability initiatives review: standards and the extractive economy. Winnipeg, Canada: International Institute for Sustainable Development.

Proética (2019) Corruption risks in the mining sector: Peru Report. Lima, Peru: National Council for Public Ethics.

Rasiewicz, Angelica, Alberto Vásquez Ruiz and Piet Wostyn (2020) The green transition challenged by the metal supply chain. European Training Network for the Remediation and Reprocessing of Sulfidic Mining Waste Sites.

RCS Global Group (s.f.) Blockchain & Traceability: Mine-To-Market Distributed Ledger Technology Platforms. Berlin, Germany: RCS Global Group.

Remme, Uwe and Markus Blesl (2008) A global perspective to achieve a low carbon society (LCS): Scenario analysis with ETSAP-TIAM modelv. Climate Policy 8(sup1):S60-S75.

Responsible Minerals Initiative (2020) Responsible Minerals Initiative Blockchain Guidelines. Second Edition. Alexandria, V.A, U.S.A.: Responsible Minerals Initiative.

Responsible Mining Foundation (2019) Mine-site ESG data disclosure by small and mid-tier mining companies. Nyon, Switzerland: Responsible Mining Foundation.

Responsible Mining Foundation and Columbia Center on Sustainable Investment (2020) Mining and the SDGs: 2020 status update. Nyon, Switzerland: Responsible Mining Foundation.

Ruiz, Valentina. "Pathways towards zero-emission copper mines." June 28, 2020. Mining.

Sanderson, Henry and Neil Hume. "Global miners count the cost of their failings". February 15, 2019. Financial Times.

Segal, Mark. UK Becomes First Country in the World to Make TCFD aligned Disclosure Mandatory. November 9, 2020. ESG Today.

Smith, James and Graham Davis (2020) Design and performance of oil, gas and mining fiscal regimes in Latin America and the Caribbean: Review of current practices, lessons learned and best practices. Washington, D.C., U.S.A.: Inter-American Development Bank.

Sustainability Accounting Standards Board (2018) Metals & Mining - Sustainability Accounting Standard. San Francisco, CA, USA: Sustainability Accounting Standards Board.

UNDP (2018) Managing Mining for Sustainable Development. Bangkok, Thailand: UNDP.

United Nations (1948) Universal Declaration of Human Rights. New York, NY, USA: United Nations.

United Nations (2011) Guiding Principles on Business and Human Rights. New York, NY, USA: United Nations.

United Nations (2018) Regional Agreement on Access to Information, Public Participation and Access to Justice in Environmental Matters in Latin America and the Caribbean. New York, NY, USA: United Nations.

Van den Brink, Susan, Rene Kleijn, Arnold Tukker and Jaco Huisman (2019) Approaches to responsible sourcing in mineral supply chains. Resources Conservation and Recycling 145(2019):389-398.

Villegas, Elisa (2016) Áreas naturales protegidas y minería en México: Perspectives and recommendations. La Paz, Mexico: Northeastern Biological Research Center.