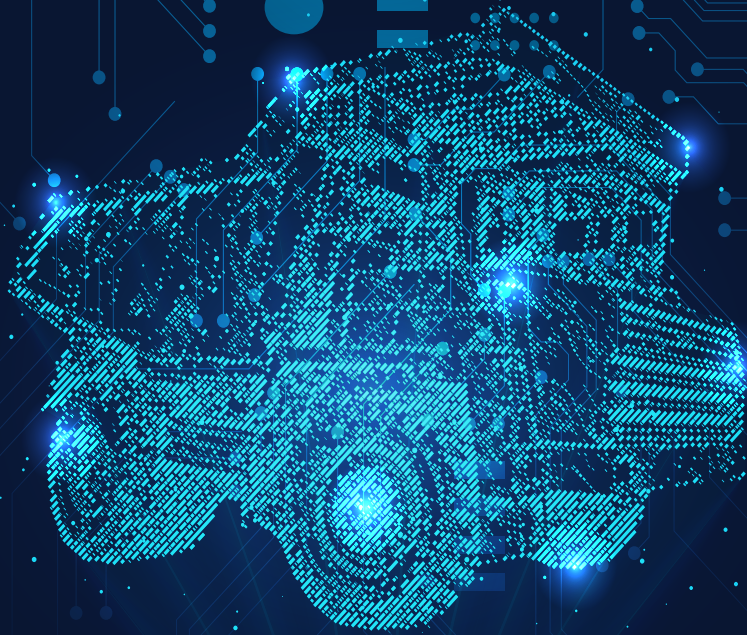
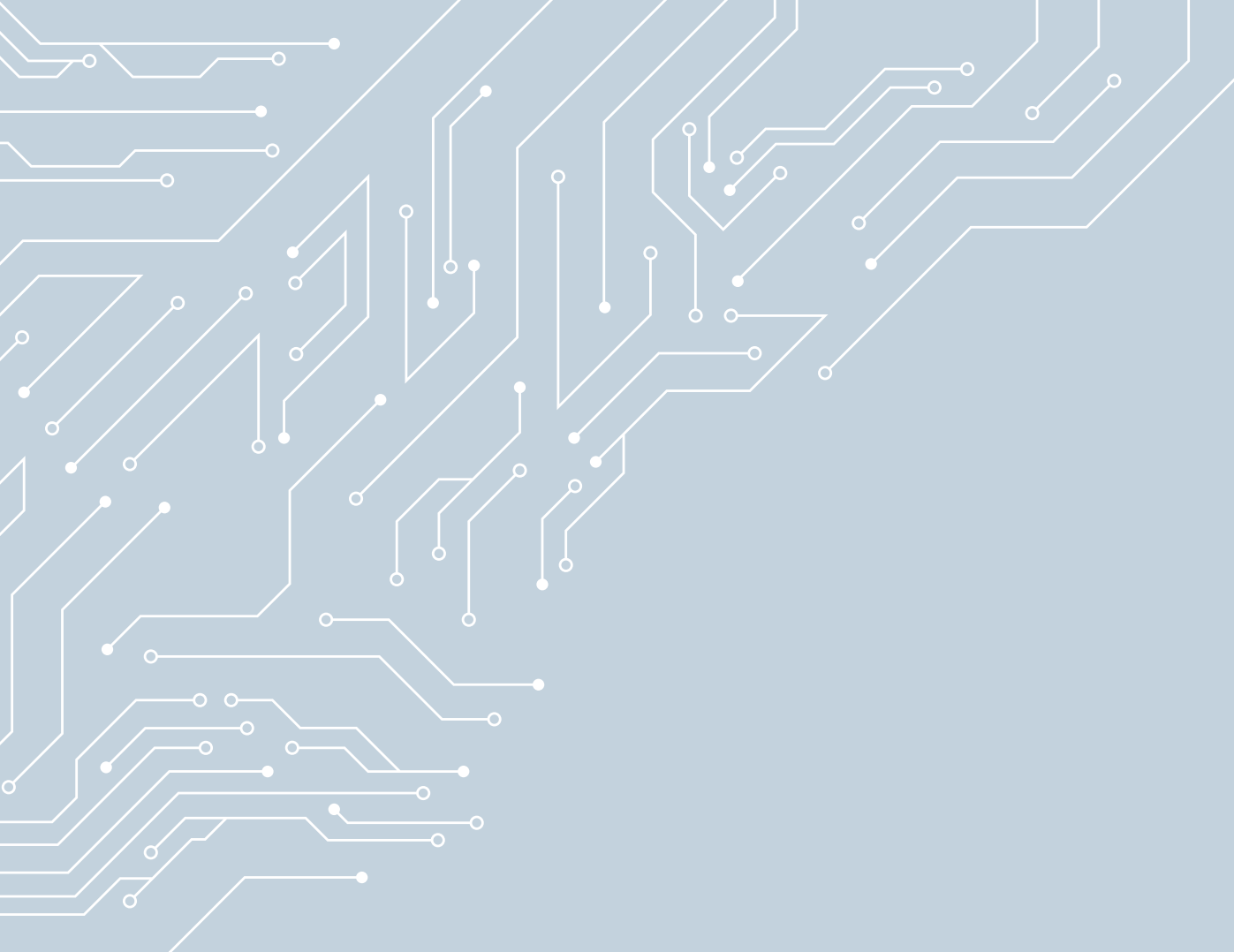


The Technological Revolution in Large-Scale Mining in the Andean Region





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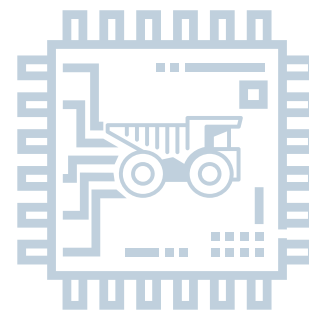
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The Technological Revolution in Large-Scale Mining in the Andean Region



Policies and collaborative efforts to fully harness the technological revolution

Executive summary

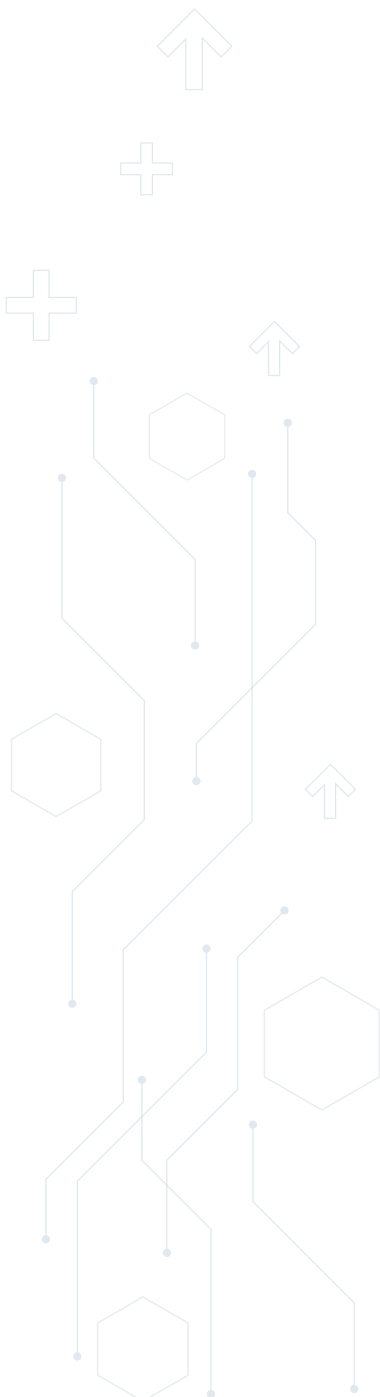
This study was conducted on the premise that technological change cannot be stopped, and using it to drive sustainable development raises issues of growth and fairness. Some technologies and activities that drive productivity and growth will not necessarily bring greater job creation but are nevertheless fundamental to enabling the development of other activities that drive inclusive prosperity and are intended to improve society's overall quality of life. These activities are complementary and must be carried out in concert: while some public policies and collective efforts will be targeted at addressing both purposes, others will focus on only one.

This is the context in which the Center for Copper and Mining Studies (CESCO) conducted this research to identify public policies and collective efforts that would help make the most of the opportunities—and mitigate the unwanted effects—of the adoption¹ of new technologies in the large-scale mining sector of the Andean Region, with a focus on copper mining, due to its importance and potential in the economies of the region. While not intended to generate a final diagnostic analysis of each country's situation and the future scenarios that they might face, it represents an initial effort to identify factors and trends that should be considered when studying the impacts of technological change and then defining policies and collaborative efforts to take advantage of them. At the same time, it lays the foundation for a community of practice that will help deepen understanding of challenges and opportunities and enable the exchange of experience at the regional level.

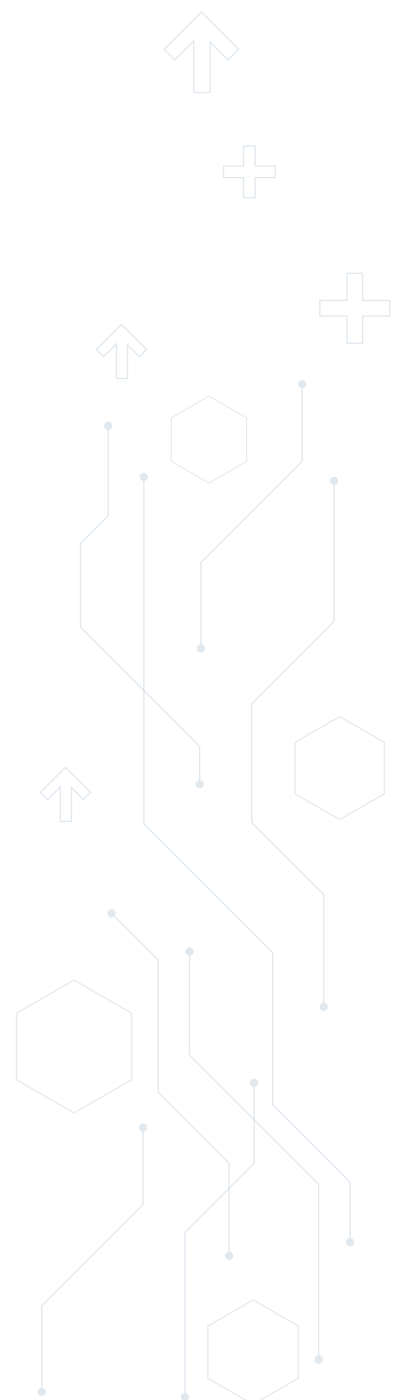
¹ The concept of "Technology Adoption" refers to the ability to use a new technology and improve productivity and operational performance, and also participation in the technological change itself, with the ability to develop innovations associated with new technologies

The preliminary findings include:

- **There is no single solution:** There are significant differences between countries in the Andean Region in terms of the impacts and opportunities of technology adoption in large-scale copper mining. In more mature mining districts, such as Chile and Peru, impacts on employment, local procurement, and innovation are causing concerns, and the sector faces the challenge of meeting society's expectations about sharing the benefits fairly. In less-mature districts, such as Ecuador and Colombia, there is a perception of a greater benefit in terms of overall employment and procurement since mining is a new activity. However, there is a lower drive to take advantage of the transformative momentum that adopting new technologies could catalyse.
- **The Fourth Industrial Revolution is unfolding apace, but the impacts and benefits of the digital era are yet to come:** Digital technologies such as automation and robotics are being rapidly adopted, with challenges in terms of generating the expected benefits still remaining. Specifically, digital infrastructure needs to be developed to then address issues of cybersecurity, systems integration, data management, automation, and process automation. The uptake of digital technologies is proceeding apace, and the impacts will emerge in coming years. This represents a unique time window to prepare properly and support the leaps in productivity and operational improvement that are fundamental to the sustainability of the industry. At the same time, there is an opportunity to address the issues of inclusion and equity that are the bedrock of the sector's social licence. Although a number of efforts pointing in this direction have been identified, there is evidence of high fragmentation and low capacity for the development of a collective, long-lasting effort that, if left unaddressed, could jeopardise the process of technology adoption and, consequently, the sustainability of the industry.
- **Public policies and collective action are crucial and lead to greater benefits:** Under scenarios built around the existence of public policies and collective action, it is possible to visualise significant improvements in virtually every impact analysed—employment, local procurement, innovation, and changing production patterns—in every territorial or demographic unit. The greatest benefits are found in the technologies of sustainability and data management. In other words, in the opinions of the experts who contributed to this research, mining can provide a forward-looking platform for development of the Andean Region if there is planned and coordinated policy action and collaboration.



- **An integrated agenda is required that incorporates digital technologies and technologies for sustainability:** The momentum for an overarching vision of the technologies that are changing the economy will enable the projection of forward-looking scenarios for technological, inclusive, and green mining in the Andean Region that addresses the dual challenges mentioned above. Digitalisation is a source of productivity and sustainable technologies—such as renewable energy, electromobility, and nature-based and circular-economy solutions—open up complementary opportunities for revenue generation or cost reduction, employment, procurement, and innovation. Furthermore, an effort that integrates digital technologies with those that increase sustainability generates more options for compensating any impacts of automation and makes it possible to respond to the challenges of productivity and socio-environmental performance.
- **Gaps in human capital are a barrier to defining an agenda of value for all:** The integration of digital technologies alongside sustainability technologies could encourage mining that promotes fairer, low-carbon and environmentally responsible growth. However, these opportunities are known only to a small group of experts, are not fully integrated into business strategies, and are not part of a coherent, long-term public policy. Examples include green hydrogen, ecosystem restoration, watershed management, and recycling. Strengthening human capital in both government and business is an enabling condition for having an informed debate, for defining actions relevant to each context, and implementing these actions through a collaborative effort. Similarly, the adoption of new technologies can open up opportunities to improve the gender balance in the industry’s workforce.
- **The mining haul (CAEX) truck fleet is an example of a high-potential niche that demands collective action:** It is estimated that Chile and Peru have among the biggest haul truck fleets in the world, possibly in excess of 3,500 units. These fleets require maintenance services and the ongoing retrofitting of new technologies: there is also a need to reduce their carbon footprints. As a result, there is a unique opportunity to build local capacities for the development of regional mining clusters around these great challenges—and these regional markets have the scale to develop production chains to take advantage of technological change and drive changes in production patterns forward. This approach could boost the development of an Andean Mining Cluster that is integrated into global value chains and has partnerships with companies and countries at the forefront of the new technological revolution.



- **Decision-makers form a small group. A coordinated agenda requires only the will:** A small group of mining companies are responsible for more than 50% of the copper production in the Andean Region, which accounts for more than 20% of worldwide copper production. This creates a great opportunity to promote a concerted development strategy around mining that is technology-based, inclusive, and green, an industry in which challenges are addressed collectively and in partnership with government and communities. The problems of agency would be addressable, opening up a promising opportunity. Nevertheless, there is a need for private and public leadership to coordinate and promote a regional agenda that has yet to appear. Understanding and addressing this challenge is essential for the successful adoption of new technologies. Coordinating the actions of mining companies could be a first step toward creating opportunities for harmonised action at the regional level and between the governments of the region.
- **COVID-19 has accelerated adoption and opened up debate on the need for changes in patterns of production:** The COVID-19 crisis accelerated the adoption of remote working practices and introduced new controls and ways of working to maintain continuity of operations without risking human health. It also led to greater concern over the support of local suppliers and communities to cope with the crisis. The need to promote a quick recovery from the crisis has generated an important debate about what form that recovery should take. Some argue that it should be accompanied by investments that, in addition to putting people back to work, could help accelerate changes in production patterns whereby the use of digital technology combined with the development of more inclusive and sustainable forms of production, marketing, and consumption would support alignment with the Paris Agreement. Others prefer to support economic recovery and employment first by means of the “traditional” forms of production that pre-date the pandemic and then gradually implement a transformation agenda.
- **There will be a debate on how to support a recovery focused on a more resilient economy:** A debate will probably open up regarding mining’s role in boosting a recovery that goes beyond returning to the economy as it was prior to the pandemic. It is not a case of simply maintaining operations and renewing investment; there will also be debate around how to use the recovery to advance toward changes in production patterns associated with new technologies and demands for a better environmental and social footprint along with greater inclusion and fairness. There are recommendations from various multilateral bodies such as the Inter-American Development Bank (IDB), International Monetary Fund (IMF) and International Labour Organization (ILO), pointing in that direction. There is also a move to unite public and private efforts, recognizing each territory’s specificities.

- **There is no need to reinvent the wheel; many solutions are already known:** There is a known set of public policies and collaborative efforts. It is crucial that their design and implementation are appropriate and coordinated in such a way that they support the change in production and include the adoption of technologies while promoting the sustainable development of the territories. They include initiatives to create employment and attract talent; initiatives to boost local procurement; initiatives to support local innovation; and initiatives to promote the transformation of production, starting with mining.



Background

The current technological revolution is transforming the economy and every productive sector worldwide and at an ever-increasing pace. Although this global process is irreversible and participating in it is not optional, since the competitiveness and viability of industry depend on it, its impact will depend on how countries prepare to reap the benefits that technology change brings while mitigating its negative effects.

Due to the depth of the transformation, the success of this change will depend on a joint, coordinated effort between industry, government, and civil society to move toward the new forms of organisation, production, and work that will emerge, taking account of each country and territory's specific social and political drivers. This is a systemic change running through the entire economy, which is why no single actor will have the capacity to successfully deal with this complexity. Against this background, public policies and collaborative efforts on the part of industry to accompany the transition to the new forms of production driven by technological and social change take on particular importance.

Also, to take an isolated view of each technology and its applications would hinder understanding of the transformation and, especially, hamper identification of newly emerging opportunities. Obviously, some technologies, such as automation, could lead to reduced opportunities for certain types of more routine and repetitive work or could lead to lower levels of local procurement. However, other technologies, such as the introduction of renewable energy, could foster new investment and generate the opposite effect by creating local employment and procurement. This obliges us to take a holistic view of this transformation and, on the basis of that view, define an appropriate set of policies and collaborative efforts. This also includes looking beyond the technologies that have been traditionally identified with the so-called Fourth Industrial Revolution², such as automation, machine learning, and data analytics, to also analysing the relationships between different industries.

² The Fourth Industrial Revolution is largely centred on interconnection, automation, machine learning, and real-time data analytics. This revolution has enabled connection and access to information and real-time knowledge of processes, products and markets. It is fundamentally changing the way we live, work and interact, having an impact on nearly every industry in every country. Source: Based on WEF (2016) "The Fourth Industrial Revolution: what it means, how to respond"; available at: <https://www.weforum.org/agenda/2016/01/the-fourth-industrial-revolution-what-it-means-and-how-to-respond/>

Mining economies in the Andean Region are not exempt from this process. In particular, large-scale mining in Chile, Colombia, Ecuador, and Peru, for example, are adopting and even developing technologies associated with the ongoing technological revolution to meet production, environmental, and safety challenges so as to maintain or strengthen their competitive positions to continue operating.

New technologies are changing forms of production and work, and this process has increased during the COVID-19 crisis. For example, working remotely has grown as a standard practice, and supply chains are more vulnerable to interruptions, especially those that involve imported components. Moreover, communities and regions are expressing their concern about the impact on employment and the level of local procurement that would accompany the use of new technologies.

It is against this background that the “Mine of the Future for Large-Scale Mining in the Andean Region” project is conducted, as part of the “New Tech, New Deal” international project.³ The objective of this project is to identify options for public policy and collaborative efforts to support the process of adopting and developing new technologies in order to secure the greatest social benefits from the technological revolution that is underway.

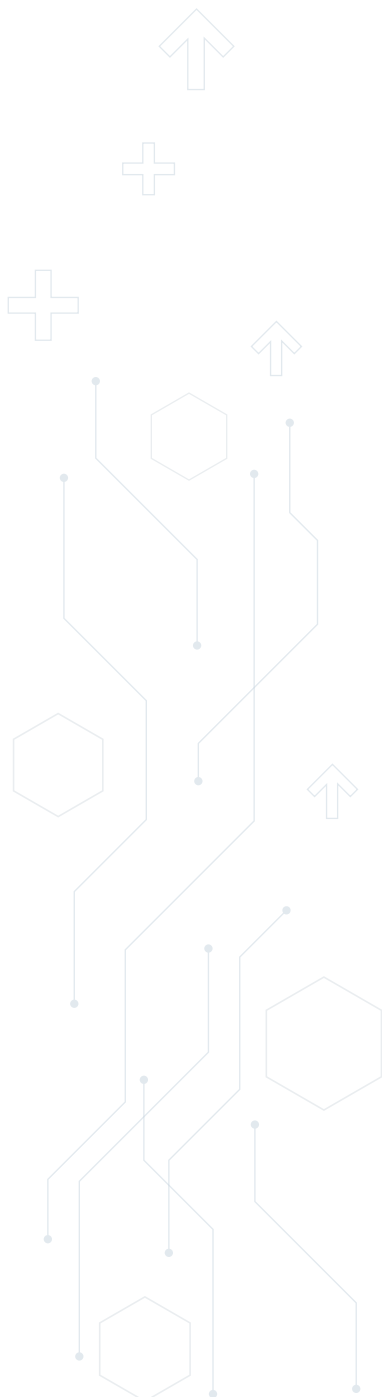
It reflects the visions of mining executives from Chile, Colombia, Ecuador, and Peru, mainly from the private sector and, to a lesser extent, from government officials. It also had significant contributions from experts in the large-scale copper mining sector in Chile. The analysis was conducted through a series of semi-structured interviews and four workshops to identify impacts and present and validate findings. The judgements or perceptions of this group of experts about how the technological change and adoption of new technologies were taking place were systematised, and public policies and a set of collaborative actions to support this process were identified.

Because technological change is driving a transformation that transcends the mining sector, understanding its impact and the possibilities it generates requires a perspective that goes beyond sector-specific considerations.

Specifically, this project seeks to identify:

A. Impacts on mining : The impacts of investment in new technology on the performance of mining companies in terms of costs, the environment, and safety.

³ “New Tech, New Deal” is an international project promoted by the Intergovernmental Forum on Mining, Minerals, Metals and Sustainable Development (IGF) in association with the Columbia Center on Sustainable Investment (CCSI) and the Mining Shared Value initiative of Engineers Without Borders Canada. The project is also supported by German Cooperation, the Federal Ministry for Economic Cooperation and Development (BMZ) and Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ).



The project seeks to understand experts' views on the adoption of technologies that are representative of the current technological revolution in large-scale copper mining in the Andean Region in order to improve its performance. Proper adoption is essential for the industry to remain competitive and an engine of growth; this is, in turn, a prerequisite for the industry to generate social benefits.

Two broad categories of technologies have been identified for analysis:

- i) Technologies that are distinctive to the Fourth Industrial Revolution, such as automation, robotics, and digital products,
- ii) Technologies that are critical for sustainable mining, such as renewable energies, electromobility, and circular solutions.

B. Impact on employment, local procurement, innovation, and production patterns: This analyses the impacts of investment in new technology on both mining companies and their supply chains in terms of employment, procurement, and participation in the generation of solutions (innovation) associated with technological change. The project also seeks to identify the opportunities opened up by the investment into—and adoption of—new technologies to drive the transformation of the local productive and social environment beyond mining, which can be facilitated by the scale of investments in the sector. For example, if mining is driving investments in electromobility, these investments could be used to incorporate electromobility technology into mining towns and regions, generating employment and new productive activity.

The project seeks to learn experts' views regarding the impact of the adoption of new technologies generated by the joint application of these solutions in communities, towns, and metropolitan areas. It is recognised that there may be differences in the impacts of the various technologies; while automation, for example, could adversely affect local employment, investment in renewable energies could boost job creation. Taking an overarching view will help to better identify both opportunities and the most effective mitigation measures.

C. Policies and collaborative efforts: This involves the set of policies and collective efforts that promote the adoption and development of new technologies in order to create value—not only for productive activity, but also for communities and society in broader terms.

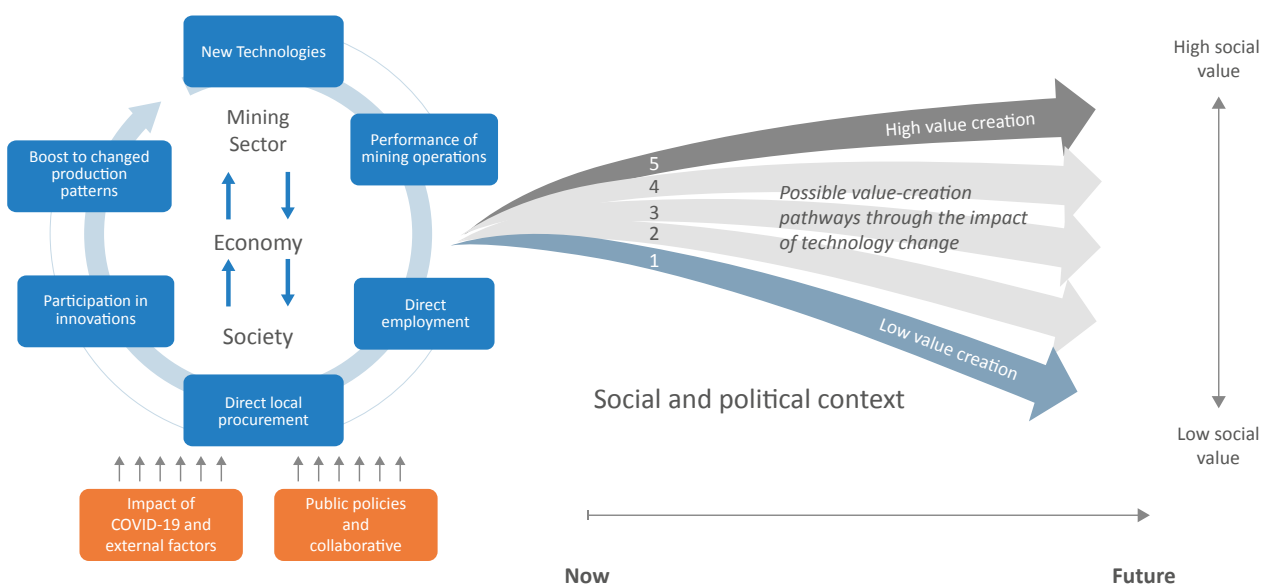
The project seeks to understand experts' perspectives on which policies and collective efforts would boost a process of technology adoption that would strengthen the competitiveness of the sector and encourage the development of the countries, territories, and communities of the Andean Region. This analysis includes the impacts of the COVID-19 crisis and of other setting-related factors that affect the transition process associated with the technological revolution. The COVID-19 crisis and the economic recovery that must follow it, along with other social and political factors specific to the setting, could generate risks or enhance opportunities to reap the benefits associated with the technology change.



For example, the use of new technologies may require enabling investments in both equipment and infrastructure, as well as in training. This could be linked with measures to revive the economy that would not only help the transition toward greater adoption of new solutions but would also contribute to the recovery of pandemic-hit economies.

Figure 1 summarises the analytical framework that was used for the project.

Figure1. Framework for analysis of the impact of technological change on large-scale copper mining
Policies and collaborative actions to drive technology change



The analysis was conducted through a series of interviews with representatives from the mining industry in Chile, Colombia, Ecuador, and Peru. In addition, four workshops were conducted (see Annex 2) with between 15 and 20 expert representatives of large-scale copper mining in Ecuador, Peru and Chile (see Annex 3). This analysis sought to systematise the opinions of experts on how technological change and the adoption of new technologies in the region’s copper industry are being carried out and to identify public policies and the joint collaborative actions recommended to be encouraged for a successful transition to new industrial, technological, and socio-environmental systems. Each workshop built on what was learned in the preceding workshop.

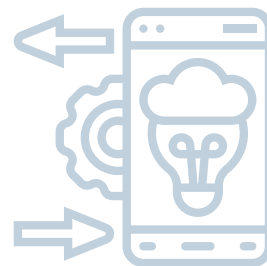
Prior to the series of workshops, more than 20 semi-structured interviews were conducted (see Annex 4) with experts from the mining sector of the whole Andean Region to identify those technologies considered to be representative of the current technological revolution, the factors that would affect the process of technology adoption, and the impacts on countries, their communities, and on the industry's social licence to operate.

The results of the four workshops are presented below, with a proposal to establish a community of practice at the Andean Region level, with the goal of deepening and sharing knowledge on the specific challenges and opportunities related to the adoption of new technologies and to suggest lines of action.

Due to the size of the Chilean mining sector and the fact that it has moved further in the process of technology adoption, this study had greater expert participation from that specific sector (50% of interviews and 74% of workshop attendees). In addition, since most mining-technology experts are from companies, there was less participation of actors representing governments or public-private partnerships (17%). However, in order to further deepen the findings and definition of public policy initiatives, future work should seek more balanced participation of the mining countries of the Andean Region and also greater involvement of experts from governments and civil society.

II.A. Technologies Identified and Their Levels of Adoption

One of the purposes of this study is to help generate a systematised picture of technological change, an integrated vision of its impacts, the opportunities that can be exploited, and the negative effects that require mitigation. The interviews with experts and the workshops identified the need for an approach able to generate this holistic vision. This will identify, for example, areas where job creation will occur as well as those where employment could stagnate or decline. Considering these together makes it possible to identify synergies and mitigating trade-off measures.



Finding 1: A successful transition is based on an integrated vision of technology change.

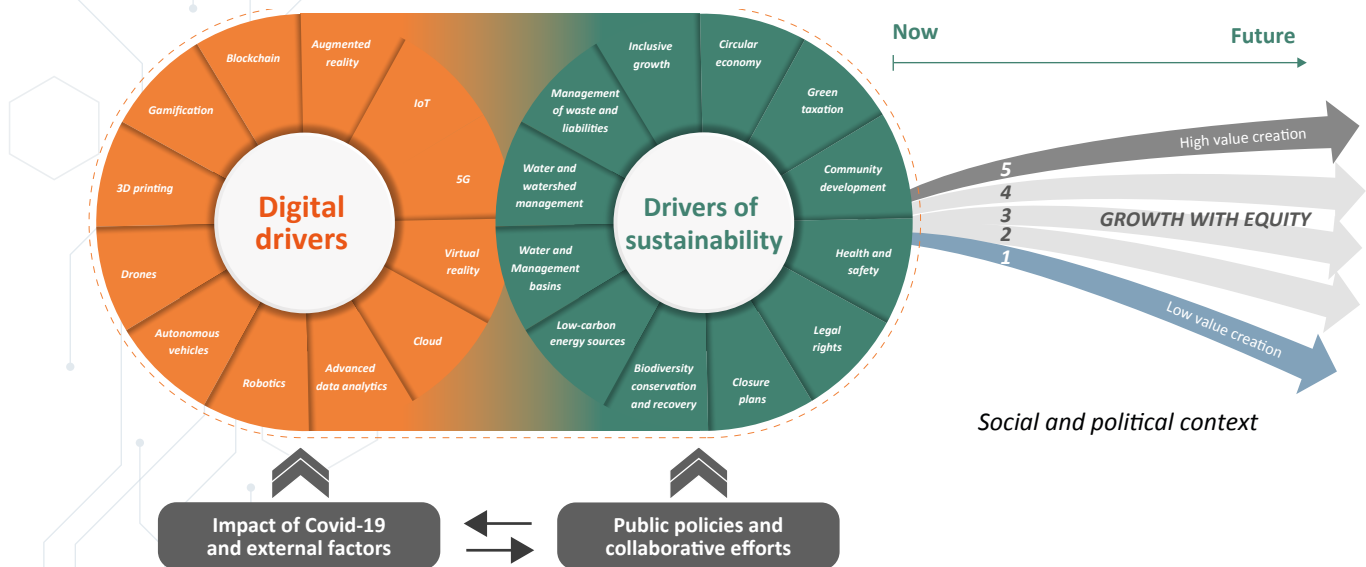
Analysing the combined effect of the solutions that characterise the current technological revolution makes it possible to better identify opportunities and actions for a transition that successfully reconciles a dual agenda of growth and prosperity for communities and territories.

The study identified six technology areas associated with the Fourth Industrial Revolution and four with technologies for sustainable mining. These are presented in Table 1. Additionally, a series of distinct associated solutions is listed for each technology area. The two groups of technology areas are not mutually exclusive. For example, digital technologies are necessary or enabling for technologies that improve the environmental performance of mining. However, despite this high degree of interconnection, it was considered appropriate to differentiate the technology areas, since doing so makes it easier to identify the opportunities that the technological change would bring in terms of increased productivity and of generation of local opportunities for more inclusive development. In the future, other technological fields could be identified to further enrich this overview.

The six areas associated with the Fourth Industrial Revolution were gathered from the work led by Alta Ley Corporation⁴ to develop technology roadmaps for large-scale copper mining, and they were confirmed in the interviews with experts. The four technology areas associated with technologies for sustainable mining were identified from the expert interviews and validated in the workshops.

Diagram 2 shows the two components of the current technological revolution and its two driving forces (digital and sustainability); it illustrates the diversity of technologies associated with this revolution and the joint effect of the two forces to drive forward growth with equity.

Figure 2. An overview for a successful transition



⁴ Alta Ley Corporation is a public-private institution representing the Chilean mining industry. Its purpose is to promote the development of the mining ecosystem and an industry of goods and knowledge-intensive services. Its role is to harmonise and coordinate initiatives, programmes and projects on the basis of defining technology roadmaps to address the most prominent challenges of mining through innovation development, technology transfer, the development of public goods, and collaborative work.

Table 1. Areas of technology of the Fourth Industrial Revolution and of solutions for sustainable mining

Areas of technology of the Fourth Industrial Revolution ⁵	Technology areas for sustainable mining
<p>1. Digital infrastructure</p> <ul style="list-style-type: none"> ▪ Connectivity (GPS, WiFi/4G/5G) ▪ Systems and sensors (Internet of Things [IoT], radio-frequency identification [RFID]) ▪ Cloud Computing and data lakes ▪ IT architecture ▪ Autonomous devices (OT/IoT/IIoT) ▪ Immersive devices (virtual reality [VR]/augmented reality [AR]/ mixed reality [MR] + <p>2. Cybersecurity</p> <ul style="list-style-type: none"> ▪ Information technology(IT)/Information Systems (IS) security ▪ OT/IoT/IIoT security ▪ Supply chain security ▪ Ecosystem security <p>3. Ecosystem integration</p> <ul style="list-style-type: none"> ▪ Interoperability of technologies and systems ▪ Interoperability standards ▪ Legacy systems ▪ Connection layers (Application Programming Interface [API], Services Oriented Architecture [SOA], Enterprise Service Bus, +) ▪ Cybersecurity ▪ Remote Chief Information Officer ▪ IT/OT convergence <p>4. Data management</p> <ul style="list-style-type: none"> ▪ Business Intelligence ▪ Data Analytics ▪ Statistics, AI: Machine / Deep Learning ▪ Blockchain, Big Data, Digital Twins, + ▪ Data Governance ▪ Data Visualization and Presentation <p>5. Automation and autonomation</p> <ul style="list-style-type: none"> ▪ Business Intelligence ▪ Data Analytics ▪ Statistics, AI: Machine / Deep Learning ▪ Blockchain, Big Data, Digital Twins, + ▪ Data Governance ▪ Data Visualisation and Presentation <p>6. Immersive experiences</p> <ul style="list-style-type: none"> ▪ VR / AR / MR & Wearables ▪ Gamification ▪ Digital Twins ▪ Protocols and standards ▪ Development of systems and processes ▪ Change management 	<p>1. Renewable and clean energy</p> <ul style="list-style-type: none"> ▪ Green hydrogen ▪ Photovoltaic solar energy ▪ Solar thermal energy ▪ Low-enthalpy geothermal energy ▪ Heat pumps ▪ Wind power ▪ Hydropower <p>2. Electromobility</p> <ul style="list-style-type: none"> ▪ Hybrid haul trucks ▪ Electric haul trucks ▪ Haul trucks with cogeneration ▪ Pantograph trucks ▪ Loading shovels ▪ Buses and vans <p>3. Nature-based solutions and water resources management</p> <ul style="list-style-type: none"> ▪ Ecosystems restoration ▪ Ecosystems protection (e.g., peat bogs) ▪ Carbon capture (planting, conservation) ▪ Integrated watershed management ▪ Desalination plants ▪ Closure plans <p>4. Circular-economy solutions</p> <ul style="list-style-type: none"> ▪ Recovery of valuable elements from tailings and waste ▪ Scrap processing ▪ Tyre recycling ▪ Sulphide leaching ▪ Spoil heap management

⁵ The identification of the technology areas associate with the Fourth Industrial Revolution was provided by Alta Ley Corporation and was generated from “Hoja de Ruta: Digitalización para una Minería 4.0,” an initiative of Consejo Minero, Fundación Chile and Alta Ley Corporation.

Finding 2: Forming holistic visions remains an ongoing challenge.

Although it is recognised that an integrated analysis of the entire set of technologies defining technology change creates greater opportunities for successful transition, taking this analysis forward is an ongoing challenge. Both business strategies and public policies tend to carry out partial analyses.

The process of technology adoption covers both the ability to use a new technology to obtain productivity gains and capacity to take part in technology change itself. Developing these capacities requires sustained, comprehensive efforts accompanied by action coordinated between the private and public sectors. This is achieved to the extent that technology adoption forms part of companies' strategies and that there are coherent public policies facilitating and promoting its adoption and include actions to mitigate any negative impacts.

It became clear in the interviews and workshops that although policies and strategies do exist to leverage technology change, these do not usually contain a vision that integrates the technologies associated with the Fourth Industrial Revolution and also those associated with more sustainable mining. There is, moreover, little coordination between policies and strategies, and this leads to significant gaps in progress toward the development of processes for collective and collaborative action.

More specifically, more progress can be seen on the integration of the Fourth Industrial Revolution into companies' strategies and into public policy concerns in relation to its impact on employment than on strategies to incorporate technology adoption to strengthen the environmental sustainability of industry.

Finding 3: The industrial revolution is proceeding apace, but its impacts are yet to come.

A successful technology adoption process takes place in stages, and full adoption of the technologies requires an enabling environment. A long-term agenda is needed and a roadmap must be agreed, as does a system of governance that gives stability to this staged development. Cycles of investment in new projects generate unique opportunities to create conditions and make leaps forward on the adoption of new solutions, as a source of growth and prosperity.

If the technologies are not adopted successfully, they will not generate the productivity or performance improvements needed by industry to be competitive and, as a further consequence, will not generate the potential for the development of mining under the desired new technological, productive, and social paradigm. This challenge is both dual and interdependent.

Adoption of a new solution requires the development of an enabling environment and a series of capabilities necessary for the new solution to provide gains in productivity and prosperity. In particular, in the case of the technologies associated with the Fourth Industrial Revolution, Table 1 shows the development of an ecosystem composed of various technology areas (digital infrastructure, cybersecurity, ecosystem integration, data management, automation and autonomation, and immersive experiences).

It is estimated that the adoption of technologies associated with the Fourth Industrial Revolution is already underway in large-scale copper mining in Chile and Peru. Significant progress has been made in respect of digital infrastructure. However, adoption is at the halfway point for cybersecurity, data management, automation, and autonomation. The areas bringing up the rear are ecosystem integration and the development of immersive experiences. This development at different levels for each technology area is to be expected; it is projected that in the next five to seven years, technology areas will be more mature, and this will lead to productivity improvements that have thus far not been significant.

The process is less well developed in Colombia and Ecuador; although these two countries have recently begun developing their investments in large-scale copper mining, it is not clear that the best use is being made of the opportunity to adopt new technologies from the start. This could be partly explained by the lack of enablers such as human capital and digital infrastructure. For example, at Quebradona, the first large-scale copper mining operation in Colombia, many of the technologies have been incorporated into the design of the project. In Ecuador, on the other hand, this has yet to happen.

Investment cycles open up unique opportunities for advances in technology adoption, including the possibility of participating in the process of technological change itself associated with the development of new solutions or innovations. No policies to actively take advantage of this window of opportunity were identified.

Finding 4: Technological niches represent an opportunity.

Technological niches exist that open up major opportunities for employment, local procurement, and innovation; these could form the basis for advancing an agenda of high-value collective action. Achieving this requires coordinated efforts from a limited number of actors.



The number of companies operating large-scale copper mining in the Andean Region is small, and, in turn, there are technological niches that represent significant opportunities for development because of their scale at national and regional levels. For example, the region's large-scale copper mining haul truck fleet is among the largest in the world, consisting of an estimated 3,500 vehicles over the entire region. This is sufficient to identify policies and programmes for collective work to transition these fleets from diesel to electric power.

Several niches with these characteristics were found that have local capabilities to develop an agenda, strategies, and policies with a regional vision. Thus, in addition to the opportunities in respect of the haul truck fleet, the following areas were identified:

- **Development of renewable energy**, such as solar (thermal and photovoltaic [PV]), wind, green hydrogen, and geothermal. Demand from the mining sector, together with the rapid technological development of renewables and a regulatory framework supporting investment in this sector, has helped speed the development of a low-emissions energy system.
- **Transition to electric-powered fleets of loading shovels, buses, vans and pantograph trucks:** Mining needs to reduce the emissions of its vehicle fleets and other mobile equipment that use fossil fuels (Scope 1 emissions) in order to advance green mining. A comprehensive strategy that includes the adoption of electric vehicle solutions helps to reduce emission levels and is also cost-effective, possibly helping to transform non-mining transport systems.
- **Development of desalination systems and integrated water supply:** The need to move toward systems to enable sustainable watershed management requires consideration of the various sources and users of water. This includes desalination; use of fresh or continental water; and recovery. Such an approach would generate reduced environmental impact and would also lead to a significant fall in investment requirements due to their being shared infrastructure developments.
- **Development of solutions for integrated watershed management and ecosystems remediation:** Along with advancing the integrated management of the water resources in each basin, there is also growing pressure to remediate and recover high-value ecosystems associated with these. The Quebradona project in Colombia, for example, is driving the development of a biodynamic park alongside the construction of a tailings dam to recover and protect the biodiversity of the ecosystem in which the project will be situated.
- **Development of circular-economy-based solutions for the management of tailings dams and closure plans:** The minerals held in tailings ponds and other mineral waste deposits open up the possibility of promoting the

development of a secondary mining industry to transform these liabilities into assets through the extraction of valuable elements (minerals) from these deposits.

- **Development of integrated tyre-recycling and scrap-recovery systems:** The requirements and regulations of extended producer responsibility (EPR) are driving the development of a recycling market that could be a source of employment and investment. Worn tyres and scrap recovery represent one of the first opportunities to boost recycling.

Each of these niches is an area of great opportunity and should be fully analysed to understand its associated potential value and the efforts that should be made to create it and ensure that it is accompanied by an inclusive process of prosperity for communities and territories.

II.B. Impacts of Change and Technology Adoption



The expert opinions of the participants in the semi-structured interviews and workshops were used to analyse the impact of technology change on the following variables: (i) employment; (ii) local procurement; (iii) national or local participation in innovation processes; and (iv) how the scale of mining drives changes in patterns of production in the economy in a broader sense. This analysis addressed the impact associated with specific technology areas and also the effect of all the technologies combined.

These impacts were also analysed for different territorial or demographic units. Specifically, we analysed the impacts on the following demographic units: (i) small local communities near mining operations; (ii) towns located in mining regions or territories; and (iii) metropolitan areas, usually the capitals of the countries of the Andean Region. One final factor included in this analysis was the possible changes in impacts on scenarios with and without public policies and collaborative work between business and government.

Finding 5: There are no one-size-fits-all solutions.

Different territorial or demographic units (communities, towns, and metropolitan areas) would be impacted differently by technological change. This implies that there are no one-size-fits-all solutions, and there will be a need for public policies and collective actions that reflect different contexts.

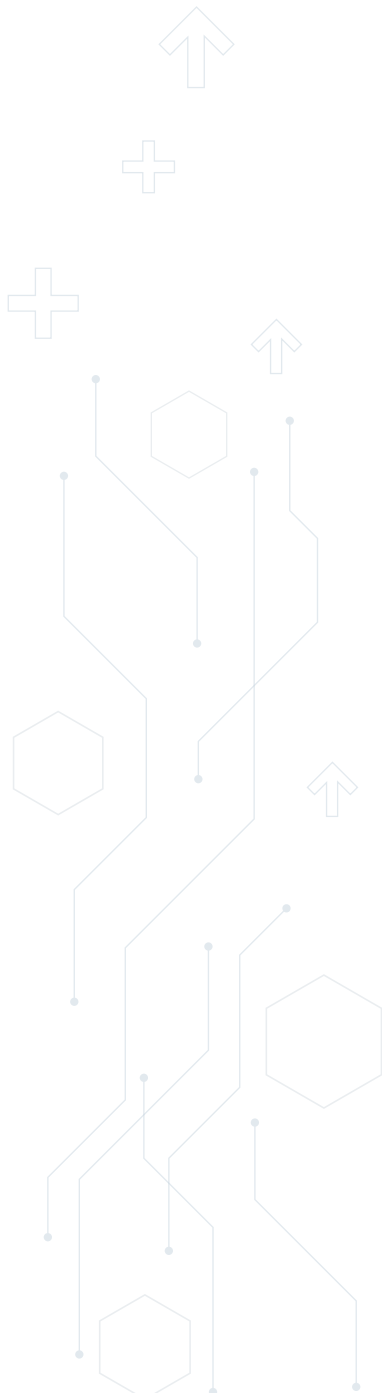
Employment: Without policies or collaborative efforts, local communities will experience the greatest impacts in terms of employment. In general, it is perceived that there would be a slight fall in employment, which could be absorbed by other sectors such as agriculture, depending on the degree of relative dependence on mining and the absorptive capacity of the agricultural industry. Obviously, the effectiveness of labour absorption in agriculture will depend on how this sector is affected by technological change. This impact would be largely mitigated in Ecuador, while in Chile—especially in communities in the mining regions of the north of the country—it is perceived that there could be a greater impact on employment.

In the towns and metropolitan areas, the impact on employment would be neutral or could be offset by the development of other productive activities. Although it is important to again emphasise that each context is different, a wide degree of variation is seen in outcomes depending on the degree of dependency on or integration in mining, especially in mining towns.

Local Procurement: Without policies or collaborative efforts, the situation is similar to that perceived for employment. In other words, local communities would experience the greatest impact. In general, it is thought that there would be a slight drop in local procurement, which could be absorbed by other sectors, depending on the degree of dependency on mining. In the towns and metropolitan areas, the impact on local procurement would be neutral or could be offset by the development of other productive activities. Once again, it must be emphasised that each context is different.

Local involvement in the innovation process: No significant changes are foreseen in terms of historical levels of participation in innovation processes in a scenario with no policies or collaborative efforts at the level of every territorial or demographic unit. It is probable that in local communities the current situation is already one of low involvement, so no great impact is foreseen. Even so, if there are policies and collective efforts in place, it is thought that there would be an increase in participation in all territorial units.

Encouragement for changes in patterns of production: In a scenario of no policies or collective actions, there would be some slight impact. That is to say that, due to its scale, mining could bring about changes in patterns of production that extend beyond the sector, for example to the development of maintenance services, which could serve other industries. With technological change, this process of transformation could weaken.



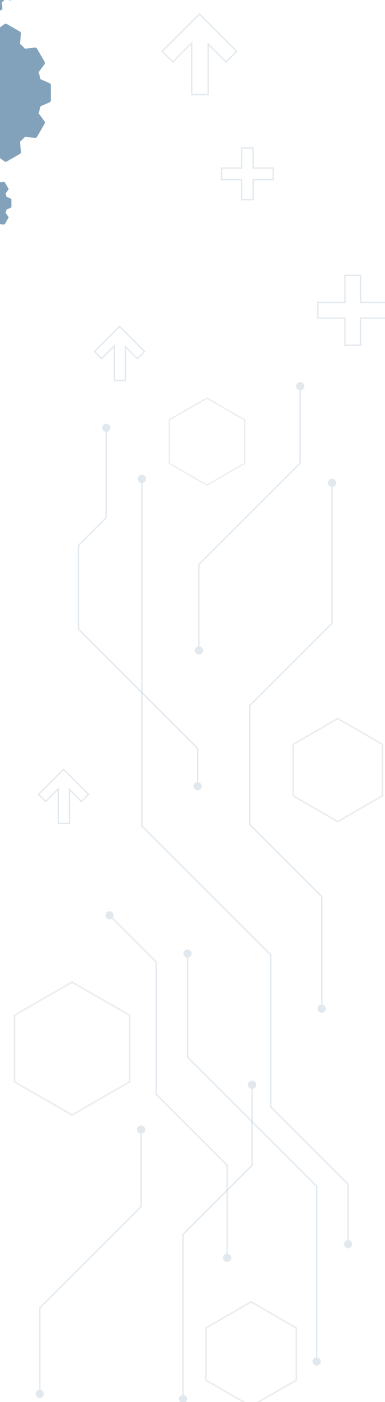
Mining has historically had a greater impact in terms of changing patterns of production in the towns and metropolitan areas, as they could be part of a process of development of a mining cluster integrated into global chains. Here, however, there would be significant variation in the potential impacts of technological change. This suggests that there are outlying scenarios whereby technological change could consolidate the development of an advanced mining cluster or lead to a deterioration in linkages. This will require that policies and collective action be proactive to avoid the less-favourable scenario.

Finding 6: Public policies and collective action are crucial and lead to greater benefits.

Public policies and collective action could generate significant impacts that will make a real difference in transforming challenges into opportunities. It is perceived that this is an area where work remains to be done, which opens up unique opportunities to create value in a sustainable and inclusive manner and move toward changes in production patterns for insertion into the 21st-century economy driven forward by mining. Decision-makers form a small group. A coordinated agenda requires sufficient will, leadership, and planning capacity.

Under a scenario of public policies and collective action, relevant improvements are perceived in practically every one of the impacts described in Finding 5 for every territorial or demographic unit: in employment, local procurement, innovation, and transformation of production. In other words, in the opinions of the experts who contributed to this research, mining can provide a forward-looking platform for the development of the Andean Region.

However, no coherent collective action can be discerned at this point. A collective effort is needed between the large mining companies and the big international suppliers operating in the region, as well as with the state, which must act as the point of articulation of agreements and the generator of enabling policies to lead this process, including the orderly participation of communities and territories. For example, most companies have plans to support territories' development, but they do not make a collective and coordinated effort with each other or with the state. Given the concentration that exists in large-scale copper mining, it should be possible to promote a unified, coordinated agenda based on a shared long-term vision that includes a collaborative effort between businesses, governments, and territories.



Finding 7: The COVID-19 pandemic could act as a catalyst.

The pandemic has accelerated the adoption of some technologies, creating the conditions to promote transition in two stages. Addressing the crisis could drive a recovery using forms of production that have adopted technology change and the integration of the region's communities, territories, and economies. Although technology adoption has mainly occurred in areas related to the digital revolution (such as remote working), this experience shows a way forward to be replicated to promote the transformation of production with a broader vision that includes the greater integration of communities and territories.

The COVID-19 health crisis accelerated the adoption of certain remote working practices and introduced new controls and ways of working to maintain continuity of operations without risking harm to human health. It also generated greater concern about disruptions to supply chains that could affect the continuity of operations and, in some countries, led to suspensions of operations and of investment-project development. It also led to greater attention to supporting local suppliers and communities in coping with the crisis.

The need to promote post-crisis recovery is generating an important debate about what it should look like and what the role of mining should be. A discussion will probably open on the policies needed to drive recovery, the types of investment and support that should be promoted to recover employment and, where possible, to take the opportunity to hasten the pace of changes in patterns of production associated with new technologies and demands for reduced emissions and environmental and social footprint in line with the recommendations of various multilateral bodies. Coordinated public-private action that recognises each territory's specificities will be critical.

Tables 2A, 2B, 2C and 2D illustrate the impacts that the group of experts predict will be associated with technological change on employment, local procurement, innovation, and production transformation, as well as the differences associated with scenarios that embody public policies and collaborative efforts—or fail to do so.

Table 2A. Impact of technology change on direct and indirect employment in communities, towns, and metropolitan areas

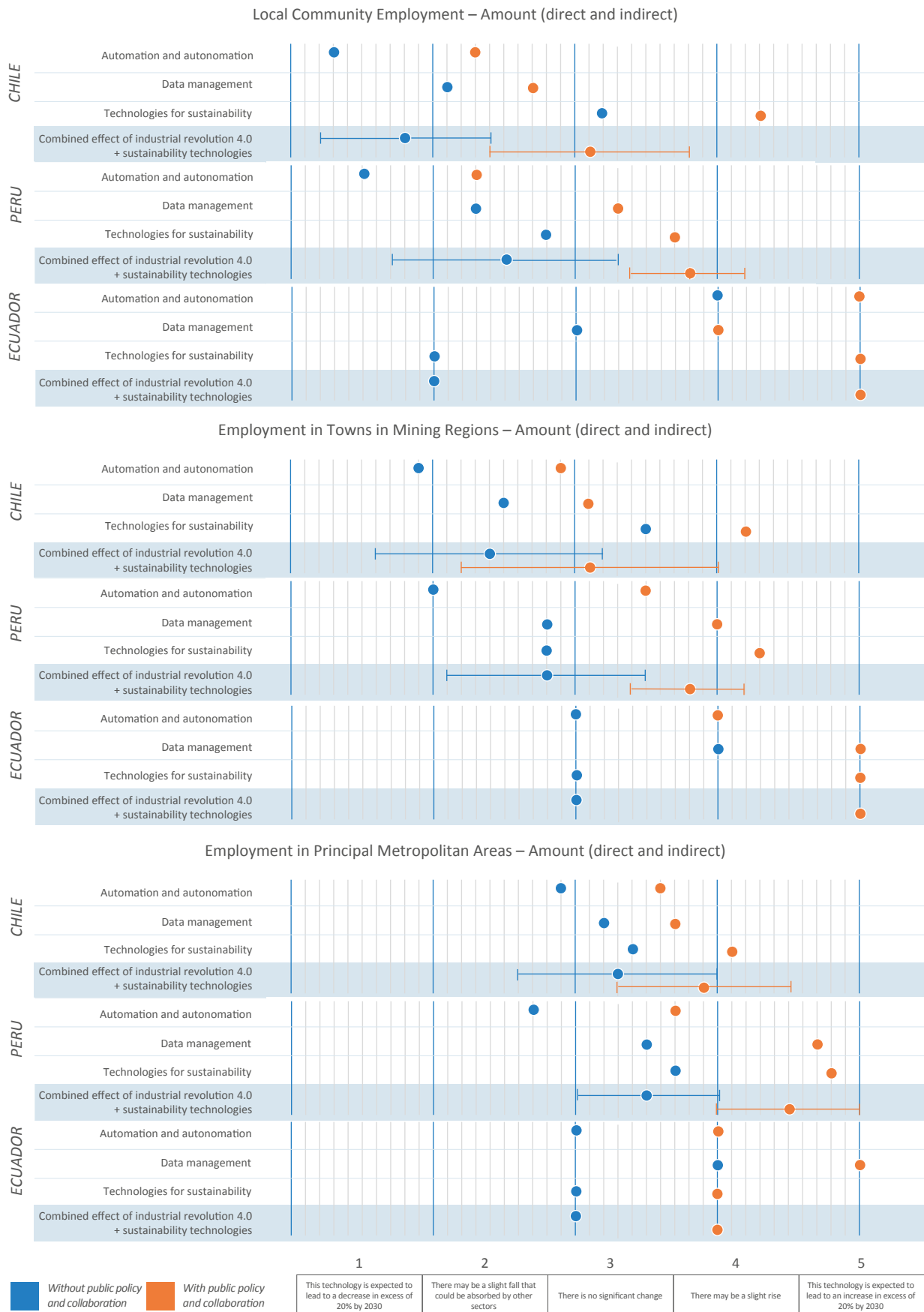


Table 2B. Impact of technology change on local procurement in communities, towns, and metropolitan areas

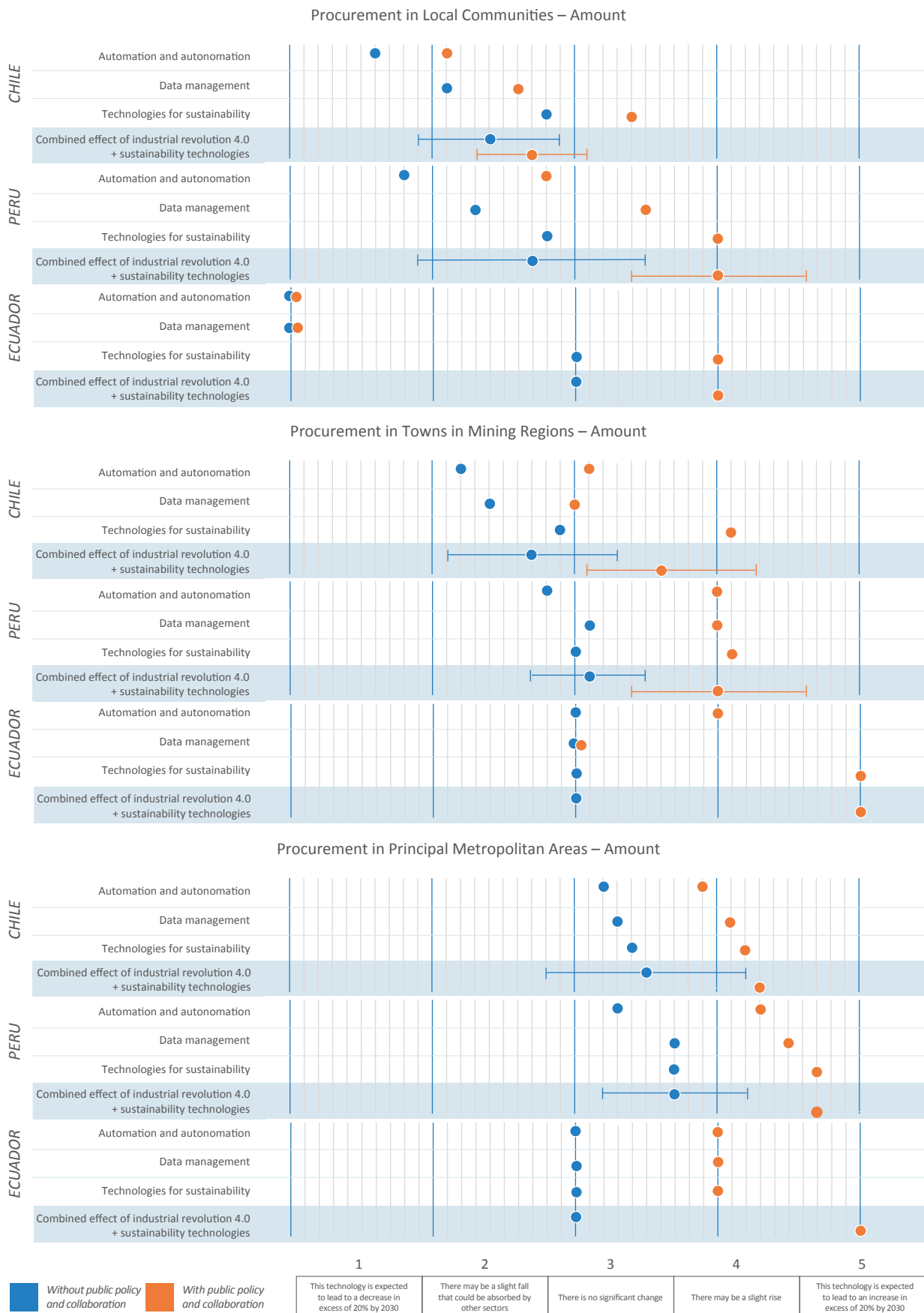


Tabla 2C. Impact of technology change on the development of local-level innovations in communities, towns, and metropolitan areas

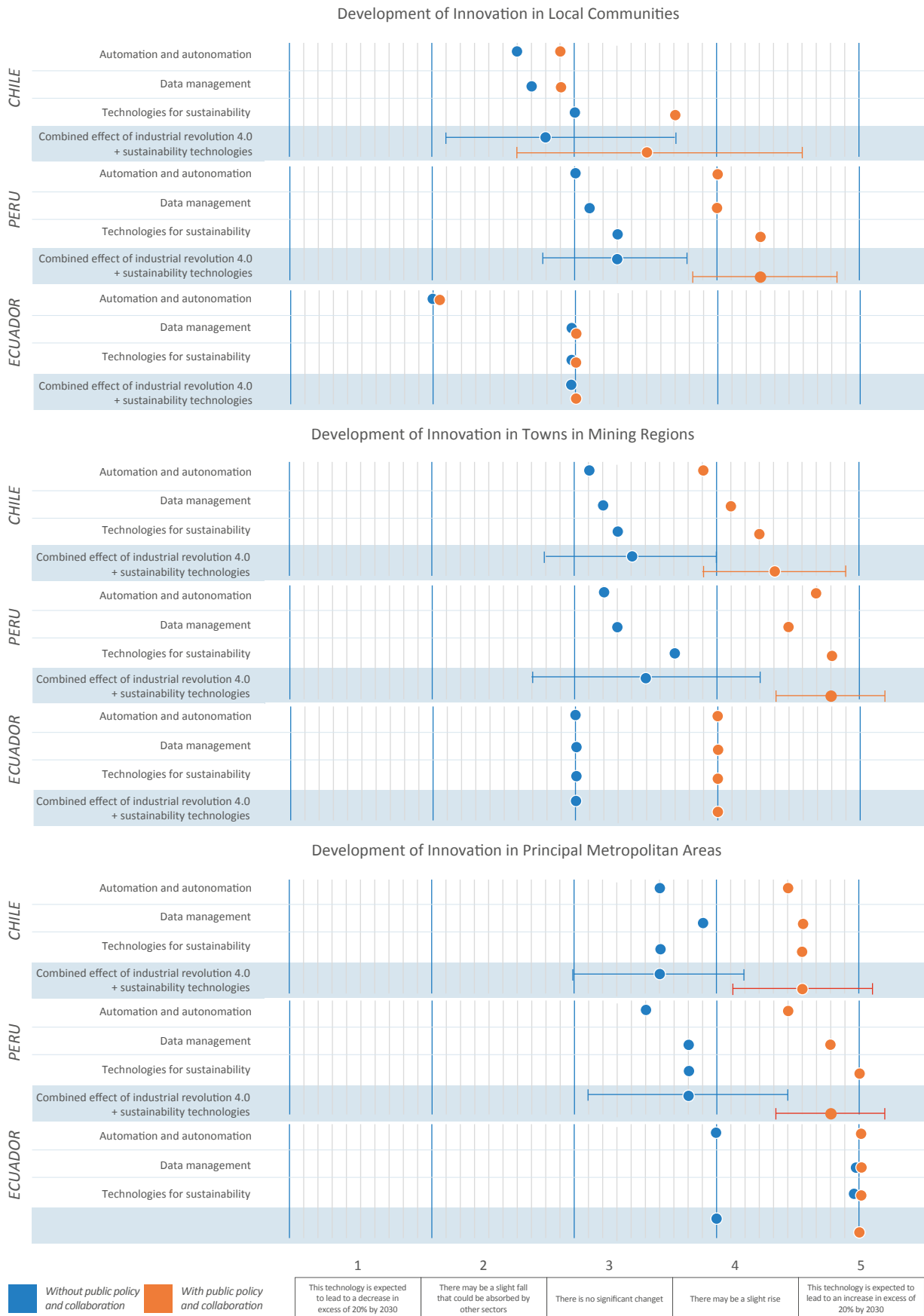
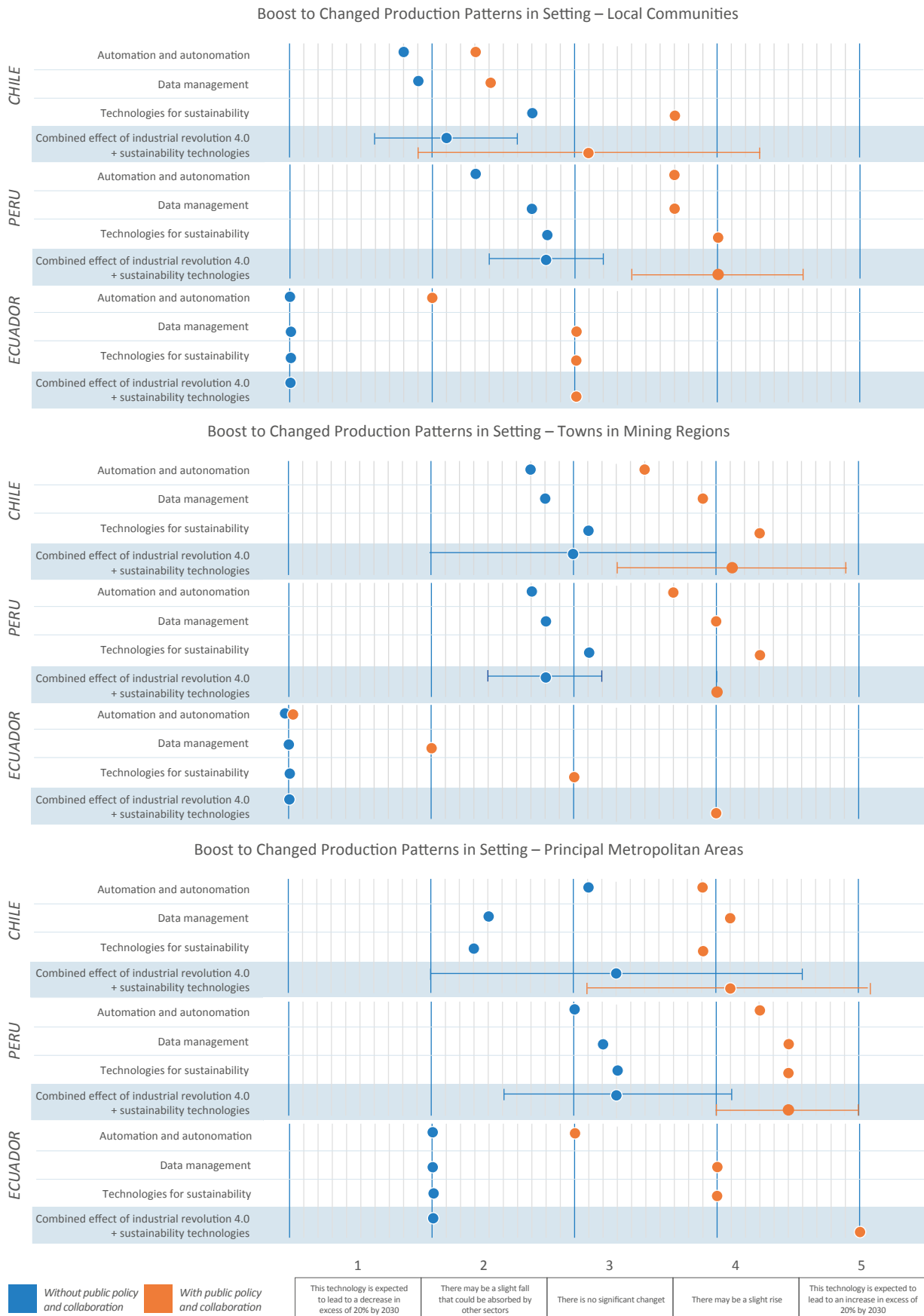
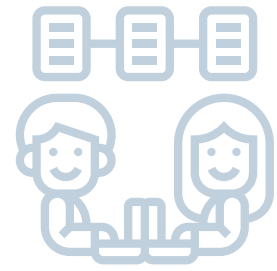


Tabla 2D. Impact of technology change on the transformation of the local productive environment in communities, towns, and metropolitan areas



II.C. Public Policies and Collaborative Efforts



The third workshop focussed on identifying public policies and collective actions that could help the adoption of new technologies to succeed in terms of economic, social, and environmental performance. Supportive policies were identified in the following areas: (i) employment; (ii) local procurement; (iii) national or local participation in innovation processes; and (iv) using the scale of mining to drive changes in patterns of production in the economy in a broader sense.

Finding 8: There is no need to reinvent the wheel, as many solutions are already known.

There are various public policy and collaborative action areas that would encourage the adoption of new technologies, securing the potential benefits of technological change, or mitigating their negative effects. Although several of these initiatives are known, they are difficult to implement due to gaps or barriers such as (i) a lack of (or a lack of access to) high-quality information; (ii) low capacities, especially for public–private coordination, planning, and harmonisation to drive coordinated efforts; (iii) little interest in working collaboratively, leading to fragmented or isolated agendas or efforts; (iv) a lack of trust for developing reciprocal and mutually beneficial relationships; and (v) a lack of leadership to promote inclusive changes to patterns of production.

Areas identified for public policy and collaborative efforts are presented below:

1. Information systems about the needs of industry (knowing the demand):

High-quality information systems are needed that are kept up to date and are easy to access in order to know the needs (and project future demand) of the mining sector for labour, procurement, and challenges that require innovative solutions. These systems require standards for the codifying of data, creation of aggregate statistics, and organisation of information.

The following may be taken as examples:

- a. Development of standardised and certifiable labour-skills profiles, recognised by the mining sector (mining companies and their suppliers) and available as a public good; this would help to predict demand for labour and align training and education efforts.

- b. Projected procurement demand, including technical requirements and volumes. These systems should cover demand for investment projects and for operations.

2. Strengthening local capacities needed to address challenges (strengthening supply): Programmes are needed that strengthen local capacities in terms of training people and developing the capacities of companies, national, and local governments and their settings, including capacities to innovate and develop public goods. The information systems described above are critical to designing work tailored to the real requirements of demand in terms of both quantity and technical skills.

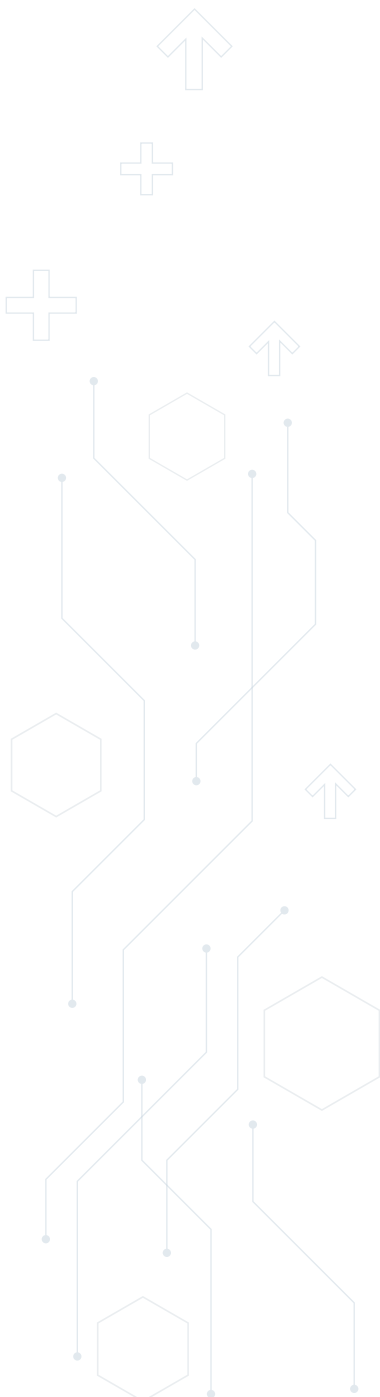
The following may be taken as examples:

- a. Strengthening and development of technical training centres in the territories to promote local employment. These strengthening and development programmes should be designed to meet the characteristics of demand.
- b. Curriculum design of university courses and advanced programmes for developing human capital, such that they meet the needs for advanced knowledge and human capital that will be required to solve the problems and challenges facing mining.

3. Coordination to connect local capacity with industry needs (connecting supply and demand): Efforts to address gaps in coordination, asymmetries of information, and lack of simple procedures that hinder an adequate connection between local/national supply and mining sector demand, in respect of employment, procurement, and challenges that need innovative solutions. These gaps hamper the proper design of capacity-building activities aligned with the present and future needs of the industry and territories.

Examples of this include:

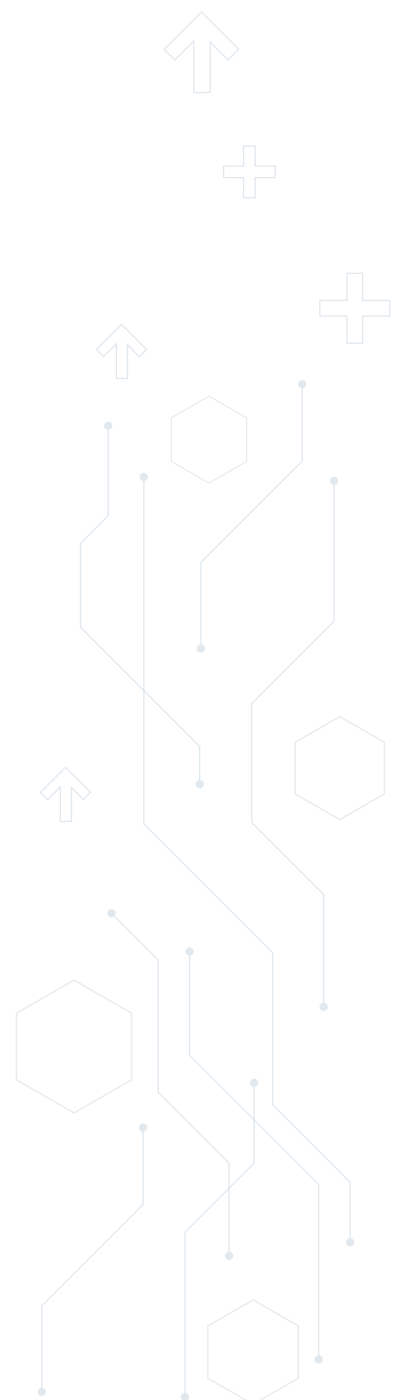
- a. Simplified local procurement systems for local businesses, including the mining companies and large suppliers, and that these have state guarantees for affordable access to credit.
- b. An open platform for innovation that gives local and national actors an opportunity to take part in developing solutions to the challenges of mining operations and large suppliers.
- c. Development of technological roadmaps around strategic challenges (such as mining without tailings). Development of these roadmaps could be approached as an effort to be made across the entire Andean Region, thus benefiting from economies of scale. Areas of specialisation could be set for each country and include international technological partnerships.



- d. A competitive mixed fund to solve industry challenges (such as a system for the online monitoring of the condition of a basin’s aquifers or circular-economy solutions to reduce mining waste). The fund should cover the entire knowledge chain through to scaling up to the industrial level and marketing in order to truly close the innovation cycle.
 - e. Development of contracts between mining companies and suppliers, and between suppliers and suppliers, to develop R&D&I that incorporates a complete overview of the process of innovation and scaling of solutions, capable of attracting investors interested in supporting innovations.
 - f. Development of opportunities for testing, piloting, and industrial upscaling for the development of innovations without risking the operational continuity of mining operations.
4. **Requirements and incentives for greater local, territorial, and national involvement and for attracting investment:** Requirements and incentives to encourage greater involvement, inclusion, and use of local and national capacities to meet employment demand, supply products and services and develop innovations for the sector in order to effectively become part of a sustainable process of value creation around mining. In addition, the changes in patterns of production driven by technology change and new social and market demands will require significant investments, and the region will have to demonstrate that its mining, including its linkages, is a great opportunity for this. Requirements and incentives also play a role in attracting the investments that the region needs.

Examples of this include:

- a. Tax incentives to support investment in training, education, and formation of human capital.
- b. Tax incentives to encourage local procurement, including the development of local content and development of local suppliers.
- c. Tax incentives to increase investment in research, development, and innovation (R&D&I) related to strategic issues.
- d. Tax incentives to support the development of high-value public infrastructure for the territories (such as the “Works for Tax” programme in Peru).
- e. Establishment of quotas for local procurement and supplies, together with strengthening productivity and competitiveness to avoid passive rentier practices.



- f. Mixed financing systems from seed capital through to industrial scaling and marketing.
- g. Programmes to develop telecommunications infrastructure to provide high-speed Internet access in every territory and location to enable remote research and work.
- h. Regulation to establish open standards for interoperability to avoid closed systems that block the participation of local actors.
- i. Position the region as a hub for the production of green, traceable copper that is a source for low-carbon solutions.

5. ollective integrated development plans: Work to develop shared visions that help define an agenda for long-term collective work in partnership with government, business, communities, and workers to address strategic challenges faced by territories and countries.

Examples of this include:

- a. An integrated master plan for changing patterns of production and developing the territory. It would guide and seek synergies between public, productive, and companies' social investment and acknowledge specific territorial vocations beyond mining.
- b. A local development plan for quality of life in mining districts, including health, education, and recreation in addition to productive development. Part of productive development can be targeted at strengthening local intermediate-level suppliers for the entire industry. The development of other activities can also be supported, depending on each territory's productive vocation beyond mining (for example, livestock, agro-industry, tourism), helping diversification.
- c. Development of regional centres of excellence around niches that have scale and need advanced capacities to drive the development of exportable products and services (such as Circular Economy Centres).
- d. Promote a plan for energy transition as a tool for recovery.

III. Recommendations and an Agenda for the Adoption of New Technologies in the Large-Scale Mining Industry in the Region as an Opportunity



The process of technology adoption is progressing apace, and the COVID-19 pandemic has accelerated it further. At the same time, it has also shone a light on the importance of technology adoption, taking account of social and political variables and, especially, the local demands of territories.

In this context, the Andean Region and its mining sector are at a crossroads. On the one hand, there is an opportunity to drive a development process forward that launches it into the future; on the other hand, there are still conflicts and tensions.

In this context and on the basis of the findings of this research, the following elements are proposed for consideration when drawing up an agenda to promote the adoption of new technologies in the mining of the Andean Region:

- I. **A holistic vision for technological, inclusive, and green mining:** Further development of a holistic vision of the impact of technologies that are changing the region's economy and mining sector, to lead the transition to technological, inclusive, and green mining and address the dual challenge of driving sustainable growth and greater equity. Work done from a holistic perspective opens up more options to offset the possible negative impacts of automation while addressing the challenges of productivity and socio-environmental performance.

For example, digitalisation is a source of productivity and sustainable technologies—such as renewable energy, electromobility, and nature-based and circular-economy solutions—that open up complementary opportunities for the generation of employment and local procurement and innovation. For example, government programmes in each territory (to encourage the development of investment and training in renewable energy and thus reduce emissions from mining) together with improved Internet and telecommunications infrastructure, would help ensure that the new jobs associated with greater digitalisation and cleaner energy were available in each territory.

II. Promote an agenda of relief and recovery with inclusion: To define an agenda to encourage the adoption of new technologies in the mining industry of the Andean Region, one cannot ignore the urgency and pressing need to relieve the health crisis and the need to drive a recovery from the impacts of COVID-19. In this context, it is probable that a debate will open around support or stimulus policies that could lead to a reallocation of public spending and possibly the seeking of new funds to finance and promote recovery.

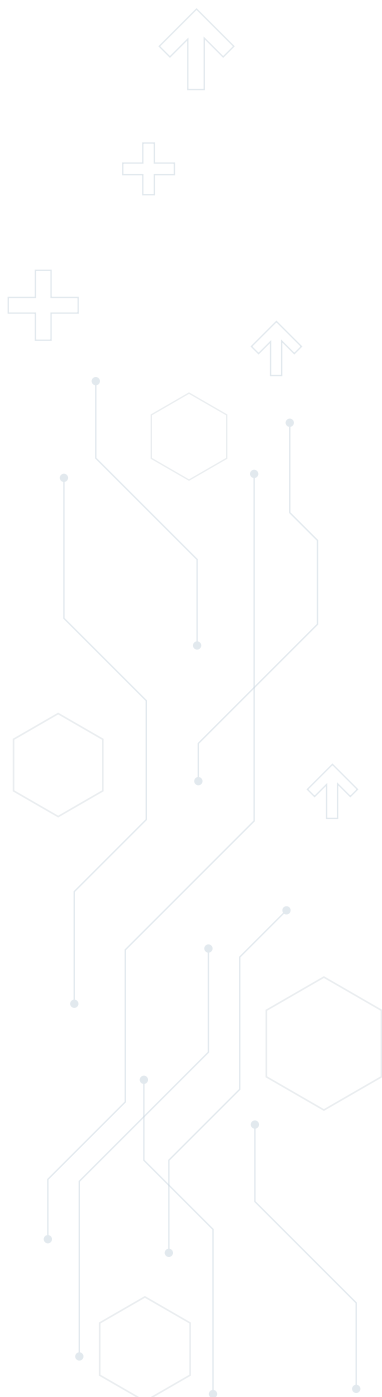
Here, the process of technology adoption should be inclusive, giving preferential consideration to capacities that already exist or can be developed, at both territory and national levels. This would be so that local actors are involved in the value creation process associated with sustainable mining, addressing gender gaps, and helping build a relationship of mutual appreciation and benefit between companies, communities, and the state.

III. Comprehensive development plans tailored to each territory's specificities, including the system of governance: Complement efforts to adopt new technologies by actively supporting comprehensive territorial development plans going beyond mining. This would not only help close any gaps that might impede local participation in the process of generating value from mining but also support more comprehensive development and a better quality of life and to drive sustainable productive and economic development that recognizes each territory's particular characteristics.

Develop governance models that facilitate collective action and public-private cooperation, that are highly transparent, and that enable the strengthening of linkages of trust between communities, businesses, government, and other stakeholders.

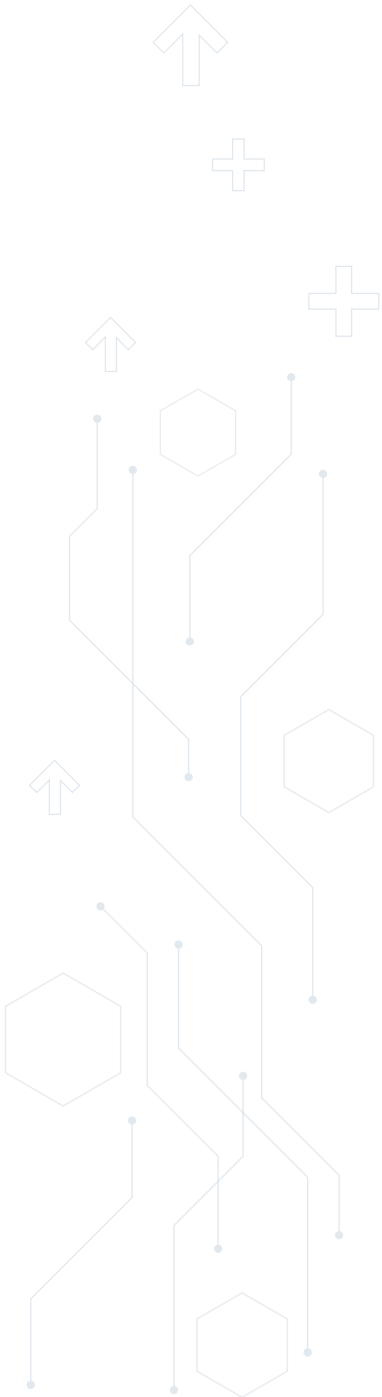
IV. The Andean Mining Cluster with strategic international alliances: Further develop the feasibility analysis of the development of an Andean mining cluster that is integrated into global value chains and developed in partnership with the companies and countries that are at the forefront of the new technological revolution, on the basis of the opportunities and challenges brought by the adoption of new technologies and in light of the fact that each context is unique and that there is no one-size-fits-all solution.

This analysis can be focused on strategic challenges that could be pull factors in the development of high-impact strategic collective agendas. For example, the size and importance of the haul truck fleet used in the region's mining operations could be a high-potential niche for defining a long-term agenda.



The following list presents a series of issues that were preliminarily identified as specific work areas that would require more detailed development:

- 1. Shared infrastructure and integrated management of water:** Development of management systems for water desalination and supply based on the development of shared infrastructure models.
- 2. Electromobility and low-carbon energy:** Development of the electromobility roadmap for the trucks, other vehicles, and mobile equipment used in the mining operations of the Andean Region (haul trucks, loading shovels, buses, vans, and pantograph trucks).
- 3. Carbon market, emissions traceability and monitoring, and nature-based solutions:** An agenda to lead the transition to low-carbon mining, together with the development of a services hub for green mining, to include mining that is 100% traceable and digital; a development plan for a regional carbon and environmental services market; promotion for renewable power, such as solar (thermal and PV), wind, green hydrogen, and geothermal energy; and solutions for integrated watershed management and ecosystems remediation.
- 4. Circular economy for low-waste mining:** Discover and exploit the potential of the circular economy in large-scale copper mining, including circular-economy-based solutions for the management of tailings dams and closure plans, along with integrated systems for tyre recycling and scrap recovery.
- 5. Other issues:**
 - a. Attracting talent from the digital and technological worlds for sustainability
 - b. Observing linkages between suppliers and development plans
 - c. Cybersecurity centre with capacity for early warning and response to cyber attacks
 - d. New leadership for a renewed social licence to operate
 - e. Monitoring and reporting of use and impact of public resources



Next steps: It is proposed that the work begun in this project be continued through the creation of communities of practice to understand the development potential of specific high-potential challenges (such as those mentioned above) and propose actions to promote an agenda of collective work and high impact (Annex 6 contains a proposal for moving in this direction).

The areas that are seen as most urgent for progressing toward development of sustainable mining in the Andean Region are linked to digitalisation and information management and reinforcing the development of solutions to challenges related to the environment and climate and social change.

Table 3 summarises how the eight findings described above link with the four elements of the aforementioned agenda.

Table 3. Elements of an agenda to drive adoption of new technologies and findings

Finding	Elements of an agenda for the successful adoption of new technologies			
	I. A holistic vision for technological, inclusive, and green mining	II. Promote an agenda of relief and recovery with inclusion	III. Comprehensive development plans tailored to each territory's specificities	IV. The Andean Mining Cluster with strategic international alliances
F1 and F2: Needs comprehensive analysis	X		X	
F3: Staged adoption and use of investment cycles		X	X	
F4: Taking advantage of niches of opportunity requires coordinated collective action (public-private)		X	X	X
F5: Different territories and urban areas, different impacts, and different solutions			X	
F6: Need for public policy and collective action for successful adoption			X	X
F7: COVID-19 accelerated technology adoption; staged planning needed for relief and recovery		X	X	
F8: Areas of public policy and collaborative efforts exist and are known			X	

In the course of the interviews and successive workshops held in this study, the government's critical role was clearly identified, at both national and territory level, to promote an agenda that supports the successful adoption of new technology along with a transformation in patterns of production in the broader sense. However, it is generally perceived that government has played a passive role and that the significant opportunities that technological change could bring, which require coordinated and collective efforts, have not been fully exploited. The same would seem to be the case regarding implementation of a coherent series of measures to mitigate the unwanted effects.

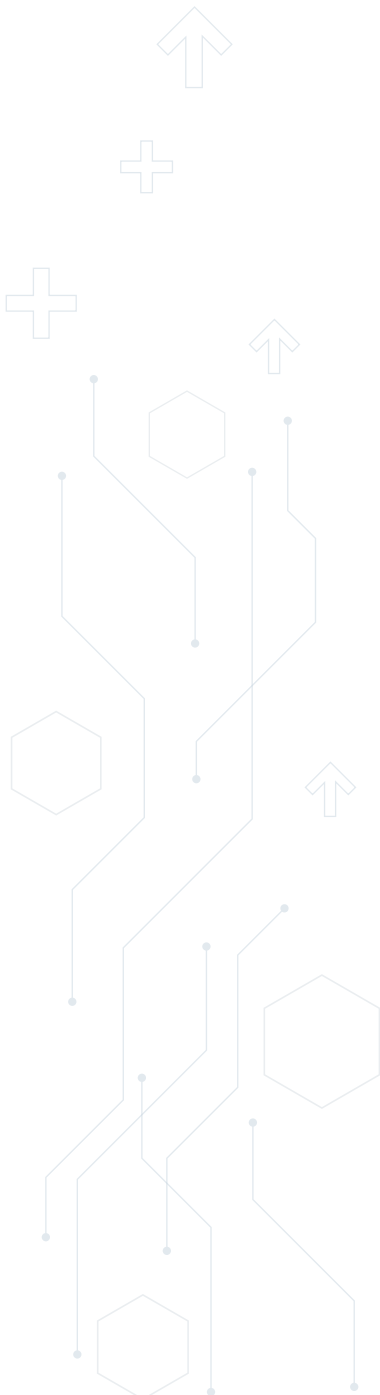
There are specific roles that exist at the central government level and others that require greater leadership from regional governments to reflect each territory's particular characteristics. Because of this, it seems essential to build capacities and trust in government, especially at the territory level, to proceed with integrated development plans that reflect each territory's specificities and are coherent with and complementary to national policies. Furthermore, momentum for an Andean Region-wide vision that includes international partnerships and a holistic approach could be a defining element of a collective agenda shared between countries. Lastly, plans for relief and recovery from the pandemic will require high degrees of coordination and consistency between all levels, under the guidance of national government



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2. Sequence of Interviews and Workshops

- **Interviews With Experts (July and August 2020):** Technologies and critical factors.

More than 20 interviews with mining-company executives, consultants, researchers and government officials to identify technologies and critical factors and to define the design of the four virtual workshops.

- **Workshop 1 (20 August 2020):** Identification of representative technologies.

Identification of the series of technologies representative of the technological evolution in large-scale copper mining in the Andean Region, and characterisation of their degree of adoption and integration into business and government strategies.

- **Workshop 2 (03 September 2020):** Impacts of technology change, contextual factors, and COVID-19.

For the series of technologies selected, the impact is estimated in terms of employment, procurement, innovation, and support for changes in patterns of production, taking account of setting-related factors affecting this process and the Covid-19 crisis.

- **Workshop 3 (15 September 2020):** Public policies and collaborative efforts.

Identification of public policies and collaborative efforts to support a successful transition.

- **Workshop 4 (26 November 2020):** Validation of findings and identification of issues.

Presentation and validation of findings and identification of issues for further work in subsequent studies.

3. Lists of Experts Interviewed and Workshop Participants



Name	Position and organisation	Country	Interview	Workshop 1	Workshop 2	Workshop 3	Workshop 4
Cleve Lightfoot	Head of Innovation, BHP	Chile			X		X
Alan Muchnik	Head of Innovation, Antofagasta Minerals	Chile		X	X		
Andres Hevia	VP Strategy and Innovation, Antofagasta Minerals	Chile	X				
Hernán Araneda	Head of Human Capital Innovation Centre, Fundación Chile	Chile	X				
Andres Mitnik	Director of Business, Expande, Fundación Chile	Chile		X	X	X	X
Sebastián Carmona	Head of Innovation, Codelco	Chile	X		X		
Pedro Damjanic	Senior VP, Minería Finning	Chile	X				
Patrick Hall	Partner, Strategy and Mining, Deloitte Consulting Chile	Chile	X				
Marcel Villegas	Leader, Energy & Resources, Deloitte Chile	Chile	X				
Nicolas Jubera	CEO Timining	Chile		X	X	X	
Dominic Collins	Mining Leader, Deloitte Chile	Chile	X				
Juan Carlos Román	Head of Operations/General Manager, Anglo American Sur, Anglo American	Chile	X	X	X		
Jorge Cantallopts	Director of Research and Public Policies, Chilean Copper Commission	Chile			X	X	
Fernando Lucchini	President, Alta Ley Corporation	Chile		X	X	X	X
Ignacio Flores	Operational Excellence Superintendent, Collahuasi	Chile		X	X	X	X
Gianni López	Director, Centro Mario Molina Chile, CORFO R&D Centre	Chile		X	X	X	X
Alejandra Molina	General Manager, Minnovex	Chile		X	X	X	X
Diego Lizana	Deputy Director, Energy Efficiency, Antofagasta Minerals	Chile		X	X	X	
Víctor Pérez	Alta Ley Corporation	Chile		X	X	X	X
Javier Ruiz del Solar	Executive Director, AMTC, University of Chile	Chile		X	X	X	
Carlos Rebolledo	Business Development Manager, EcoMetales Limited	Chile		X	X	X	X
Nancy Pérez	Codelco	Chile			X		
José Antonio Díaz	FME and CEIM	Chile		X			X
Eduardo Valente	Lead Partner, EY Consulting	Chile					
Ricardo Labó	Mining Partner, LQ Energy Group	Perú		X	X	X	X
Gonzalo Delgado	Executive Director, CEMS, University of the Pacific of Peru	Perú	X		X	X	
Benjamin Quijandria	Director, Minero del Sur Cluster	Perú	X	X	X	X	
Emilio Gómez de la Torre	General Manager, Linkminers	Perú			X	X	X
Cory Stevens	VP Operational Improvement, Freeport	Perú	X				
Rafael Estrada	ICT Manager, Antamina	Perú		X	X	X	X
Laura Zurita	Former Manager, Government Relations, Mirador (CRCC)	Ecuador	X	X	X	X	X
Fernando Benalcazar	Deputy Minister of Mines	Ecuador	X				
Felipe Márquez	President, Anglo Gold Ashanti (Quebradona)	Colombia	X				
David González	VP Promotion and Development, National Mining Agency	Colombia	X				
CESCO Team		Country	Interview	Workshop 1	Workshop 2	Workshop 3	Workshop 4
Oswaldo Urzúa		Chile	X	X	X	X	X
José Joaquín Jara		Chile	X	X	X	X	X
Nicolás Jubera		Chile		X	X	X	
Alejandra Wood		Chile	X	X	X	X	X
Alejandra Rivera		Chile		X	X	X	X
América Rodríguez		Chile		X	X	X	X

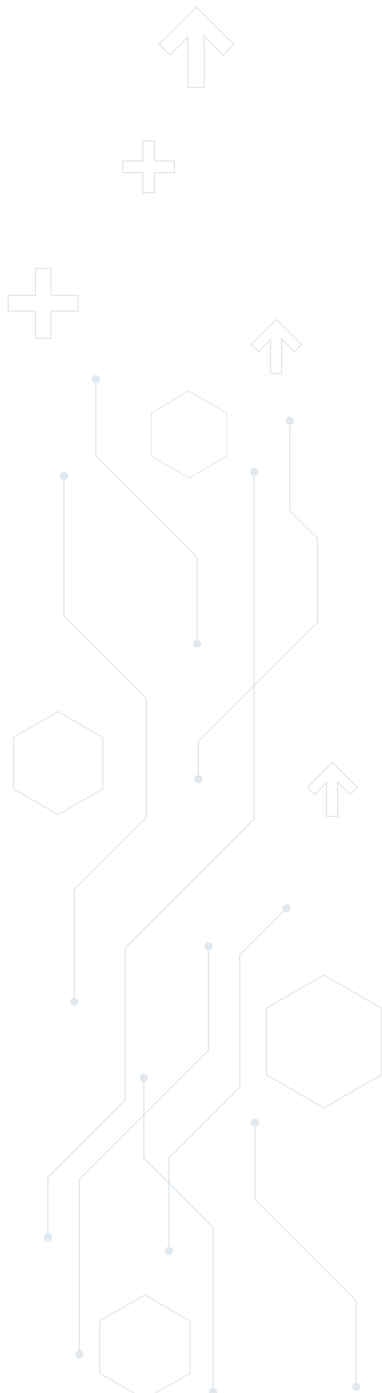


4. Interview Guide

Name and position: Date:

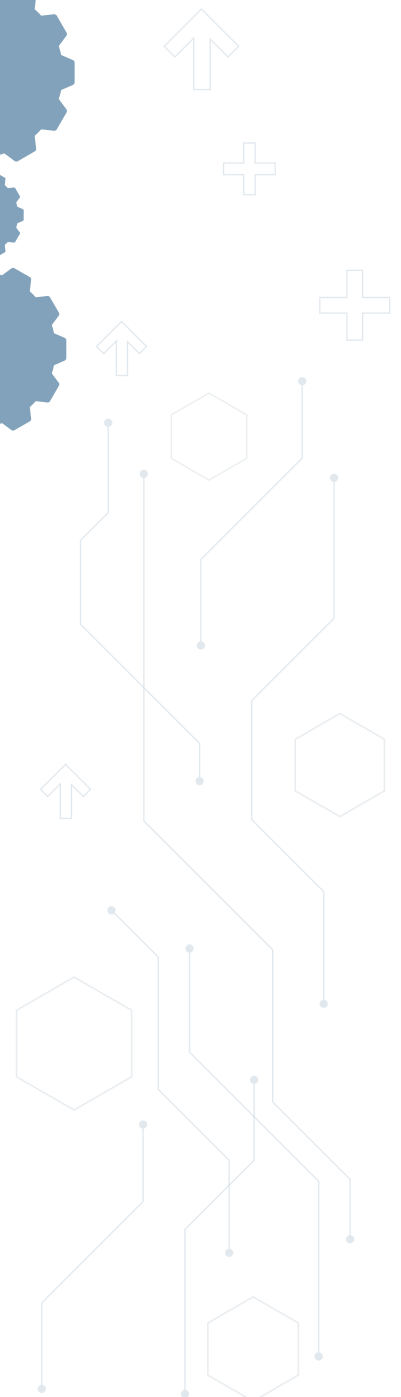
Background:

- The goal of this project is to assess the **full impact of new technologies** and to propose **pragmatic options for policies and collaborative efforts** to support obtaining the full potential of these new technologies.
- It is an **international project** of the Intergovernmental Forum on Mining, Minerals and Sustainable Development (IGF) in partnership with the Columbia Center for Sustainable Investment (CCSI) and Mining Shared Value/Engineers Without Borders Canada. The **countries** studied include Burkina Faso, Democratic Republic of Congo, Mongolia, South Africa and the Andean Region (Chile, Colombia, Ecuador, and Peru), with a focus on copper.
- It has the support of German Cooperation, the Federal Ministry for Economic Cooperation and Development (BMZ), and Deutsche Gesellschaft für Internationale Zusammenarbeit.
- CESCO is conducting the study of the Andean Region.
- **Totally confidential** (Chatham House Rules)
- Research questions:
 1. What **technologies are being adopted**, and how have they affected operational performance?
 2. How **will the workforce change** as new technologies are adopted?
 3. How **will the supply chain change** as new technologies are adopted? When?
 4. How will technological change impact **local communities** and mining regions?
 5. What are the main **risks and opportunities** associated with the adoption of new technologies, and how is Covid-19 shaping that process?
 6. What are the **main initiatives** of the mining companies, suppliers, and governments to support the adoption and development of new technologies?



Key Questions for This Interview:

- What are the **most important technologies** being or going to be adopted? Why? Can you give some features or examples? Any sources of information?
- What is happening with the **impact on communities**? Which technologies will impact communities the most?
- What are the **main challenges**? Political, economic, social, technological, legal?
- Are you receiving any **relevant government support**? Support from others?
- Is there a difference between the adoption of technologies in **copper mining** and mining for other minerals? Is there any technology used only in copper?
- We would like to select a sample of processes/technologies for detailed analysis and, on the basis of this sample, get a better understanding of what is shaping the process of implementing new technologies. **What processes or technologies would you suggest? Why?** We would like to have a degree of diversity to represent the different realities that exist from exploration through to processing.
- Could you suggest a **name for contact or reference**? Could you suggest a successful or unsuccessful **experience** for us to look at?
- Do you have any **suggestions** or matters of interest?





5. Critical Factors Survey

A set of statements is presented below on the challenges, opportunities and actions associated with change and the adoption of new technologies in large-scale mining in the Andean Region. Please state the extent to which you agree with them, using the following scale:

1. I strongly disagree.
 2. I disagree, but there are some elements with which I agree.
 3. I partially agree.
 4. I agree, differing on some small details.
 5. I strongly agree.
- I. The technologies of the Fourth Industrial Revolution (such as digitalisation) and the technologies associated with improving environmental performance (such as the use of low-emissions renewable energy) are considered crucial to the development of sustainable mining.
 - II. The mining companies have fully integrated adoption of the Fourth Industrial Revolution into their growth strategies; they have units responsible for this with the necessary powers and budgets to coherently address the work required.
 - III. The mining companies have fully integrated into their growth strategies the use of technologies with high impact on sustainability, such as renewable energy, electromobility, nature-based solutions, and circular-economy solutions; they have units responsible for this with the necessary powers and budgets to coherently address the work required.
 - IV. Governments have fully integrated promotion of adoption of the Fourth Industrial Revolution into their policies, regulations, programmes, and plans; they have units responsible for this with the necessary powers and budgets to coherently address the work required.
 - V. Governments have fully integrated, into their policies, regulations, programmes, and plans, promotion of the development and use of technologies with high impact for sustainability, such as renewable energy, electromobility, nature-based solutions, and circular-economy solutions; they have units responsible for this with the necessary powers and budgets to coherently address the work required.
 - VI. There is a set of technologies that could be important sources of solutions for sustainable mining but which are known only to a small group of experts; they are not integrated into business strategies and are not part of public policy. There could be significant opportunities to create value that are not being exploited. Particularly noteworthy in Chile are green hydrogen, electric mining haul trucks, ecosystem restoration, and watershed management. In Peru, they particularly include solar PV, electric mining haul trucks, ecosystem restoration, watershed management, and recycling.

VII. Green hydrogen may be a mature technology in the next decade.

VIII. Although green hydrogen is not yet a mature technology, the Andean Region should participate in its development in partnership with international frontrunners that are already making decisive moves, in order to have the opportunity to lead a strategic sector of the world economy.

IX. Chile and Peru have, between them, one of the biggest fleets of mining haul trucks in the world. It is estimated at more than 3,500 trucks. These fleets require maintenance services, need to continually retrofit new technologies, and should reduce their carbon footprints. This opens up a unique opportunity to generate local capacities for the development of local clusters around this equipment.

X. A small group of mining companies are responsible for more than 50% of the copper produced in the region, which certainly accounts for around 20% of world copper production. This creates a significant opportunity to promote a concerted development strategy around mining, in which challenges are addressed collectively and in partnership with government and communities.

XI. This requires leadership and commitment from both the private sector and government, and a high level of community support.

XII. The size of the region's potential to develop nature-based solutions is poorly understood and insufficient work is being done to understand and harness it. This includes systems to protect watersheds and their ecosystems, to infiltrate watersheds, for mine closure, for CO₂ capture using algae, among many others.

XIII. Harnessing technological change requires an integrated analysis of the combined effect of the adoption of different technologies and identification of the negative impacts and opportunities in terms of employment, local procurement, and innovation. Analyses of this type are rare, making it difficult to identify opportunities.



6. Proposals for the Development of Communities of Practice

The learning community is a community of experts that meets from time to time for an informed debate (information of value is shared prior to each meeting), to characterise and define high-value opportunities and propose actions to advance the development of opportunity.

For each opportunity or challenge, it is proposed to hold four virtual meetings under a predefined structure as follows:

0. Preparation: CESCO identifies a set of strategic topics of high interest
1. Meeting 1: Definition of opportunity or challenge
2. Meeting 2: Preliminary estimate of relevant value
3. Meeting 3: Identification of solutions and actions
4. Meeting 4: Fundamentals for an action plan

The following list presents a series of issues that were preliminarily identified as specific work areas that would require more detailed development:

- I. Shared infrastructure and integrated management of water
- II. Electromobility and low-carbon energy
- III. Carbon market, emissions traceability and monitoring, and nature-based solutions
- IV. Circular economy for low-waste mining
- V. Attracting talent from the digital and technological worlds for sustainability
- VI. Observatories of linkages between suppliers and development plans
- VII. Cybersecurity centre with capacity for early warning and response to cyber attacks
- VIII. New leadership for a renewed social licence to operate
- IX. Monitoring and reporting of use and impact of public resources

