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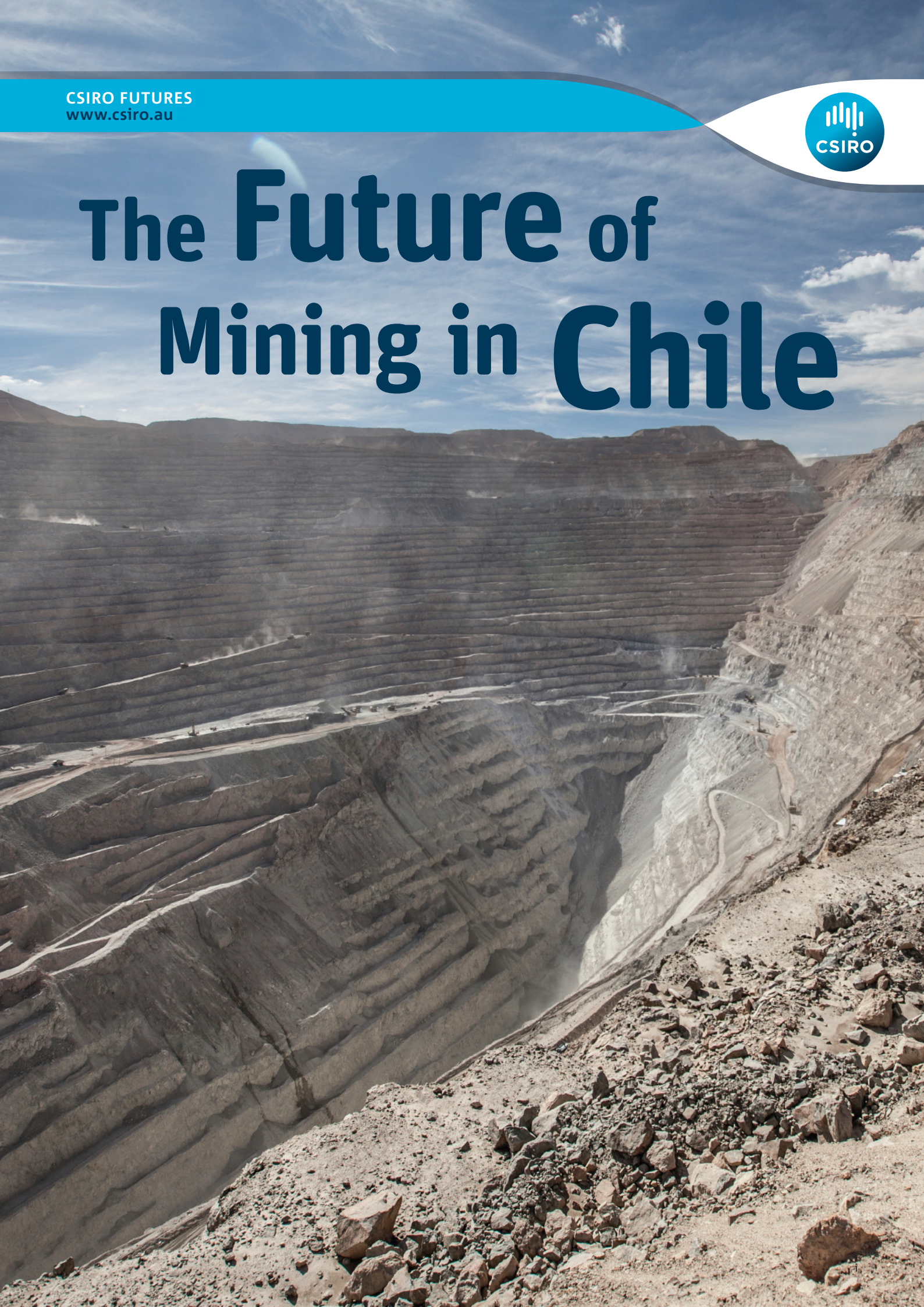
The Future of Mining in Chile



Cover image: CODELCO's Chuquicamata open pit copper mine near Calama, Chile

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COCHILCO (Comisión Chilena del Cobre)

Consejo Minero

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Fundación Chile

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Komatsu Chile

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Universidad Católica del Norte

Universidad de Antofagasta

Universidad de Chile

Prólogo

Este trabajo es el fruto del esfuerzo conjunto entre el Centro de Excelencia en Minería y Procesamiento Mineral de CSIRO Chile y CSIRO *Futures*, el brazo de análisis estratégico prospectivo de CSIRO.

"El Futuro de la Minería en Chile" cumple con uno de las misiones declaradas por CSIRO Chile, la de entregar una hoja de ruta estratégica para la industria minería, contribuyendo así a desarrollar una visión compartida del futuro de la minería en Chile, facilitando la toma de decisiones por parte de los actores relevantes de la industria, gobierno y la comunidad científica.

Esta publicación presenta una radiografía del estado actual de la industria, con sus oportunidades y desafíos, en el marco de las mega-tendencias globales que la afectarán durante los próximos 20 años, estableciendo así mismo las potenciales direcciones estratégicas que el país puede tomar. Así, a través de escenarios futuros basados en evidencia concretos, tanto positivos como negativos, se facilita un lenguaje común para fomentar un diálogo constructivo nacional que busque avanzar hacia un ideal común de productividad y prosperidad.

En consecuencia, el propósito de este estudio no es entregar recomendaciones estáticas, sino que más bien alimentar una conversación provechosa sobre el camino hacia adelante.

Imaginarse el Chile del futuro sin la minería no es posible. Construir el futuro de la minería en Chile pasa por quienes hoy en día, en el presente, contribuyen a que este sector produzca y se desarrolle. Por eso agradecemos de manera especial a aquellas personas e instituciones que apoyaron este proyecto con su valiosa opinión, información y experiencia, en particular a los participantes del seminario llevado a cabo en Santiago el día 17 de junio en conjunto con la Sociedad de Fomento Fabril, SOFOFA.

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Prologue

This work is the result of a joint effort between the CSIRO Chile Centre for Excellence in Mining and Mineral Processing and CSIRO Futures, the strategic foresighting arm of CSIRO.

"The Future of Mining in Chile" fulfills one of CSIRO Chile's declared missions, to deliver a strategic roadmap for the mining industry, contributing to develop a shared vision of the future of mining in Chile, facilitating decision-making by stakeholders from industry, government and the research community.

This publication presents a snapshot of the current state of the industry, its opportunities and challenges in the context of the global mega-trends that will affect it over the next 20 years, as well as establishing potential strategic directions that the country can take. Thus, through concrete evidence-based future scenarios, both positive and negative, it facilitates a common language to promote a constructive national dialogue that seeks to advance towards a common ideal of productivity and prosperity.

Accordingly, the purpose of this study is not to deliver static recommendations, but rather to help create a fruitful conversation about the way forward.

It is not possible to imagine the Chile of the future without mining. Building the future of mining in Chile is the responsibility of those who today, in the present, contribute to the production and development of this sector. This is why we would like to especially thank those people and institutions that supported this project through their valuable opinion, information and expertise, particularly to the participants of the seminar held in Santiago on 17 June in conjunction with the *Sociedad de Fomento Fabril*, SOFOFA.

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Introduction

Chile's mining industry is at a crossroads. Mining has led the country towards greater levels of wealth and prosperity and is a large part of the reason why Chile is well on its way to being considered as an advanced economy. Chile is, by far, the world's dominant producer of copper ore but this position should not be taken for granted. Rising costs, declining productivity and rising social and regulatory pressure in the areas of community engagement and environmental sustainability are hampering the sector's profitability and ability to remain globally competitive.

The industry can choose to continue on its current path and address these challenges through short-term solutions that provide incremental improvements. Alternatively, it can identify the opportunities for step-change innovation within the changing global landscape in order to forge a new upward trajectory for economic growth for both the industry and the nation.

In this way, mining has the potential to act as a platform for change in Chile. Through advances in scientific research and development and technological innovation it can address the challenges that not only hinder the productivity of the industry but of the country, such as rising energy costs. It can drive the growth of a new mining services sector that helps to diversify the economy. It can take a leadership position on issues such as environmental and social sustainability. Changes such as these will be vital for ensuring that Chile remains a key player within the global mining value chain over the coming decades.

However, this sort of progress will not be possible without successful collaboration across industry, government and the research community. There is a need for these different stakeholders to unite behind a shared vision for the future of mining in Chile and work together to move towards this ideal.

This report aims to provide a starting point for the development of this shared vision. It can help to create a common language across stakeholder groups as well as provide a common understanding of where the mining industry currently stands, the changing global landscape in which it operates, and the potential directions it could take. This is done through an assessment of the current state of the industry, an overview of the major global megatrends that will impact the industry over the next twenty years, and a forward- looking scenario analysis. It is not the intention of this report to provide concrete recommendations but rather to help create a national conversation about the way forward.

Mining has given a lot to Chile. A shared vision, an appetite for innovation and strong leadership will ensure that mining continues to drive economic growth for the country well into the future.

High-Level Approach – Primary Components of the Report

1. Key challenges and opportunities facing the Chilean mining industry A high-level overview of the current state of the mining sector in Chile based on an analysis of the most pertinent challenges and opportunities facing the industry, within the global mining context.
2. Global megatrends shaping the future of mining around the world
   A foresight analysis of the megatrends that are likely to impact the global mining industry over the next 20 years. This includes geopolitical, economic, environmental, social, and technological drivers and their potential implications for Chile.
3. Conceptual scenarios for the future of mining in Chile
   An analysis of five conceptual future scenarios for the Chilean mining sector and the broader Chilean economy. These scenarios look forward over a twenty year time horizon and are focused on how industry, government, and researchers can work together to create desirable outcomes.
4. Using scenarios for strategy development An analysis of the different actions that can be taken to drive towards positive scenarios and mitigate risks associated with the negative scenario.

Mining in Chile: Current Perspective

Identifying the most significant challenges and opportunities for Chile's mining industry

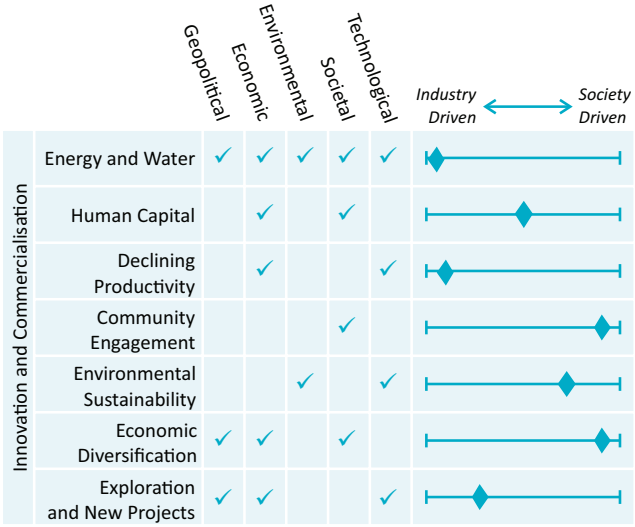
Key Challenges and Opportunities

While there may not currently be a clear consensus on the future direction Chile's mining industry should take, there is a widespread understanding of the current challenges, and resulting opportunities, facing the industry.

The 'challenges and opportunities' outlined here highlight the key themes that emerged from extensive consultation across industry and government as well as a review of existing research.

Each challenge and opportunity has implications across geopolitical, economic, environmental, societal and/or technological dimensions. Some of them are unique to or driven by the mining industry while others have implications across other industries and the community. Innovation and commercialisation is different from the others in that it is inherent in all of the other challenges and opportunities that exist.

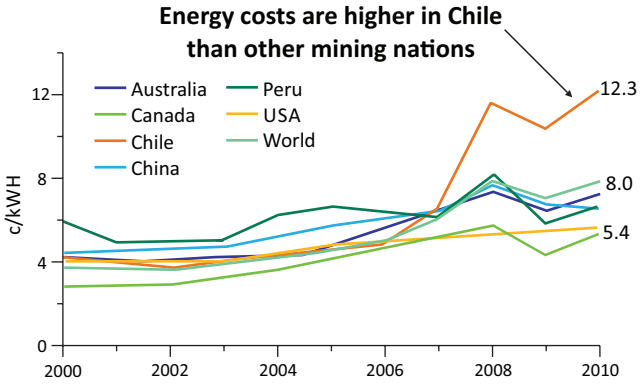
These challenges and opportunities help to provide an understanding of the current position of Chile's mining industry. Future strategies for the industry need to identify ways to mitigate the risks associated with the challenges and capitalise on the opportunities that exist.

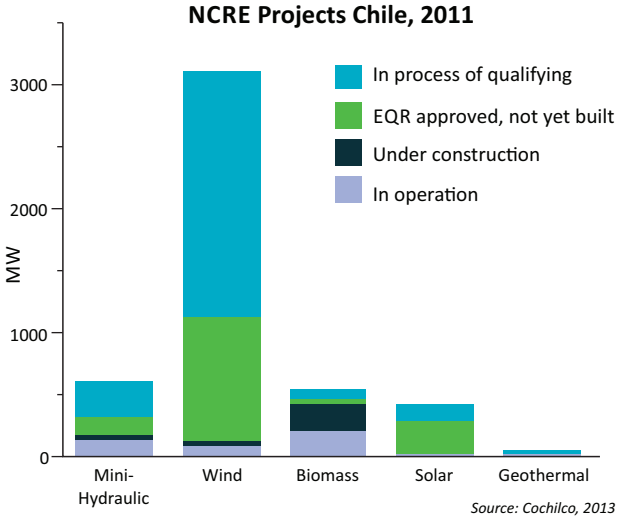


Access to Energy

Chile doesn't have any sizeable domestic petroleum sources; it has hydro-power and imports. Energy costs are also significantly higher in Chile compared to other copper mining countries.

- Mining is the most energy-intensive industry in Chile, responsible for over 20% of total electricity consumption.[1] Energy requirements for Chile's mining industry are set to rise by 68% between 2013 and 2020.2
- Chile's energy costs are much higher than in other mining nations.[3]
- The mining industry's energy operating costs represent up to 14% of total production costs, the highest level registered in Chile since 2000.[2]
- Miners are beginning to realise they may need to invest in building their own energy capacity, rather than relying on public infrastructure.[1]
- Chile's reliance on energy imports creates volatility in both price and supply. Fossil fuels (oil, coal and natural gas) account for 87% of the country's total primary energy consumption and almost all of these fuels are imported.[4]
- There is significant opportunity for growth in conventional hydropower in Chile but potential impacts of global warming[5], the lack of dams near mine sites and community opposition inhibit growth in this area.
- The government is committed to Non Conventional Renewable Energy (NCRE) sources, introducing a law specifying that 10% of total production in new energy contracts must be provided by NCRE sources by 2024.[5] This goal was recently doubled to 20% by 2025.[6]
- The government estimates that electricity generation from NCRE sources across Chile could increase from 3% of total capacity in 2011 to 10% of total capacity by 2020.[7]



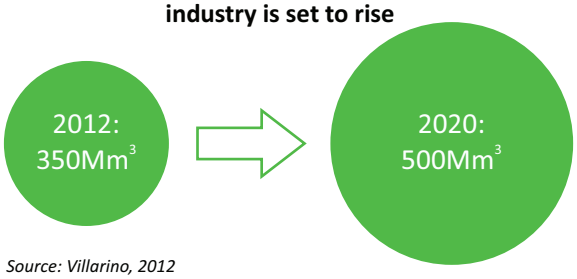


Access to Water

Most of Chile's copper mines are in the Atacama desert - one of the driest places on earth and with high elevation. Water must be desalinated and pumped into the mountains, a process that is both expensive and energy-intensive.

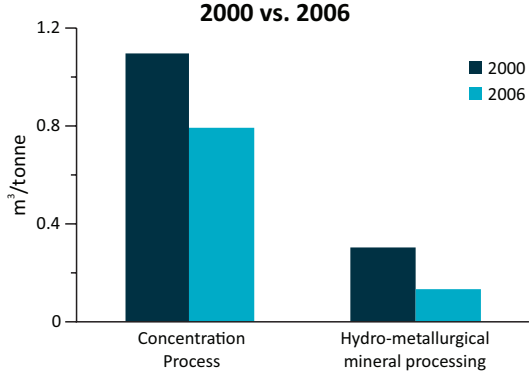
- The demand for water in Chile's mining industry is set to increase substantially, from 350Mm^3 in 2012 to 500Mm^3 in 2020.[8]
- Fierce competition for water use among the various sectors of Chile's economy (e.g. mining vs. agriculture) has seen many mining companies invest in desalination plants and is forcing the industry to consider the options of water purification and recycling, as well as the use of saline water in its operations.[9]
- As a result of this increased commitment to water efficiency, between 2000 and 2006, on average, freshwater consumption in the concentration process fell from 1.10m^3 per tonne of material to 0.79m^3/tonne. Consumption in hydro-metallurgical mineral processing fell from 0.30m^3/tonne to 0.13m^3/tonne over the same period.[10]
- A number of companies, such as BHP Billiton, have switched to desalination to avoid having to drain the water table. Desalination plants and their associated pipelines require significant upfront capital investment. However, the main challenge is the ongoing energy costs associated with desalinating the water and pumping it from the coast to the mine sites. Using desalinated water in Chile costs, on average, three times more than using fresh water.[11]
- It can be argued that Chile's water troubles are, in fact, caused by the energy challenges it faces. If new energy sources are developed and energy costs decline, desalination will become a more cost-efficient option, helping to solve the water challenges currently facing Chile's mining industry.

Demand for water in Chile's mining industry is set to rise



Source: Villarino, 2012

Freshwater Consumption in Mining in Chile, 2000 vs. 2006

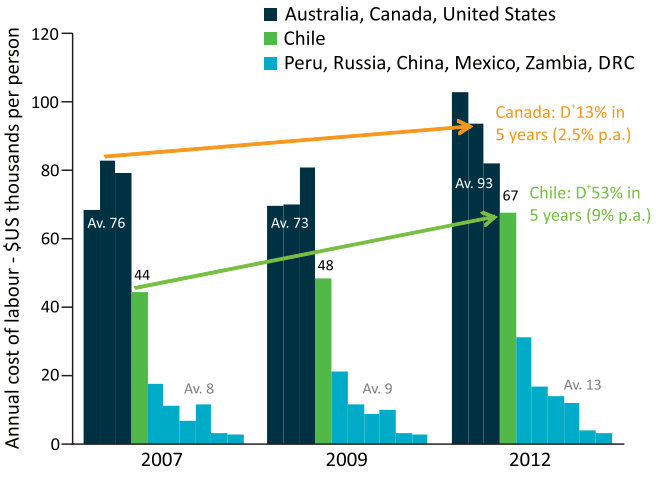


Source: Cochilco, 2008

Human Capital

Chile faces a shortage of skilled labour, which is driving up labour costs. Policies and investments in areas such as education, training and immigration can be utilised to ensure Chile has access to the labour and skills it needs.

- Chile lacks an integrated, accredited system of education stretching from primary school to PhD, in which credits are transferable at the appropriate levels and consistent with international norms.12
- The inconsistency in quality across Chile's education system has created an excess of professionals in areas such as business management and accounting with insufficient numbers of graduates in fields such as engineering and IT.[13]
- Mining is not a popular career choice for Chilean students because of distance to the job sites, the difficulties of working in the mines, the sector's poor image and discontinuous financial support for students.[14]
- Chilean professionals working in the mining industry now earn the highest salaries in Latin America and the sixth highest in the world.[15]
- Between 2012 and 2020 there will be a need for an additional 37,638 workers, an increase of 24.5% from the current workforce. The main gaps in human capital are expected to be seen in the areas of maintenance and fixed plant and mobile equipment operators. Due to a lack of programs that offer training in these areas, mining companies and contractors must develop on-the-job training programs.[16]
- The government recognises the importance of attracting talent from abroad in order to help grow Chile's economy, demonstrated by programs such as Start-Up Chile and a new immigration bill.
- In 2012, BHP Billiton and ten other mining companies created the Council on Mining Skills (CCM) to better align the needs of the industry with the programs being provided in Chile's educational institutions.



Source: Hernández, 2013

Declining Productivity

As costs continue to rise, one of the industry's biggest challenges becomes one of productivity. This is an issue not just for individual firms but one that threatens the global competitiveness of Chile's mining industry as a whole.

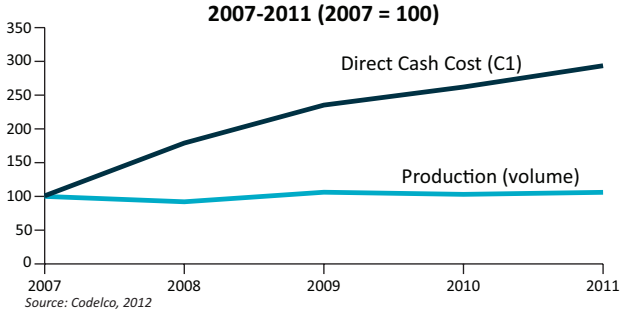
- Declining ore grades mean that more ore must be processed to get the same quantity of metal. When Escondida began production in 1991, average ore grades in Chile were 1.4% copper. Estimates suggest that ore grades have dropped to a level somewhere between 0.7% and 1% today, and are expected to fall to as low as 0.6% copper by 2020.[11] [17]
- The need to dig deeper to access reserves is another factor driving up extraction costs. For example, Codelco is investing US$3.5 billion in its El Teniente New Mine Level project to allow for extraction 300m below the current operating level.[18] [19]
- Production costs have increased rapidly while growth in production volume struggles to keep up. Codelco's direct cash costs increased by 193% between 2007 and 2011 while production increased by 8%.[20]
- Productivity in copper mining in Chile dropped from a peak of 146 tonnes of copper per worker in 2004 to 99 tonnes of copper per worker in 2012, a decline of 32%.[11]
- The issue of productivity is not unique to Chile's mining sector. Productivity levels for the nation (measured as GDP per person employed) are the highest in Latin America at US$32,114 in 2012 but remain well below the OECD average of US$77,080 for that year.[13]
- While Chile's mining sector faces a number of unique cost challenges that need to be addressed to solve the issue of productivity, there are also factors that require more of a national approach, such as effectiveness of the education system and capacity for innovation.[13]

Environmental Sustainability

Mining companies in Chile must now meet local and international expectations in regards to the environmental impact of their operations.

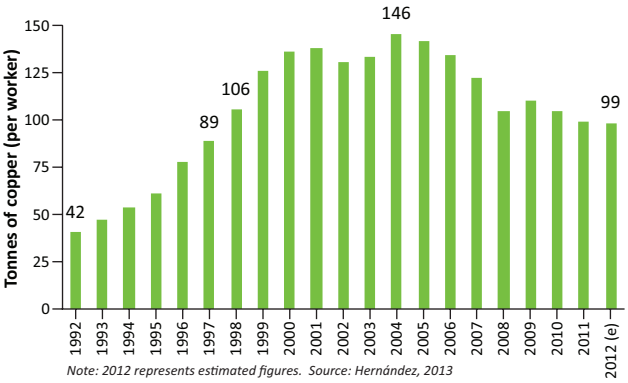
- Since the beginning of the 1990s, environmental awareness has had a significant impact on policy making activities in Chile.
- The Environmental Framework Law was introduced in 1994 and the Environmental Impact Assessment System began operating in 1997.
- In 2010 the government introduced significant reforms, creating a Ministry of Environment, an environmental assessment agency and a compliance agency – the Superintendencia del Medio Ambiente (SMA). In 2013 the SMA imposed the maximum fine possible on Barrick Gold (8 billion pesos/US$16m), setting a precedent for what the industry can expect in the future.

Indexed Growth of Costs vs. Production for Codelco, 2007-2011 (2007 = 100)



Source: Codelco, 2012

Per Worker Productivity in Copper Mining in Chile



Note: 2012 represents estimated figures. Source: Hernández, 2013

- A new law introduced in 2011 obligates mining companies to reduce environmental and health hazards relating to the closure of mine sites.
- Mining companies are increasing their commitment to sustainability in order to remain globally competitive. All Codelco operations achieved ISO 14001 certification by 2003 and a survey found that 97% of Codelco's clients considered this certification to be important.[21]
- A number of the biggest players in Chile's mining industry have committed to implementing the Sustainable Development Framework of the International Council on Mining and Metals.
- The environmental challenges facing Chile's mining industry are diverse and complex, spanning areas such as water, emissions, biodiversity and waste disposal. Pressure from communities and regulatory bodies will continue to increase across all areas of environmental sustainability.

Source: Newbold, 2006

The $16m fine imposed on Barrick Gold in 2013 set a new record for environmental infringement in Chile

Community Engagement

Much of the wealth from mining has been transferred to Santiago and Antofagasta. There is a large issue around ensuring that the wealth accrued from the mining industry transfers to the local communities most affected by it. There is also a heightening need to engage these communities to earn and maintain a social licence to operate, in order to reduce risk.

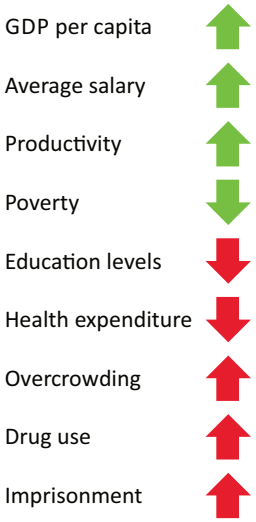
- In mining regions, GDP per capita is 163% higher, the average salary is 63% higher, and productivity levels are 153% higher compared to non-mining regions. Poverty levels are also 24% lower in mining regions.[22]
- However, mining regions experience lower education levels and per-capita expenditure on health is 14% lower compared to non-mining regions. There is also an increased level of overcrowding in housing in these regions and higher levels of drug use and imprisonment.[22]
- Mining companies are expected to contribute to regional development in areas of operation and must work closely with local communities to create development plans for local services and infrastructure.
- As part of its Buen Vecino (good neighbour) program, Codelco works with social organisations and public and private institutions near its operations to improve quality of education, social integration and to support culture and local development.
- Miners are increasingly required to seek and maintain a 'social licence to operate' across all stages of a project's life cycle. Failure to do so can result in large fines, the suspension of existing operations, or the delay or even cancellation of planned operations.
- In 2008 the Chilean Government ratified the International Labour Organisation Indigenous and Tribal Peoples Convention No. 169 that seeks to ensure that indigenous and tribal people are consulted and participate in decision making concerning their rights.

Economic Diversification

Copper represents over half of Chile's exports and a significant proportion of GDP. This lack of diversification exposes the country's economy to enormous risk but at the same time presents an opportunity to develop a services/knowledge-based economy in support of the global mining industry.

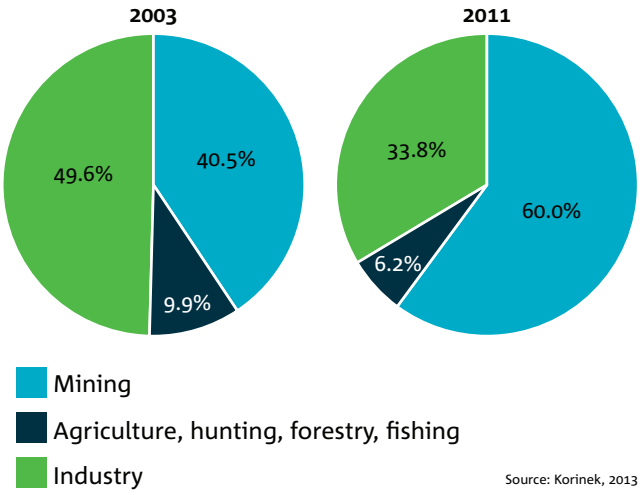
- In 2011, mining accounted for 60% of exports (by value), up from 40.5% in 2003. It also accounted for one-third of foreign direct investment in Chile.[23]
- The Hirschman Herfindahl index confirms the lack of diversification in Chile's export portfolio. Chile's index in 2010 was 0.1830. Other OECD countries with strong mining sectors have index values closer to zero, indicating more diversified export portfolios: Australia 0.0905, Canada, 0.0319 and USA 0.0396.[23]
- Mining's share of GDP grew from just 7% in 2000 to 16% of GDP in 2010, although this declined slightly to 13% in 2012.[23] [24]

How Chile's mining regions compare to other (non mining) regions



Source: Based on data from Meller, 2013

Value Share of Exports by Sector in Chile



Source: Korinek, 2013

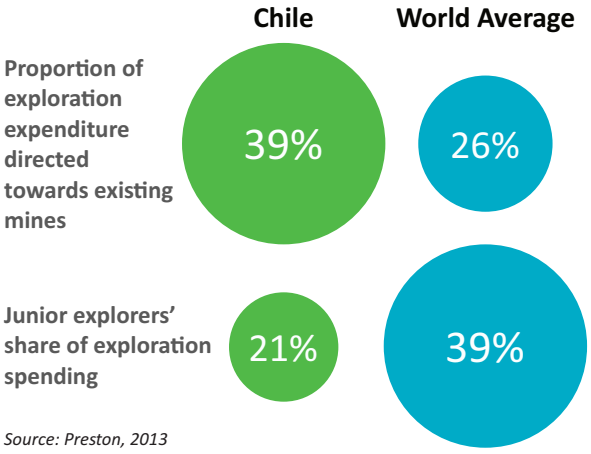
- Due to this lack of diversification, Chile's vulnerability to commodity price shocks has increased and is an ongoing problem. Chile's GDP has been shown to rise and fall in line with copper prices. Alvaro Merino, Sonami research manager, told MINING.com that for each cent (US$) copper prices fall, the Chilean economy loses $120 million, and the treasury loses close to $55 million.[25]
- The lack of diversification has also made Chile reliant on Chinese economic growth as China accounts for around one-quarter of Chile's total exports (mainly copper).[13]
- At the same time, the country's specialisation in this area presents an opportunity to develop a knowledge/services hub for mining. BHP Billiton, Codelco and the Chilean government, are currently working to develop mining sector suppliers through a mining cluster program.

Exploration and New Projects

Falling ore grades mean that existing projects alone cannot sustain growth for Chile's mining industry. Exploration and the development of new resources will be required to ensure Chile's copper output doesn't begin to decline in the coming years.

- 39% of exploration expenditure in Chile is directed towards expanding the resources at existing mines, rather than searching for new opportunities, a figure much higher than the global average of 26%.[26]
- In most mining countries, junior explorers play an important role in the discovery of new ore bodies. However, in 2012 junior explorers in Chile accounted for only 21% of total exploration spending, considerably lower than the global average of 39%.[26]
- Gaining access to land for exploration can be difficult in Chile. The current concession system allows companies to hold land indefinitely with no obligation to explore the grounds and this can limit exploration efforts. Ten companies currently hold exploration concessions covering almost 40% of Chile's exploration grounds.[26]
- Accessing capital is another major challenge facing junior explorers in Chile and there is a heavy reliance on foreign investment. In an effort to support long-term growth through the discovery of new mineral deposits, the government is working on a proposed system that would encourage mining companies to sell shares on the stock exchange to raise investment and would offer incentives to investors, such as capital-gains tax breaks.[1]

Exploration in Chile vs. the Rest of the World



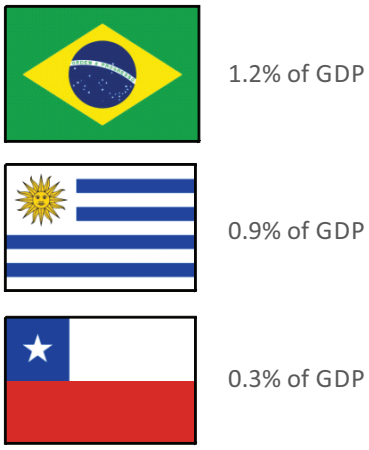
Source: Preston, 2013

Innovation and Commercialisation

As Chile lacks a culture of innovation, an opportunity exists to maximise collaboration between research groups, universities and industry in a way that provides social and economic benefit for all Chileans.

- Chile's R&D expenditure grew by 42% between 2007 and 2012 (from CLP281 billion to CLP400 billion). However, this expenditure represented just 0.3% of GDP in 2012, compared to regional leaders Brazil (1.2% of GDP) and Uruguay (0.9% of GDP).[13]
- Most R&D is financed by the Chilean government and carried out in the universities with few connections to the business sector. Business sector R&D spending (BERD) accounts for about 45% of Gross Expenditure on R&D (GERD). This is much lower than the most developed countries where BERD typically represents two-thirds to three-quarters of GERD.[12]
- The majority of Chilean firms' innovation spending (80-90%) is on importing machinery with little investment in internal R&D.[12]
- More emphasis is given to basic research, rather than productive or commercial oriented research, demonstrated by the lack of pre-competitive collaborative research in Chile.12 As a result, Chile is underperforming in relation to technology transfer and the efficiency of its R&D expenditures.[27]
- Declaring 2013 the Year of Innovation is just one of many positive steps that the Chilean government has taken to try and build a stronger, more efficient innovation system.

Chile's R&D expenditure as a percentage of GDP is low compared to other countries in Latin America



Source: Euromonitor International, 2013

Mining: A Global Perspective

Five megatrends that are shaping the future of mining around the world

Global Megatrends Shaping the Future of Mining

A megatrend is defined as a substantial shift in social, economic, environmental, technological or geopolitical conditions that may reshape the way an industry operates in the long-run.

Megatrends are cross-sectoral and occur at the intersection of many trends. A trend is a significant pattern of activity typically occurring within an industry sector, societal sector or within a localised geographic region with implications for decision making. Compared to trends, megatrends have a higher impact and develop over a longer timeframe.

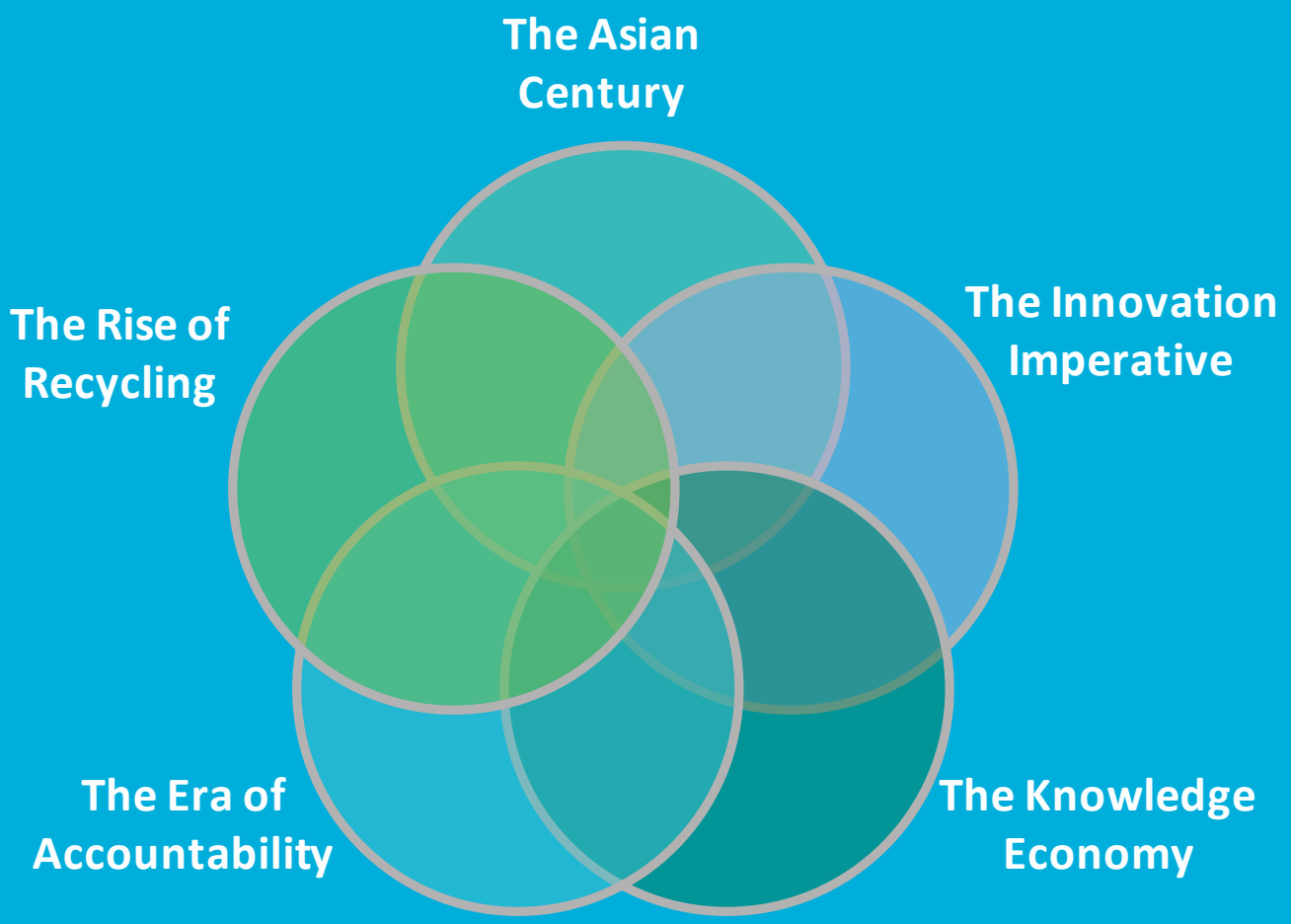
The key characteristics of a megatrend include:

- There is evidence that it is already occurring;
- It is relevant to decision makers;
- It is significant and has far-reaching implications for an organisation/industry; and
- It will continue play out over the future time frame (and possibly beyond) of the foresight study.

Importantly, megatrends are not mutually exclusive and the trends that make up one megatrend can influence or contribute to another. Showing the megatrends in a Venn diagram of overlapping circles helps to illustrate this interrelation.

The five megatrends outlined in this report represent the most significant global shifts that will have an impact on the mining industry over the next 20 years. Some elements will have greater relevance in the short term, while others will grow in significance over time.

From the eastward shift in the centre of economic output to the new resource business models that could be created based on recycling materials, all of these megatrends have both supply-side and demand-side implications and present specific considerations for the Chilean mining industry. As the mining industry continues to become more globally interconnected, any strategy for the future needs to give due consideration to the global context and how Chile can remain competitive in this changing environment.



The Asian Century

Over the next twenty years, Asia will become the most important region for the world's mining industry, exerting significant influence across both supply- and demand-side dynamics. The staggering pace and scale of growth in the region has sparked a demand for raw materials used in infrastructure development, as well as in the production of consumer goods for the world's fastest growing middle class. This demand for minerals and metals will also see Asia become responsible for a growing proportion of global mining investment. It is widely predicted that the growth seen in the region will continue over the coming decades, albeit at a slightly slower pace, leading the mining industry further into 'The Asian Century'.

ASIA IS BECOMING THE WORLD'S ECONOMIC HOTSPOT

The global economy's centre of gravity is on a clear trajectory towards Asia.[28] By 2025, four of the world's ten largest economies will be in Asia (China, Japan, India and Indonesia) and Asia will account for over half of the world's economic output.[29]

Alongside rapid growth in the region, Asia will continue to become more open to the rest of the world, negotiating trade agreements that will play a key role in shaping the future global economy.

ECONOMIC DEVELOPMENT IN ASIA IS DRIVING DEMAND FOR MINERALS AND METALS

China is already the world's largest consumer of steel, aluminium and copper, accounting for around 40% of global consumption for each of these metals.[29] By 2025 China will account for over 50% of global copper demand. Indian demand for copper is forecast to grow at 9% per annum through 2025.[30]

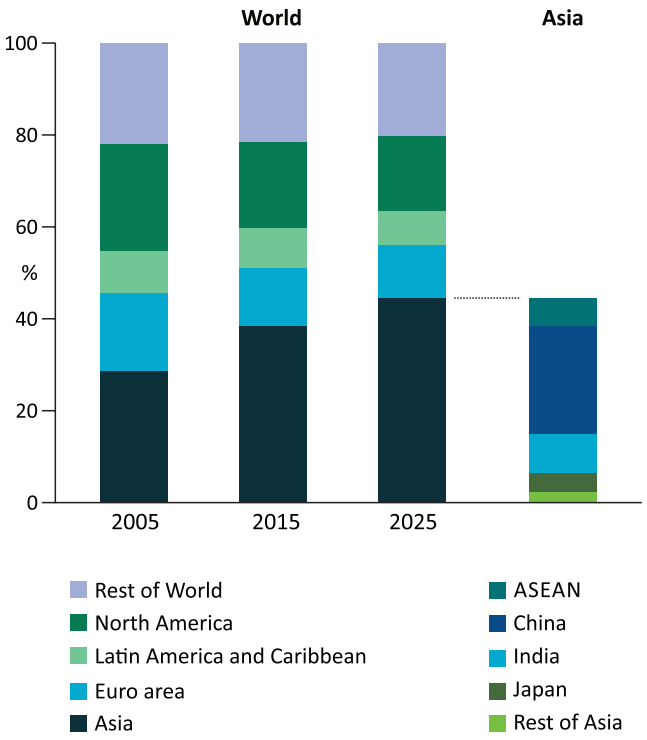
This growth in demand is driven largely by rapid urbanisation in the region (particularly India and China) as each year around 44 million people migrate from rural areas to Asia's cities.[29] It is estimated that between 2010 and 2020, developing Asia will require investments of around US$8 trillion in national infrastructure capacity and US$287 billion in regional infrastructure projects to support this rise in urbanisation.[31]

There is also growing demand for consumer products manufactured, in part, from minerals and metals, such as computers, mobile phones, jewellery and automobiles, driven by the rise of the world's fastest growing middle class.[29]

ASIA'S GROWING INFLUENCE ON SUPPLY

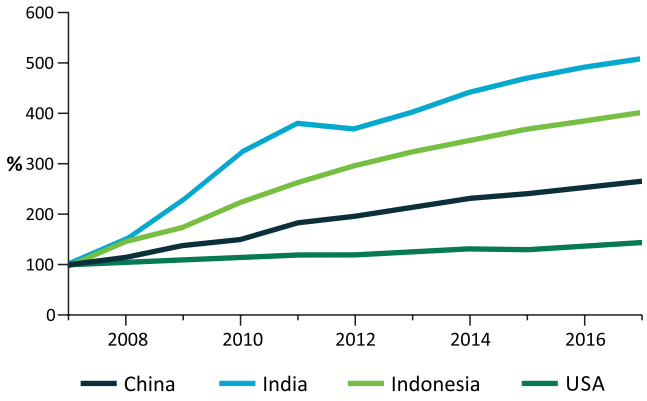
China is the world's leading producer of black coal, iron ore, gold, zinc, manganese, rock phosphate, rare earths, tungsten, and lead.[29] Annual turnover in iron ore mining in China is expected to increase from US$183.7 billion in 2012 to US$484.2 billion in 2017 while turnover in non-ferrous metal ore mining is predicted to grow from US$101.6 billion in 2012 to US$228.3 billion in 2017.[32]

World Output Shares

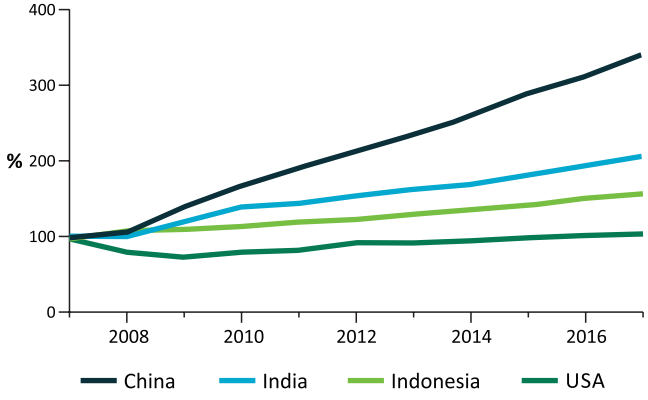


Note: GDP adjusted for purchasing power parity (2011 prices)
Source: Commonwealth of Australia, 2012

Indexed Growth in Mobile Telephone Subscriptions

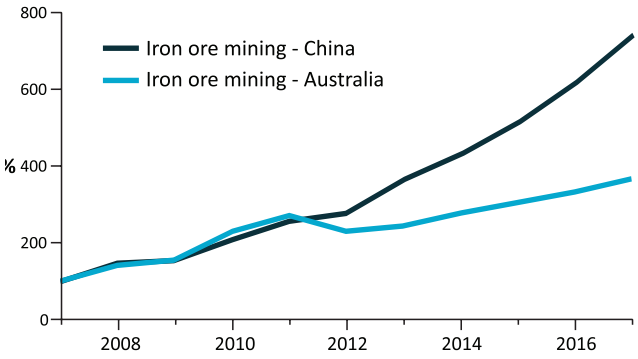


Indexed Growth in Consumer Expenditure on Purchase of Cars, Motorcycles and Other Vehicles

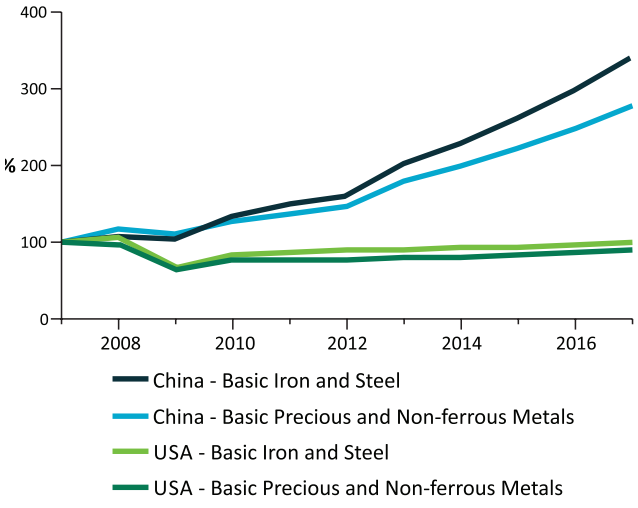


Note: 2007 = 100; 2007-2012 represents actual growth; 2013-2017 represents forecast growth. Source: Euromonitor International, 2013

Indexed Growth in Production Value of Iron Ore Mining in China vs. Australia



Indexed Growth in Production Value of Basic Iron and Steel and Basic Precious and Non-ferrous Metals in China vs. the USA



Note: 2007 = 100; 2007-2012 represents actual growth; 2013-2017 represents forecast growth. Source: Euromonitor International, 2013

Production value in non-ferrous metal ore mining in Indonesia increased threefold between 2002 (US$9.3 billion) and 2012 (US$28.8 billion) and is expected to reach US$37.7 billion by 2017.[32] India has significant mineral reserves as well, and has sought to remain primarily self-sufficient in mineral production.[29]

Asia's role in production further downstream is also growing in significance. The turnover for Chinese producers of basic precious and non-ferrous metals grew from US$362.2 billion in 2007 to US$587.5 billion in 2012. Production is forecast to reach US$1.2 trillion by 2017. China is also expected to continue to grow its output of iron and steel from US$1.1 trillion in 2012 to just over US$2 trillion in 2017.[32] Asia has become the leading region for refined copper production and copper smelter output.[33]

The growing demand for natural resources in China is also driving investment in mining production in other emerging economies, such as Africa, South America and central Asia.[34] Chinese investment in Africa's mining sector totalled US$15.6 billion in 2011, a tenfold increase from the previous year.[35]

THE PREDICTED SLOWDOWN

Even though some are predicting a slowdown in economic growth in Asia, particularly in China, this will be relative to the rapid pace of growth seen over the last eight years. The five year outlook by the International Monetary Fund still has year-on-year economic growth at 7 to 8 percent for the "developing Asia" region compared to economic growth in advanced economies of around 2 to 3 percent.[36]

It is likely that as China develops it will follow the path of most developed nations and transition to a more services-oriented economy. As a result, we may see the importance of manufacturing decrease, reducing industrial demand for raw materials in China. However, we are not likely to see this shift too dramatically over the coming twenty years and any reduction in the size of manufacturing in China would likely lead to growth in the manufacturing industry of another Asian nation, such as India.

Asia will continue to be responsible for driving growth in end-user demand for metals and minerals as urbanisation in the region is set to climb at a rapid pace beyond 2050 and disposable incomes in the region will continue to rise.[37] Therefore, Asia's dominance and influence on mining, whether direct or indirect, is likely to be felt well into the twenty-first century.

CHILEAN PERSPECTIVE

- Demand from Asia will continue to drive demand for Chile's minerals and metals.
- China accounts for around one-quarter of Chile's total exports[13], mainly copper. In 2012, 63% of the country's copper exports were bound for Asia.[38] This represents both enormous opportunity and risk for Chile's economy.
- China dominates global copper smelter production and refined copper production, so is not only a primary consumer of Chile's copper output but also a direct competitor in these activities.
- Asian investment in mining, both in and outside of Asia, also creates competition for Chile's mining industry. At the same time, there is an opportunity to attract Chinese investment in the Chilean industry.
- The Pacific Alliance will help to provide a gateway to Asian markets for Latin America. In addition, both Chile and Peru have signed free-trade-agreements with China.
- Peru and Brazil currently attract the bulk of China's mining investment in Latin America. Chinese investment prospects in Chile have suffered due to Minmetals' failure to purchase a stake in the Gaby mine. While an agreement had been reached in 2006, Codelco backed out of it due to political and social pressure. Chilean citizens (particularly workers from the mine) were concerned about the potential effects of privatisation.[39] If Chile wishes to benefit from Chinese investment in its mining industry, a strategy needs to be developed for how to attract investment while appeasing the concerns of Chilean citizens.

The Innovation Imperative

A new wave of technology and innovation will be required in the future, as the mining industry is forced to find ways to get more from less. Innovation has always been a key driver of the industry's success, improving efficiencies across exploration, extraction and processing. The importance of innovation will become particularly prominent in the coming years as commodity prices come off their highs and the mining industry faces a new combination of challenges, the aggregate effects of which threaten the future profitability of the sector. Productivity improvements will not be gained through traditional approaches focused on moving more material, as mining doesn't just need better ways of doing things; it needs smarter ways of doing things. New innovations have already begun to emerge and will continue to do so over the coming decades as mining companies look not just for incremental improvements on existing methods but for entirely new ways of operating.

THE CASE FOR INNOVATION

There is an abundance of evidence to support innovation as an important (often the most important) contributor to progress at a business, industry and national level. In particular, innovation can be linked to increased productivity levels.[40] [41]

Over the last fifty years, the countries that have made a commitment to innovation have had much greater success in making the transition from middle income to advanced economies.[42] One of the most important factors required to achieve the sustained growth that will transition an economy out of middle income status is investment in human capital and innovation policies.[43]

The World Bank writes that "innovation has always played a decisive role in the economic and social development of countries: it is the main source of economic growth, it helps improve productivity, it is the foundation of competitiveness, and it improves welfare."[44]

MINING'S INNOVATIVE PAST

Since its early beginnings, the mining industry has continued to find new, better ways of operating. Notable innovations have been seen across the entire mining value chain including geophysical exploration techniques, cheaper and safer explosives, froth flotation, flash smelting technology and SX-EW processing.

"As production has moved from 'cheap and easy' to more 'difficult and expensive', technological development is increasingly needed to solve economic and production problems," Giurco et al., 2009.

We are starting to see a shift away from innovation focused solely on finding ways to move more ore out

of the ground and through the supply chain, as mining companies realise that this will not be enough to address the complex challenges they face.

INNOVATION HAS NEVER BEEN MORE IMPORTANT

The ten year period from 2003 to 2012 saw remarkably strong growth in global minerals commodities markets not experienced for the previous half-century.[46] As prices rose, miners rushed to build new production capacity, investing heavily in capital. This has led to inefficiencies that are now structurally ingrained into mining operations and that hamper productivity.[47]

Profits for the world's forty largest mining companies fell 49% in 2012, while costs rose 9%, indicating an urgent need to address the productivity issues that have previously been overlooked.[47]

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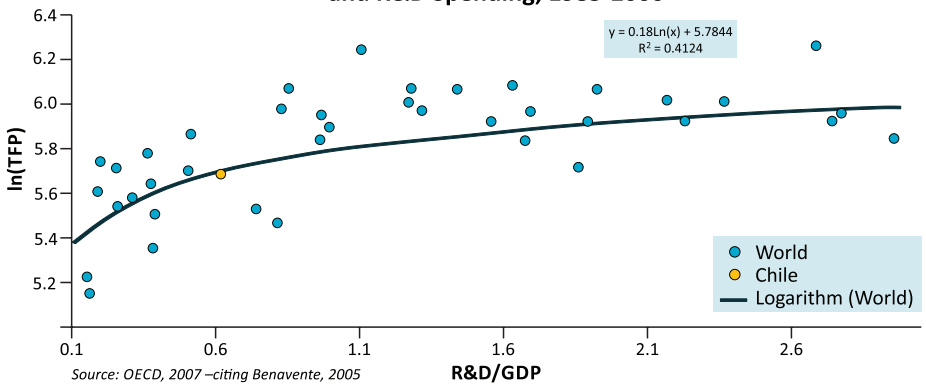
DRIVERS OF RISING COSTS AND DECLINING PRODUCTIVITY

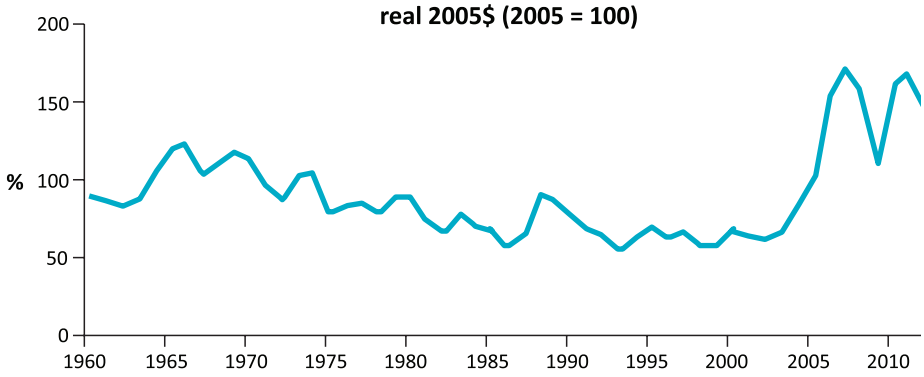
- Declining ore grades – In the mid-1800s copper grades were over 10% in Australia and around 8% in Canada. Australia, Canada and the USA currently have copper ore grades of less than 1%. Global copper ore grades are forecast to drop from 0.55% in 2012 to just 0.16% by 2088.[48]
- Deeper deposits and complex ores – Mining now regularly reaches depths of over 1 kilometre, with gold mines of the Witwatersrand field in South Africa now at depths of 4.3 kilometres.[45] Furthermore, miners can no longer rely on deposits with simple mineralogy and are being forced to deal with complex ores that are more difficult to process.
- Labour – Mining must constantly compete for highly skilled people with the necessary technical and managerial skills required to execute projects. Among the world's top 40 mining companies, reported headcounts grew by only 2% in 2012 while average employee costs increased by 13%.[47] In Chile and Australia, mining employees earn more than twice the national average salary.[23] [49] The related issue of worker safety and increasing regulation in this area also brings with it additional cost considerations.
- Energy & Water – Mining and minerals processing require significant energy inputs. In Australia mining is the third most energy-intensive industry, behind transport and manufacturing.[50] South Africa's

Relationship Between Total Factor Productivity (TFP) and R&D Spending, 1985-2000



Source: OECD, 2007 –citing Benavente, 2005

Indexed Growth in Prices of Metals and Minerals, real 2005$ (2005 = 100)



Source: The World Bank Group, 2013

mining industry uses 6% of all energy consumed in the country[51] and in Chile, over 20% of electricity is consumed within the mining sector.[1] Energy prices are forecast to continue to rise over the next 20-30 years, making the development of alternative solutions to fossil fuels increasingly urgent. The U.S. Energy Information Administration predicts that between 2012 and 2040 the Brent crude oil spot price will increase by 27%, the price of domestic coal will increase by 42% and natural gas prices will rise by 88%.[52]

Mining accounts for just under 3% of global industry water consumption and many of the world's mines are located in arid and semi-arid regions where gaining access to water for use in mining is an ongoing challenge.[53] Existing solutions to this problem bring with them a range of other challenges – e.g. desalination is highly energy intensive.

Looking forward, it is expected that both energy and water costs will increase as companies move to more remote regions in search of higher-grade deposits. There will also be costs associated with environmental compliance as governments introduce more regulation in this area aimed at the mining industry.

A TECHNOLOGY-DRIVEN FUTURE

There are a number of areas where innovation is beginning to play a role in helping to solve mining's productivity challenges:

- Innovations relating to automation can help to address labour costs in mining – from lower level automation where technology simply plays an assistive role, through to full automation allowing for remote operation.[54]
- Data modelling/predictive analytics is the use of historical data to model possible outcomes in future situations55 and has the potential to drive much greater efficiencies across mining operations. For example, the Common Mine Model (CMM) developed by CSIRO is a 3D data model of a deposit that integrates the flow of data over the mine site and mining process to provide feedback on the face or operations.
- Geologically intelligent processing involves an autonomous mining system capable of mining ore selected for grade and with an ability to sort ore as it is mined. Intelligent processing has the potential to speed up assessment of the viability of new ore deposits, select the most effective crushing and grinding technologies to enhance the processing performance of an ore, keep people isolated from hazardous activities, as well as reduce environmental impact through keyhole mining techniques.
- Some mining companies have made significant investments in renewable energy technologies. For example, in 2011, Barrick Gold opened its US$50 million Punta Colorada Wind Farm in northern Chile. With rising energy prices and increased environmental regulation, non-conventional renewable sources of energy will begin to make greater economic sense.

CHILEAN PERSPECTIVE

- The recent growth of Chile's mining industry has been driven by a rise in prices, not output. Labour costs in Chile have risen and are now on par with labour costs in the USA and Canada, however output hasn't grown in line with this increase. Issues such as declining ore grades and access to energy and water are also of particular significance to the Chilean mining industry.
- There have been some significant developments in Chile in the area of automation. For example, Codelco has been a pioneer in the area of remote operations. However, there is still progress to be made in regards to the efficient use of technology in this area.
- While progress is being made through government initiatives, Chile still lacks a culture of innovation and underperforms in technology transfer and commercialisation. Boosting productivity requires a shift in culture to get people to operate in new ways.
- Changes to the R&D tax credit (Law 20.570) introduced in 2012 have had a significant impact. In the ten months since the new law was implemented, 33 R&D projects with a cumulative value of around US$11.5 million were certified, compared to a total of just US$14.6 million of certified R&D projects over the four year period prior to the new law.[56]
- A number of challenges exist regarding the relationship between academia and industry that will need to be overcome if the level of innovation is to improve.
- Chile is one of the most economically and technologically developed countries in its region. Innovation will be one of the key factors responsible for helping with the completion of the country's transition from middle income to high income status.

The Knowledge Economy

As emerging economies rise as the mining powerhouses of the future, a lack of human capital and skills in these regions will open up opportunities for developed countries with more advanced mining skills to export their knowledge. At the same time, the mining industries of developed countries are facing major productivity challenges that will only be addressed through new expertise and innovation. The solutions for the future will be less about mining machinery and equipment and more about mining services and know-how. Regions with a history of success in extractive industries and a desire to invest in building expertise will be best placed to capitalise on this opportunity for economic growth in the knowledge economy.

KNOWLEDGE AS THE KEY TO SUCCESS

The developed world is in the process of shifting to a new economic model, in which knowledge will be the most important currency. The 'knowledge economy' is defined as "production and services based on knowledge-intensive activities that contribute to an accelerated pace of technological and scientific advance as well as equally rapid obsolescence."[57]

The global output of knowledge- and technology-intensive industries accounted for around 30% of global GDP in 2007, with knowledge-intensive services accounting for the greatest share at 26%, and high-technology manufacturing industries accounting for 4%.[58]

A company's health used to be judged based on its tangible assets (e.g. factories and equipment) but many firms are now realising that success in a knowledge economy is best derived through intellectual capabilities, rather than physical inputs. The productivity challenges facing mining are seeing the focus of mining companies shift away from machinery and equipment towards greater know-how.

"Three decades ago advanced industrial economies were dominated by sectors that invested large amounts in plant and machinery. By contrast, the rapidly growing sectors of recent decades such as electronics, pharmaceuticals and telecommunications invest mainly in R&D, software and information technology, advertising and training," OECD, 2007.

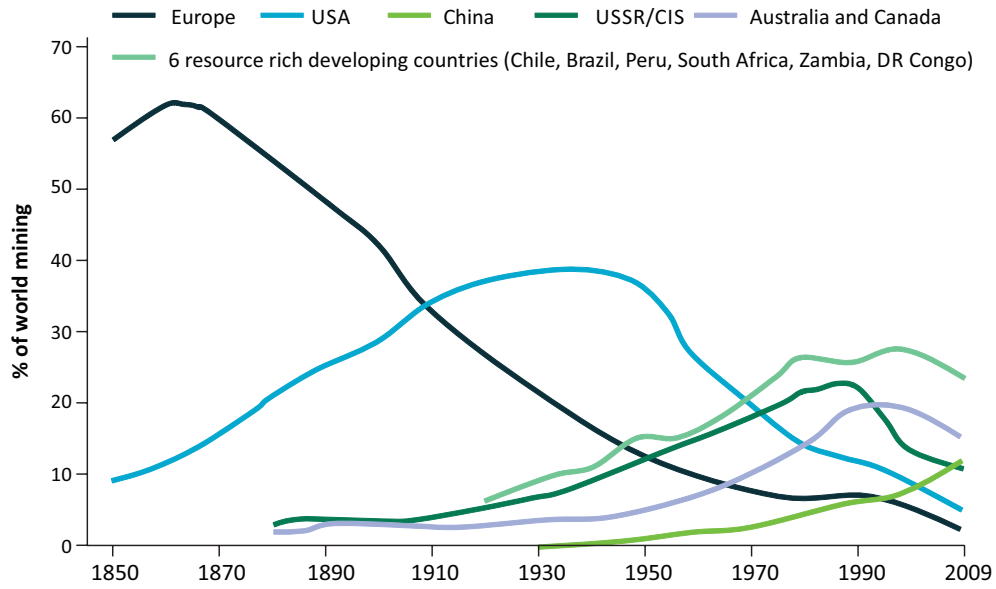
KNOWLEDGE SUPPLY-DEMAND IN MINING

The centre of gravity for mining has shifted dramatically over the last two centuries, from developed to developing countries. The former mining powerhouses of USA and Europe (excluding Russia) that accounted for over half of total metal mining value in the mid 19th century, now account for less than 10 percent of world mining.[59]

Emerging economies such as Latin America, Africa and Asia have attracted significant mining investment as they are often associated with lower production costs. More developed regions therefore need to find new ways to compete.

Emerging economies, however, often lack the skills, technology and expertise (i.e. knowledge) required for efficient exploitation of mineral reserves. They can either invest in developing local capabilities, which may take decades, or they can import the required skills and expertise, usually from more developed regions with long-standing extractive industries.

Location of World Mining by Region, 1850 to Present



Note: World mining is measured as the total value at the mine stage of all metals produced in all countries
Source: ICMM, 2012 – citing Raw Materials Group

This dynamic is a key driver for the growing global METS (mining equipment, technology and services) sector. A number of regions around the world have developed as clusters of expertise in this field, originally to serve local markets. However, the knowledge-demand gap that is being created as mining investments are directed towards emerging economies provides a broader export opportunity for suppliers in the METS sector.

FROM ORE TO MORE

North Ontario, Canada is an example of a region that is home to a number of world-class METS suppliers. A downsizing of the region's mining industry in the 1980s led to the release of skilled labour and management, resulting in the formation of a number of small firms and the development of a mining supply and services cluster.[60] The METS sector in Ontario now includes around 500 firms and organisations, and employs approximately 23,000 people. Sales in 2010 totalled C$5.6 billion, of which around 19% came from the international market.[61] While the Ontario region is still responsible for 25% of all Canadian nonfuel mineral production[62], it is leveraging latent expertise to move beyond primary production and identify global industry needs that can be addressed by its local suppliers.

More recently, Australia's resources boom has seen the country's METS sector grow from sales of A$1.2 billion in 1995-6 to sales of A$8.7 billion in 2008-9, with export sales representing 29% of this total.[63] While Australia's mining industry Gross Value Added grew by a compound annual growth rate (CAGR) of around 3% between 1995-96 and 2008-09, Australia's METS sector global sales grew by a CAGR of over 16% during the same period.[63] [64]

A number of countries/regions with strong mining industries are in a position to leverage and build on the knowledge and skills they have to develop a thriving METS sector that can supply both the local industry and overseas markets.

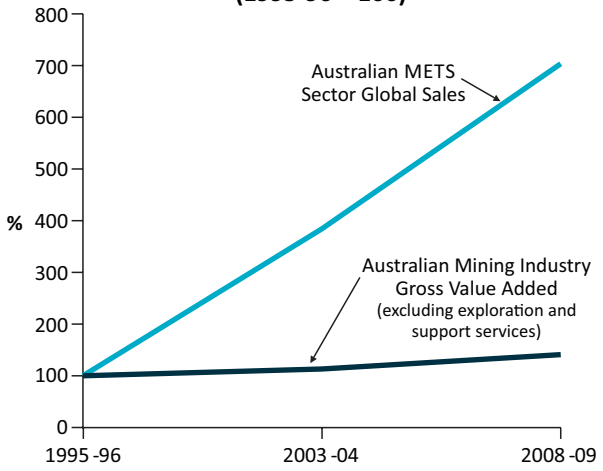
GLOBAL REACH, LOCAL BENEFITS

A thriving METS sector means that local issues can be addressed through local innovation, without the need to import a knowledge base from overseas. This can provide aggregate economic benefits for a country as it sees growth not only in its traditional extractive industries (through innovation) but also in the newly created METS industry.

In fact, innovation that occurs in the development of mining-related equipment, technology and services can often also be applied to other industries, such as manufacturing or agriculture, extending the sector's economic benefits even further. Moving beyond production into knowledge-based activities can therefore increase economic diversification, helping to stave off the dreaded resources curse.

Successful mining clusters around the world (e.g. Sweden, Finland, Canada, and Australia) have shown that there are a number of factors that play a role in developing a prosperous, new, knowledge-based

Indexed Growth of Australia's METS Sector vs. Australia's Mining Industry (1995-96 = 100)



Source: ABS, 2013; Tedesco and Haseltine, 2010

industry. These include trade openness, a strong national innovation system and a solid talent base. One of the most important factors, however, is the role of institutions that facilitate cooperation and collaboration between industry, government, education and research organisations.[61] There needs to be a commitment from both the public and private sectors to the development of knowledge and skills if there is going to be an economy-wide transition into more knowledge-based activities.

GAINING COMPETITIVE ADVANTAGE

Production in emerging economies will continue to grow as resources sector infrastructure is developed to access abundant mineral and energy resources. This creates a significant opportunity for more 'experienced' regions to step up and fill the gap in human capital and technology. As more suppliers enter the market, however, there will be increased pressure on them to establish a competitive advantage. This will require ongoing investment in innovation and R&D.

We are already seeing this in Australia where business expenditure on research and development in mining represented just 1.5% of gross value added in 2008-0965, while in the country's METS sector, R&D expenditure totalled over 11% of sales.[61]

The global mining industry is facing a number of significant challenges relating to both inputs (e.g. energy, water, labour) and outputs (e.g. declining ore grades) that will require innovative approaches (not just new machines) if they are ever to be solved. As a result, the firms that get ahead in the knowledge economy and the global METS sector will be those that develop, through innovation, 'complete' or 'integrated' mining solutions, rather than just parts and equipment.[61]

A NEW IP LANDSCAPE

Managing the ownership of knowledge is an increasingly complex issue in a world where knowledge is both created (through cross-country collaboration) and traded across global markets. Intellectual property rights,

namely patents and copyrights, are well-known methods for protecting technological advances.

However, intellectual property laws were originally created when such advances were associated with the production of physical goods.66 Markets for intangible information goods can't work in the same way as markets for tangible goods because knowledge is non-rival (use by one person doesn't affect use by another) and because it is difficult to exclude others from accessing knowledge.[67]

As a result, we are seeing a move beyond traditional forms of IP licensing and the emergence of new 'collaborative mechanisms', including new IP intermediaries such as IP clearinghouses, exchanges, auctions and brokerages; model agreements; and frameworks for IP sharing.[58] We have also seen the introduction of new IP policies and practices by industry, government and universities.

The IP landscape will need to continue to evolve and adapt to better serve the knowledge-based markets of the future. It is also likely that as the trade in knowledge becomes increasingly global in nature, there will be a move towards a more integrated approach to managing IP internationally.

CHILEAN PERSPECTIVE

- Chile currently ranks 40th (out of 145 countries) in the World Bank's Knowledge Economy Index. It has the highest ranking of any Latin American country and is ranked 4th out of 34 upper middle income countries. While it sits behind other, more developed, resource-rich countries such as Canada (7th), Australia (9th) and the USA (12th), it is in a strong position to export knowledge and skills to other Latin American countries, Africa and possibly even Asia.[68]
- Chile has a strong commitment to global free trade. Developing a services-based export economy would align with this long-term vision.
- Other mining leaders (e.g. Canada and Australia) are looking to target Chile as a key market for their METS exports. Chile can reduce its dependency on imports by developing these skills locally.
- While exports of mining-related services from Chile are growing, the industry lags behind the world's leading METS industries of Canada, Japan, USA, Australia and Scandinavia. The World Class Providers Program, an initiative of BHP Billiton, Codelco and the Chilean government, has made some progress in this area but there is still an enormous opportunity to continue the development of a mining services sector.
- Developing a strong mining services sector will help to diversify the economy to ensure Chile doesn't fall victim to the resources curse.

The Era of Accountability

In the coming decades the operations of mining companies will need to be planned to meet both rising societal expectations as well as greater regulation relating to environmental and social accountability. Mining companies will be expected to be true corporate citizens and consider the needs of everyone affected (either directly or indirectly) by their operations. This expectation will translate into greater levels of sustainability reporting and regulation as well as greater levels of community action. Earning and maintaining community support for mining projects will be one of the most important factors for managing risk over the next twenty years, especially as we see levels of environmental and social concern grow in the world's developing economies. Mining companies that underestimate this trend towards accountability will not only experience issues relating to project operations and company reputation but will also miss out on the opportunity to leverage sustainable practices for greater financial performance.

HEIGHTENED EXPECTATIONS

The global environmental movement began to build momentum in the 1960s, accelerated in the 1980s and, in many regions, environmental responsibility has now become a society-wide expectation. For example, 'Earth Hour' began in Australia in 2007, asking Sydney businesses to switch off their lights for one hour as a signal that they support environmental action to protect the planet. By 2012, over 6,950 cities around the world participated in the event.[69]

Expectations for socially responsible behaviour, outside of environmental action, are just as high and, again, people are looking for ways to get involved. Globally, retail sales of Fairtrade certified products have more than quadrupled in the last eight years.70; 71 More people are beginning to understand that they have the power to make a difference at an individual level which, in turn, creates pressure for companies and industries to meet rising consumer and community expectations.

TELL ME MORE

People continue to expect access to more, transparent information and today 95% of the world's 250 largest companies conduct sustainability reporting on a regular basis, compared to just 35% back in 1999.[72]

Several initiatives aim to increase consistency and raise reporting standards, such as the widely applied Global Reporting Initiative's Sustainability Reporting Framework. In the resources sector, the Extractive Industries Transparency Initiative (EITI) is a global standard that promotes revenue transparency and accountability at a national level. It was established to help ensure that the potential society-wide benefits of oil, gas and mining are fully realised.

The International Council on Mining and Metals (ICMM) also publishes an annual assessment of

member performance against commitments relating to sustainable development.

FROM GUIDELINES TO MANDATES

Beyond sustainability reporting, there are a number of other global sustainability initiatives applicable to mining including the International Finance Corporation Performance Standards, the UN's Guiding Principles on Business and Human Rights, OECD Guidelines for Multinational Enterprises, the Framework for Responsible Mining and the Natural Resource Charter.

While many of the guidelines and initiatives relating to environmental and social sustainability have been partly or wholly voluntary until now, this is likely to change in the coming years. Increased awareness of the benefits of sustainable practices (and the damage that can be caused in the absence of such practices) has led to greater societal pressure and, as a result, an increase in the amount of regulation in this area.

Several countries have already adopted laws and regulations that mandate sustainability reporting including Australia, France, Italy, Malaysia, the Netherlands, and Sweden. The Minerals Council of Australia believes that the minerals resources sector is now the most heavily regulated industry in the country claiming that mining approvals in the country can take five to seven years to complete.[73]

Putting a price on carbon, through emissions trading schemes or other similar mechanisms, is another way of indirectly regulating the environmental impacts of the mining industry. More than 40 national and 20 sub-national jurisdictions have either implemented or are in the process of considering carbon pricing mechanisms.[74]

GLOBAL FRAMEWORKS

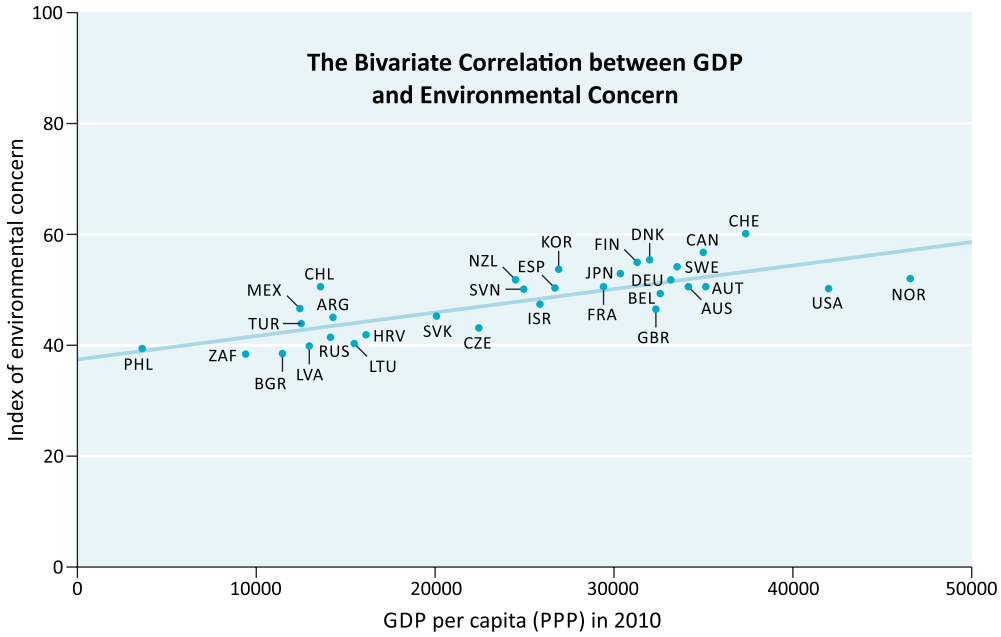
Many of the world's biggest mining companies now boast an international footprint and are therefore subject to international scrutiny. While there are a number of disjointed sustainability initiatives, there is no primary global standard-setter for the industry. In the future we may see the development of a global regulator of mining, similar to the Basel Committee on Banking Supervision in the banking sector, to allow for the creation of global standards for a global mining industry.

The World Economic Forum's 'Mining and Metals Scenarios to 2030' report discusses a potential future in which the world is divided and countries are defined economically by whether or not they belong to a 'Green Trade Alliance'. In this new world a metric has been created called 'GDP+' which incorporates environmental, sustainability and social indicators.[75] While it is yet to be determined whether such a future will pan out, it does appear that regulation concerning environmental and social sustainability will continue to rise at both a local and global level.

SOCIAL LICENCE TO OPERATE

Environmentally and socially responsible practices are needed to earn more than just a tick of approval from the regulators. Such practices are also required to earn and maintain community support and approval, often referred to as 'social licence to operate'. The benefits from a mine site are expected to flow down to all community stakeholders through improved infrastructure, employment and training opportunities and access to better services, such as healthcare. At the same time, mining companies are expected to minimise the detrimental effects (often environmental) of their operations.

While the budgets for mining projects continue to tighten, community expectations are constantly expanding. As a result, mining companies will have to find smarter ways to ensure that nearby communities are affected in a positive way by the presence of their mining operations. For example, when developing a new mine site, mining companies could consider how their



Source: Franzen & Vogl, 2013

infrastructure needs (roads, housing etc.) align with the infrastructure needs of the surrounding communities, in order to establish development plans that are mutually beneficial without adding significantly to project costs.

Where regulations fail to meet community standards, local residents will often take matters into their own hands, as was seen when citizens in Chile became concerned about the Pascua-Lama gold mine and the effect it was having on the water supply and glaciers.

ECONOMIC DEVELOPMENT LEADS TO GREATER LEVELS OF CONCERN

Studies have shown that environmental concern can be linked to a country's wealth.[76] Mining is already under significant pressure to improve in the areas of environmental and social sustainability and this pressure will continue to grow as a number of mining operations exist in highly populated developing nations across Asia, South America and Africa. In fact, the ban on open pit mining enforced in the South Cotabato province in the Philippines in 2010 indicates the level of environmental and social concern that already exists in many developing nations.

MINING NEEDS TO LIFT ITS GAME

In terms of sustainability reporting mining is currently leading the way, with 84% of the industry reporting on corporate responsibility initiatives.[72] However, in regards to taking action other indicators suggest that the industry still has a long way to go. For example, in the Corporate Responsibility Magazine's '100 Best Corporate Citizens of 2013', only one mining company – Freeport-McMoran Copper and Gold Inc. – features in the list. By comparison, a number of oil and gas companies can be found in the top 100 list, including Chevron, ConocoPhillips and Exxon Mobil.[77]

Public opinion of the sector as a whole is poor and many NGOs, such as Oxfam and Friends of the Earth, have campaigns specifically targeted at the mining industry. Mining has a significant reputational issue that will require effort above and beyond minimum/mandatory requirements if it is to foster more widespread community support.

Just as mining companies around the world have made worker safety a top priority over the last twenty years, they must now apply that same sense of commitment and quantitative targets beyond employee wellbeing to the wellbeing of the environment and the communities in which they operate.

THE BOTTOM LINE

Corporate responsibility doesn't just have to be about appeasing the regulators and the environmentally and socially minded; it has also been shown to contribute to a firm's financial performance. A Harvard Business School study found a clear link between environmental and social sustainability and economic performance over an 18 year period.[78] In addition, a recent study shows that one in every eight individual investors is willing to forgo financial returns to achieve ethical principles.[79]

A growing demand for sustainably sourced materials will also see investment flow to companies with a track record in sustainability. Certification programs across industries such as construction and jewellery are leading to greater concern for how minerals and metals have been sourced. For example, in order to achieve a green building credit under BREEAM (an assessment method for rating the sustainability of buildings), the Handball Arena for the 2012 London Olympic Games used copper sourced from the Minera Escondida mine in Chile, due to the mine's ISO 14001 certification and the existence of a corporate responsibility policy.[80]

This megatrend also brings about new opportunities for companies in areas such as carbon sequestration, clean coal technology, renewable energy, water-efficiency technology and desalination. In the Era of Accountability many companies will just be looking for ways to survive and carry on with business as usual. However, the companies that embrace the trend towards sustainability and adapt to capitalise on the opportunities it presents will experience the greatest success.

CHILEAN PERSPECTIVE

- Chile faces a number of environmental challenges, particularly in relation to access to water and tailings disposal.
- As Chile transitions to a developed economy it is likely that its citizens will continue to demand more from the companies operating in their backyard. In the absence of strong regulations in this area, mining companies will have to self regulate in order to avoid potential negative consequences, as seen with case of Pascua-Lama.
- Chile has voluntary reporting standards but no mandatory standards for reporting sustainability. However, the majority of major mining companies operating in Chile, including Anglo American, Barrick, BHP Billiton, XStrata and Codelco, are members of the International Council of Mining and Metals which was founded to improve sustainable development performance in the mining industry. As members of the ICMM these companies have a commitment to conduct sustainability reporting according to the Global Reporting Initiative guidelines.
- In 2008 the Chilean Government ratified the International Labour Organisation Indigenous and Tribal Peoples Convention No. 169 – a legally binding instrument that seeks to ensure that indigenous and tribal people are consulted and participate in decision making concerning their rights. This essentially makes earning a social licence to operate an almost mandatory part of the approval process for any mining project.

The Rise of Recycling

With declining ore grades and rising mining production costs, the mine of the future may be increasingly concerned with materials that lie above, rather than below, the earth's surface. We can expect to see a 'rise of recycling' as many recyclable materials contain rich and accessible mineral content. For example an open pit mine will yield between 1 and 5 grams of gold for every one tonne of ore body extracted. This compares to 350 grams of gold yielded by one tonne of discarded mobile phones and 250 grams of gold yielded by one tonne of computer circuit boards.[81] While primary production is still strongly favoured today, mineral scarcity and a range of other factors indicate that recycling is going to play an increasingly significant role in international commodity markets and global supply chains in the future.

MINERAL SCARCITY POINTS TO SECONDARY MATERIALS

Recycling rates are still fairly low due to the relatively low efficiencies in the collection and processing of discarded metal-bearing products, limitations of recycling processes, and the relative abundance and low-cost of primary materials. For example, copper is 100% recyclable without loss of performance and 80% of all copper mined over the last 10,000 years is still in use somewhere today.[82] Yet less than one-fifth of global refined copper production comes from secondary sources.[30]

The ratio of secondary to primary production is likely to increase as a recent study finds that mineral scarcity is a bigger issue than energy scarcity. Total non-renewable energy resources (that can power recycling plants) are expected to last the world another 574 years while total mineral resources will last 191 years.[83]

When the demand for certain minerals exceeds production levels, recycling could be one way to fill the gap. For example, copper reserves are expected to meet global demand until around 2040[48], after which there will need to be a reduction in copper consumption or an increase in secondary copper production.

SUBSTITUTES VS. SECONDARY MATERIALS

A noteworthy trend running concurrently to the Rise of Recycling megatrend is the rise of substitute materials. Nickel pig iron was developed in China as a cheaper alternative to pure nickel for use in the production of stainless steel. Nickel pig iron usage accounted for 25% of Chinese stainless steelmaking raw materials in 2011, up from 16% in 2008.[84] Graphene (a single-atom thick sheet of hexagonally-arranged carbon atoms) is being touted as having the potential to act as a substitute for silicon, steel and even copper due to its flexibility, strength and thermal conductivity.[85] [86] And with a density similar to that of gold, tungsten is being used as a substitute for gold in jewellery.

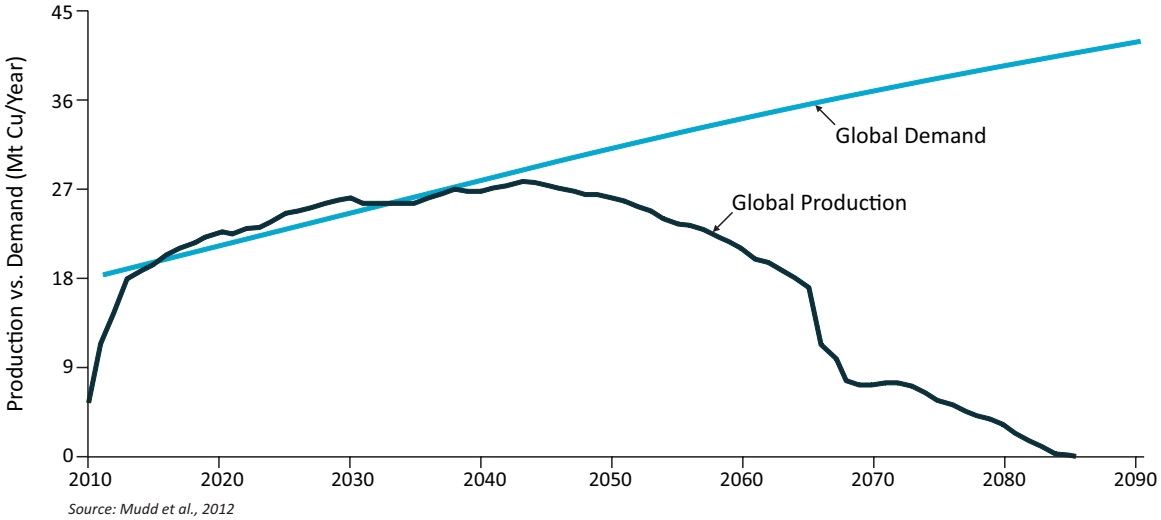
While there is no doubt that the expected future mineral supply deficit will create a need for alternatives to mined ore, the true potential of a number of identified substitutes (e.g. graphene) is yet to be determined and there will often be limitations to their applications or other issues that reduce their favourability. For example, nickel pig iron has been labelled "dirty nickel" due to the poor environmental outcomes of the production process.[87]

Due to the widespread understanding of the basic environmental benefits of recycling as well as the growing strength of a number of other drivers, it is likely that secondary materials will be responsible for filling a significant proportion of the supply deficit created in a world with increasing mineral scarcity.

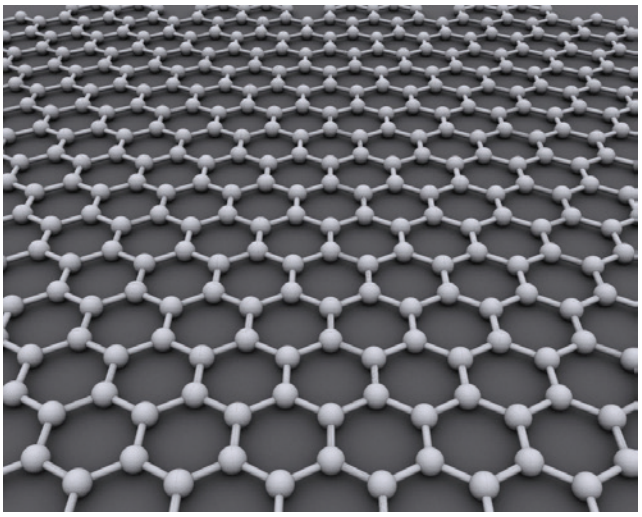
THE KEY DRIVERS OF RECYCLING

- Abundance of some energy resources – The world has an abundance of certain energy sources including uranium, coal and natural gas that can supply the energy needed to convert anthropocentric waste streams into useful materials.[85]
- Rising energy costs and a demand for more sustainable mining practices – While there is an abundance of

Projected Global Copper Demand and Mine Production to 2090



Source: Mudd et al., 2012



Graphene is a single-atom thick sheet of carbon atoms packed tightly into a honeycomb arrangement. It could be a future substitute for silicon, steel and copper due to its flexibility, strength and thermal conductivity. Image Source: AlexanderAIUS, Wikimedia Commons

certain energy sources, there is still significant pressure to reduce energy consumption in order to reduce operational costs as well as stem greenhouse gas emissions. Producing aluminium from recycled sources requires 95% less energy than producing it from virgin materials90 and copper reclaimed through recycling requires 75-92% less energy than the amount needed to convert copper ores to metal.[84]

- Growing demand for more sustainable materials – Companies and consumers are beginning to show a preference for the use of recycled, rather than new, materials. For example, 'green buildings' are growing in popularity and two of the world's most widely recognised green building certification programs, BREEAM and LEED, both assign points/credits for the use of recycled content, such as recycled steel.[91] [92]
- Gradual decline in mineral ore grades – Ore grades are declining for many mineral commodities as the richer deposits have been increasingly extracted.
- Improvement of recycling technology – Product complexity has been a significant barrier for recycling due to the effort required to separate materials of interest. Coming decades, however, will see the continued advancement of chemical and physical processes for recycling and computer tools to make recycling more efficient and less costly.
- Increased generation of waste material – Ten years ago, around 0.68 billion tonnes of urban municipal solid waste was generated globally each year. Today, this has increased to around 1.3 billion tonnes and by 2025 it is likely to reach 2.2 billion tonnes per year.[93]
- Rising cost of waste disposal – Globally, solid waste management costs will increase from US$205.4 billion per year in 2010 to around US$375.5 billion in 2025.[93]
- Ongoing growth in demand for metals, plastics, glass and other materials – This demand continues to be driven, to a large extent, by economic growth in Asia.

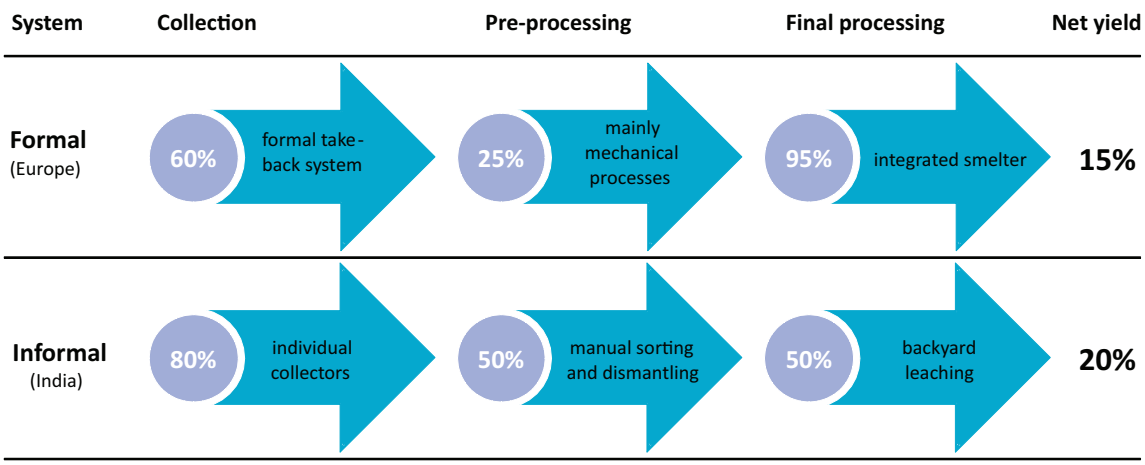
POLICY AND REGULATION

Government initiatives, such as the End of Live Vehicle Directive and the Waste Electrical and Electronic Equipment Directive in the EU, can help to increase consumer awareness and action around recycling as well as improve the productivity of recycling operations.

Government intervention will also be important in developing countries with informal recycling systems – it is estimated that there are more than two million informal waste pickers around the world.[93] Initiatives will be required in order to try and maintain the currently high collection rates[94] that will likely decline as employment prospects increase in developing regions, and to improve the currently low processing rates.

- As governments continue to introduce new policies and regulations the following is likely to occur:
- Companies will be required to design products with a consideration for end-of-life recyclability;

Recycling Efficiency Between a Common Form System in Europe and the Informal Sector in India for the Gold Yield from Printed Wire Boards



Source: UNEP, 2013

- Manufacturers will be held more responsible for the recovery of their products (either through incentives to act or punishment for non-compliance);
- Collection systems will improve to involve less effort on the part of the consumer; and
- Public awareness will increase around the benefits of recycling a broader range of products (beyond current common recyclables such as aluminium cans, plastic bottles and newspapers).

RECYCLING AS A GLOBAL MARKET

Recent decades have seen the emergence of the recycling industry as a global business with international markets and extensive supply and transportation networks. The world market for post-consumer scrap metal is estimated at 400 million tonnes per year while paper and cardboard is around 175 million tonnes annually, representing a global value of at least US$30 billion per year.[93] World trade in copper and copper alloy scrap has increased by more than 385 percent over the last two decades.[95]

China has recognised the value of secondary sources, creating a tax regime that facilitates access to more recycled copper at lower prices. China's Ministry of Finance allows duty-free treatment of copper scrap imported into China, while imposing heavy taxes on exports of copper scrap from China. This has seen the cost of copper scrap and prices for downstream products increase for producers in the US and Europe, and decrease for producers in China.[95]

As recycling grows, we may see an entirely new industry model emerge in which materials are controlled centrally and are then loaned, rather than bought, by individual companies. Rather than purchasing materials such as copper and aluminium, these materials could be loaned for a lower cost with the promise that they would be returned at the end of the loan period. While this is only speculative and it will likely take more than 20 years for this aspect of the Rise of Recycling megatrend to come to fruition, it does demonstrate the potential for recycling to completely reshape global commodity markets.

CHILEAN PERSPECTIVE

- Recycling and other substitutes for copper ore have the potential to create new/increased competition for Chile's mining industry.
- Chile has significant expertise in regards to copper, one of the most recyclable materials in existence, but has little expertise in copper recycling. There is a potential opportunity to apply Chile's extensive knowledge relating to smelting and refining copper ore to the secondary copper production supply chain. While there may not be the economies of scale required to make copper recycling a new industry in Chile, knowledge could be developed in this area and then exported to other regions, such as Asia, as part of a growing mining services sector.

Mining in Chile: Future Scenarios

Five conceptual scenarios for the future of mining in Chile

Scenario Analysis

Scenarios are evidence-based narratives of the world at a future point in time. They help decision makers think about futures to guide strategic directions and to better understand trade-offs between possible decisions.

Scenarios also provide a means for clearly communicating a wide range of possible outcomes and the consequences of each. This can be used to build consensus across a diverse set of stakeholders by putting these outcomes in the appropriate context for individual stakeholders.

This report includes five scenarios for the Future of Mining in Chile: a baseline, three positive scenarios, and one negative scenario. These scenarios were crafted from an understanding of the current state in Chile and possible ways that the global mining megatrends could impact Chile in the future.

In general, scenarios are more useful for broadening thinking than giving a strong prediction of what will happen in the future. The scenarios presented in this report are conceptual; no conclusive evidence exists that one scenario is more likely than another.

Scenarios provide a framework for thinking about allocation of scarce resources (labour, capital, government expenditure, etc.) across a range of possible futures. By identifying common features across scenarios, a long-term strategy can be formulated that optimises resource allocation under the widest range of scenarios.

Scenario planning is useful not only to understand possible futures and react to them, but also to guide proactive actions that will influence ideal outcomes. Each of the positive scenarios includes a set of high-level "key actions" to drive the associated outcomes.

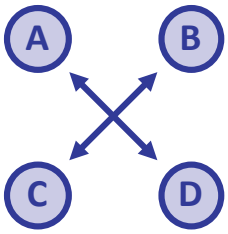
Scenarios can be used to identify major risks associated with negative futures. The negative scenario in this report looks at the current weaknesses and indicators that must be addressed to avoid the consequences of these scenarios.

Scenario Characteristics

START WITH A BASELINE

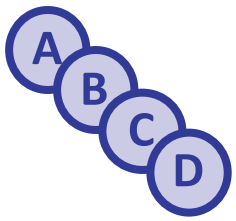
The "Uncertain Future" scenario is a baseline that describes a likely set of future conditions if no significant actions are taken to influence outcomes. This baseline provides a point of comparison for the other scenarios. The timeframe for the outcomes described in all of the scenarios is roughly the next 20 years.

EXTREMES



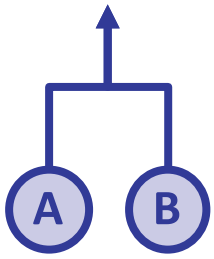
The five identified scenarios for the future of mining in Chile represent a diverse set of possible outcomes. While it is unlikely that any of these scenarios will play out exactly as stated, by looking at extreme cases we can more clearly illustrate the trade offs between different scenarios.

OVERLAPPING



The scenarios presented in this report are not meant to be strictly mutually exclusive, and contain some overlap. For instance, the outcomes in the "Mining Powerhouse" scenarios would not preclude the outcomes described in "Strong Services" and in fact, the two scenarios could be considered complementary.

IDEAL MAY BE A COMBINATION



This report contains three predominately positive scenarios, each with different characteristics that would be beneficial to Chile in the long run ("Mining Powerhouse", "Strong Services" and "Sustainability Leader"). An ideal future could include some aspects of all of the positive scenarios.

Scenarios for the Future of Mining in Chile

Mining Powerhouse

Demand for copper remains strong and Chilean miners use technology and innovation to increase productivity, reduce costs, and remain globally competitive. Mining profits continue to drive growth in the Chilean economy and foreign investment fuels a new wave of mineral exploration.

Strong Services

Chile diversifies its economy through the development of a strong knowledge and services economy built on innovation. Mining services (METS) pave the way for ICT and other service industries. This creates export opportunities and bolsters Chile's regional and global trade.

Sustainability Leader

A national approach is taken to developing Chile's reputation as a world leader in sustainable mining practices. A commitment to 'green' technology and innovation sees Chile become a major exporter of technology and services relating to sustainability.

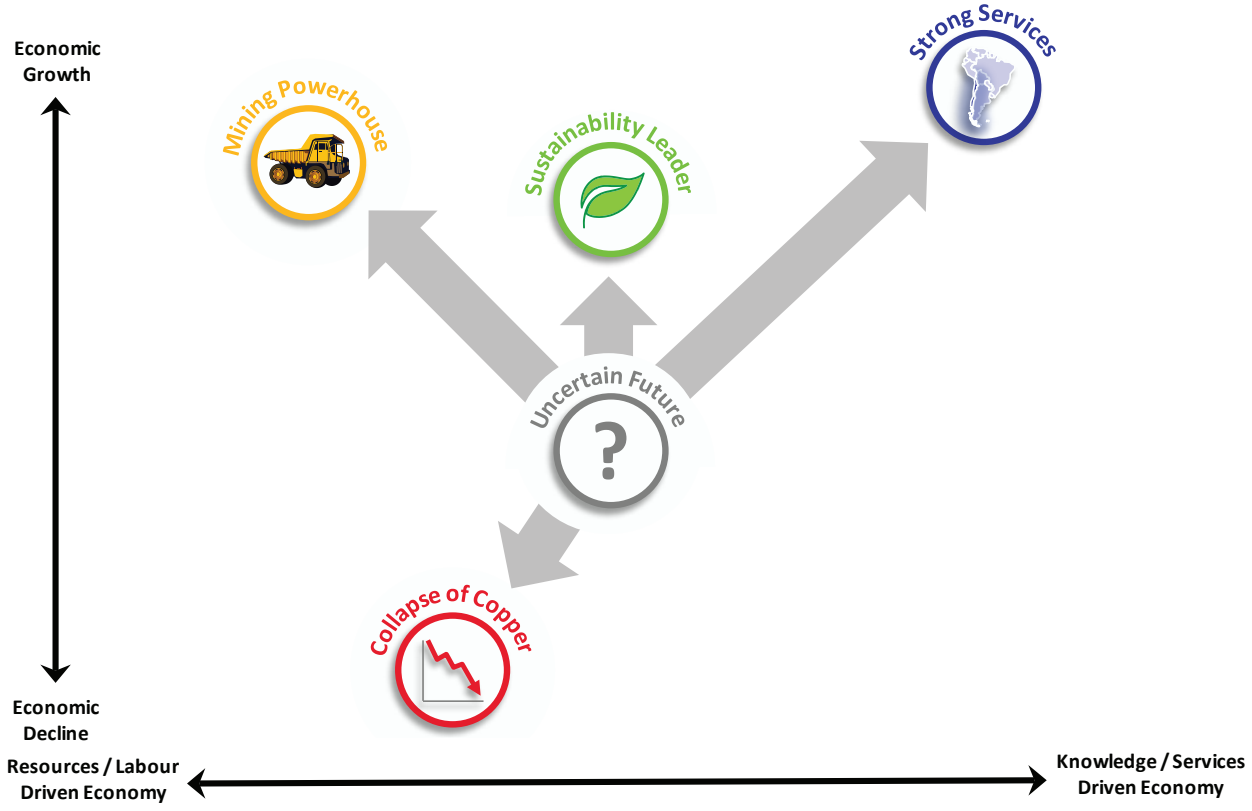
Collapse of Copper

Chile's copper industry fails to remain globally competitive as domestic labour and energy costs rise. Lower cost competition emerges in developing countries and the rise of recycling and potential substitutes squeezes out demand for raw copper.

Uncertain Future

This scenario is based on Chile's current trajectory. In this scenario Chile's economic growth levels off as demand for copper stabilises and costs continue to rise. Chile's mining services industry grows slowly and mining companies continue to import labour, technology and services. Efforts to develop a thriving national innovation system are hampered.

Scenarios – Economic Drivers and Output



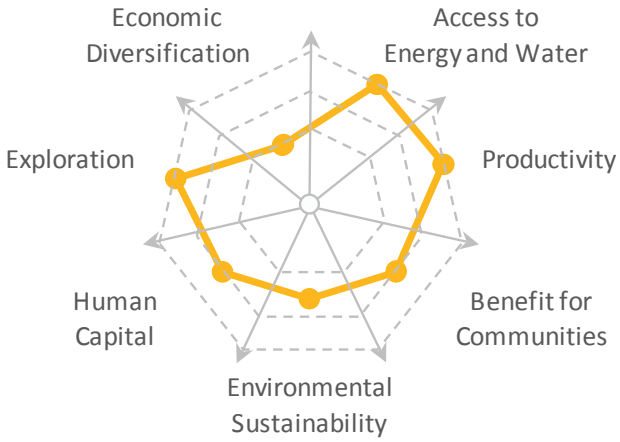
Mining Powerhouse

Demand for copper remains strong and Chilean miners use technology and innovation to increase productivity, reduce costs, and remain globally competitive. Mining profits continue to drive growth in the Chilean economy and foreign investment fuels a new wave of mineral exploration.

KEY CHARACTERISTICS

- Mining remains a major industry in Chile, continuing to drive both GDP growth and exports.
- Strong global economic growth continues to fuel demand for copper and copper prices remain level or slowly increase. Decreases in Chinese growth rates are offset by rapid growth in India and other developing countries.
- Multi-factor productivity (MFP) in Chile's mining sector rises and becomes comparable to MFP in other developed mining countries such as the United States and Australia. This is driven by research, innovation, and use of advanced technologies in automation, remote operations, advanced processing, and smart information platforms.
- Increased production of unconventional oil and gas resources drive down global energy prices, reducing one of the key input costs for the Chilean mining industry.
- A new wave of mineral exploration is driven by the development of a national pre-competitive geosciences database and the reformation of exploration rights.
- Research in deep exploration technologies and in-situ mining allows deeper and more difficult resources to be mined profitably.
- Mining companies partner with government and universities to make large investments in human capital development.
- Copper remains competitive against potential substitute materials.

OPPORTUNITIES AND CHALLENGES



KEY SUPPORTING MEGATRENDS

- The Asian Century
- Innovation Imperative

Mining Powerhouse

Key Actions to Drive Outcomes

PRODUCTIVITY GAINS THROUGH TECHNOLOGY INNOVATION

- Chilean miners continue to drive productivity through the use of automation and successfully apply automated solutions as they convert from open-pit to underground mines to pursue deeper resources.
- "Mining in the cloud" becomes a reality as Chilean miners develop remote operations centres in major metropolitan areas to take advantage of network effects and a skilled labour force. These centres are capable of controlling mine sites and operations nationwide.
- Mining companies develop common mine models that allow a single integrated mine model to be used to drive operations across the value chain.
- Mining companies develop and deploy control systems that integrate seamlessly with the mine model for near real-time optimisation of both excavation and processing at an increasingly granular level.
- Intelligent processing plants can analyse ore content in real time and feed ore grade data into the mine model. Processing can also be optimised based on external conditions such as commodity spot prices and current transportation costs.

SOLVE THE ENERGY AND WATER CHALLENGE

- Research in dry processing techniques, seawater processing, water reuse, and water conservation methods reduces water feedstock requirements, driving down energy requirements and costs.
- The central electrical grid (SIC) and northern electrical grid (SING) are integrated, allowing northern mining operations to use the south's hydropower during wet years.
- Research into desalinisation efficiency drives down water costs by reducing energy requirements for northern desalinisation plants.
- Chile reconsiders its policy on energy regulation and becomes a leader in market-driven energy solutions that also account for the natural monopoly/oligopoly in energy generation.

NEW EXPLORATION / INVESTMENT

- Chilean miners collaborate with SERNAGEOMIN to develop a national pre-competitive geo-scientific database – similar to Geosciences Australia – that integrates a wide range of geosciences data and makes it available online.
- Chile supplements foreign direct investment with domestic investment through the development of a resources bourse, perhaps in conjunction with other Pacific Alliance members.
- Hyperspectral core analysis (using tools such as CSIRO's Hylogger) gives insights into the characteristics of geological and mineral systems and the potential to more rapidly develop new resources.
- Research in deep-drilling technology, advanced drill sensors, large-scale geophysical analysis (e.g., ASTER mapping), and 3D resource modelling allows deeper and more difficult resources to be profitably mined.

ENVIRONMENTAL SUSTAINABILITY AND SOCIAL BENEFIT

- Development of in-situ mines brings Chile closer to the concept of the "invisible mine" and allows access to deeper resources without the environmental damage associated with open cut mines.
- Chile develops a national vocational training program to developed human capital in mining-related skilled labour.

Current strengths to capitalise on and indicators that support this scenario

- Longstanding expertise in mining, especially copper.
- Significant mining investment expected between now and 2021 – approx. US$112 billion.
- R&D expenditure has increased over the last 5 years.
- Demonstrated ability to use desalination as a means to access water.
- Demonstrated ability to incorporate remote operation into mine site operations.

Risks and challenges associated with this scenario

- Exposure to global copper demand and prices – a large decline in either would have a significant impact on the Chilean economy.
- Lack of economic diversification and a "two-speed economy" – a highly successful resource-dependent export economy will likely face rising input prices and a strong currency which will make it difficult for other industries to complete globally.
- Opportunity cost – capital invested in mining activities will be at the expense of other opportunities such as novel innovations and new markets.

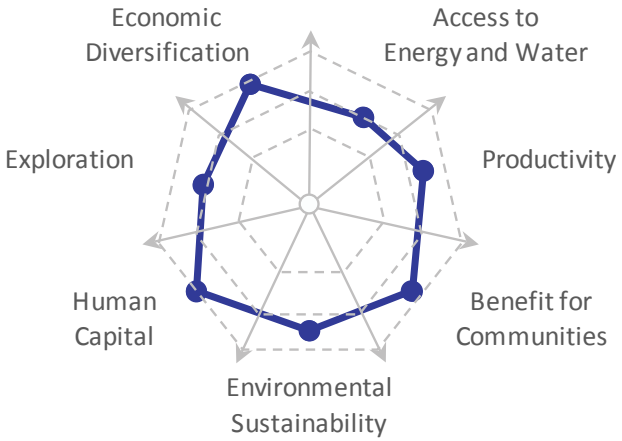
Strong Services

Chile diversifies its economy through the development of a strong knowledge and services economy built on innovation. Mining services (METS) pave the way for ICT and other service industries. This creates export opportunities and bolsters Chile's regional and global trade.

KEY CHARACTERISTICS

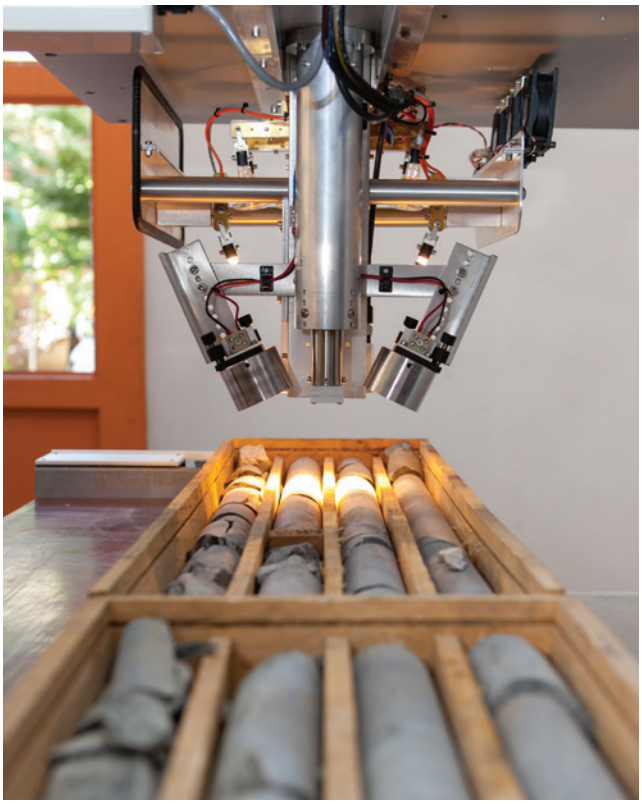
- Chile builds a more diversified economy through the development of a thriving and globally competitive mining equipment, services, and technology (METS) sector based on strong research and innovation. This accelerates economic growth and reduces dependence on imported mining services.
- Capitalising on successes in mining services, Chile's economy flourishes which encourages strong innovation and investment in additional service industries in areas such as ICT, agriculture, aquaculture, forestry, and energy.
- Chile exports services, specialised skills, and innovative technologies throughout Latin American and to developing mining countries around the world, strengthening its exports and terms of trade.
- Santiago and Antofagasta develop into global innovation hubs with world-class research universities, strong entrepreneurial cultures, access to global venture capital, and the 'creative classes'. Santiago centres around ICT and high-technology services and Antofagasta around mining and energy-related innovation and services.
- The Pacific Alliance strengthens and increases trade between Latin America and Asia. This gives Chile the scale necessary for advantageous terms of trade.
- Chile fosters cultural change towards innovation and risk-taking through the development of government, industry, and university programs to encourage entrepreneurship and investment.

OPPORTUNITIES AND CHALLENGES



KEY SUPPORTING MEGATRENDS

- Innovation Imperative
- Knowledge Economy
- The Rise of Recycling



Strong Services

Key Actions to Drive Outcomes

MINING SERVICES

- Development of Antofagasta as a world-leading mining research, education, and innovation precinct, including both a strong university applied research program and vocational/technical training programs. Partnership with major mining companies to create a "living mine" research centre. Industry, SMEs and researchers are all co-located here and collaborate on fundamental and mission-directed research, through a strong partnership model, similar to Australia's CRC program.
- Expansion of BHP Billiton/Codelco's "Proveedores de Clase Mundial" program into more innovative and technology-oriented services.

INNOVATION AND BROADER SERVICES SECTOR

- Develop a series of industry precincts or collaborative research centres that act as innovation hubs and bring together industry, university researchers, government, and SMEs in core Chilean industries: agriculture, forestry, aquaculture, winemaking.
- Create an ICT services incubator (using the Techstars/Y-Combinator model) in Santiago that provides common facilities, support, funding and mentorship for entrepreneurs.
- Universities bolster their technology transfer offices and build programs that provide incentives to staff and students to commercialise research.

EDUCATION AND HUMAN CAPITAL

- Invest in the development of multiple world-class (top 100) science and research universities.
- Foster a cultural shift that encourages more PhDs to move into industry and facilitates a stronger relationship between the university research community and industry research groups
- Creation of a regional vocational program, modelled on Australia's TAFE system – jointly funded by government and industry – that prepares workers for the transition from resources to service-related jobs.
- Create a researcher and skilled labour exchange program with other countries with common industries and challenges, such as Australia, Canada and South Africa.

Current strengths to capitalise on and indicators that support this scenario

- Over 60 suppliers participating in BHP Billiton/ Codelco's World Class Providers program, working on challenges across areas such as dust reduction and management, water, energy, equipment maintenance, human resources, and leaching.
- Several government initiatives have been implemented that are aimed at bringing about cultural change, including "The Year of Innovation (2013)", "Start-up Chile", and "Competitiveness Boost Agenda."
- The recently introduced R&D tax credit and new IP laws.
- Chile's mining provider exports grew from US$3.4 million in 2001 to US$294.6 million in 2011.

Risks and challenges associated with this scenario

- Structural economic shifts could cause rapid displacement of workers from the mining industry and a high unemployment rate in the short term.
- In the short-run, investment in non-mining sectors could divert capital away from the mining industry.

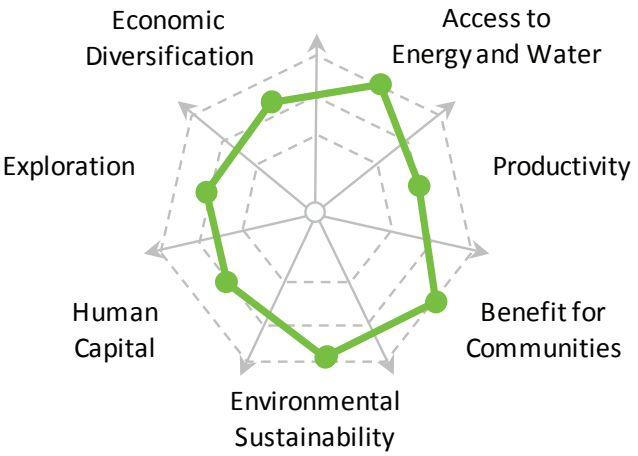
Sustainability Leader

A national approach is taken to developing Chile's reputation as a world leader in sustainable mining practices. A commitment to 'green' technology and innovation sees Chile develop a comparative advantage in sustainable minerals and become a major exporter of technology and services relating to sustainability.

KEY CHARACTERISTICS

- The global trend towards greater accountability in mining continues and mining companies around the world seek out new solutions in environmental and social sustainability.
- Global interest in sustainable sourcing of raw materials increases. Sustainability metrics for buildings and consumer goods provide greater transparency of sustainable practices across the entire metals and minerals supply chain.
- Chile's reputation in responsible mining practices gives it a comparative advantage as buyers develop a preference for Chilean sourced copper – e.g. for building materials required to meet green standards.
- Chile makes a large investment in renewable energy to decrease its dependency on imports and lower its greenhouse gas emissions. Research and innovation in unconventional renewable energy and energy storage technologies drives up efficiency and reduces costs.
- The increase in sustainable practices and a more trusted regulatory system sees social support for mining rise significantly. This opens up opportunities for new projects and reduces opposition to current projects.
- Chile uses its strengths in primary copper production to develop core capabilities in copper recycling and related services.

OPPORTUNITIES AND CHALLENGES



KEY SUPPORTING MEGATRENDS

- Innovation Imperative
- Knowledge Economy
- Era of Accountability
- The Rise of Recycling

Sustainability Leader

Key Actions to Drive Outcomes

RENEWABLE ENERGY AND WATER

- Chile partners with international research teams and suppliers to develop pilot programs in a number of promising renewable energy sources – solar thermal, wind, wave, and geothermal.
- The most successful technologies are developed into large-scale renewable energy facilities, and Chile comfortably meets its unconventional renewable energy target of 20% by 2025.
- Mining companies in the Atacama region co-locate large solar-thermal generation plants with mine operations. Advances in energy storage allow mining operations to use 100% solar energy, reducing operating costs and greenhouse gas emissions.
- Chilean mining companies fund research into sustainable desalinisation technologies – such as using wave energy to power reverse osmosis desalinisation – that decrease energy requirements for production water.

ENVIRONMENTAL REGULATION

- Chile strengthens its environmental regulatory framework, which increases cost of compliance for mining companies but also improves public trust in the industry.
- Chile improves environmental transparency by working with mining companies to develop a crowd-sourced regulation system. Miners are required to make public their environmental monitoring and other regulatory data and the public is encouraged to develop applications to monitor this data.

SUSTAINABILITY

- Through its world-leading network of Free Trade Agreements, Chile works to develop bilateral and multilateral trade alliances that encourage (and provide incentives) for trading environmentally and socially sustainable goods and services.
- Chile develops a "GreenChile" brand and works with trading partners to promote the benefits of sustainable practices in Chile's top industries – mining, agriculture, aquaculture, etc.

COMMUNITY INVESTMENT

- Mining companies develop closer ties with local communities and become directly involved in community planning and investment to ensure that basic infrastructure and services are adequately provided in mining regions.
- This leads to an increase in quality-of-life in mining regions and allows mining companies to attract top-tier skilled labour – both Chileans and skilled migrants.

CLEAN / GREEN SERVICES

- Chile develops a strong 'cleantech' sector to address challenges in areas such as energy and water management, emissions and waste – particularly in support of mining operations. The sector begins to export technology and services to other mining countries, helping Chile to carve out a niche in the global METS industry.
- Chile uses its strengths in copper production to develop copper recycling services that it exports to major copper consumers in Asia and elsewhere.
- Chile develops a renewable energy research precinct to support collaboration between major universities, energy companies, and mining companies on technologies that support Chile's unique environment – marine (wave) power, solar thermal power, and geothermal power are particularly promising.

Current strengths to capitalise on and indicators that support this scenario

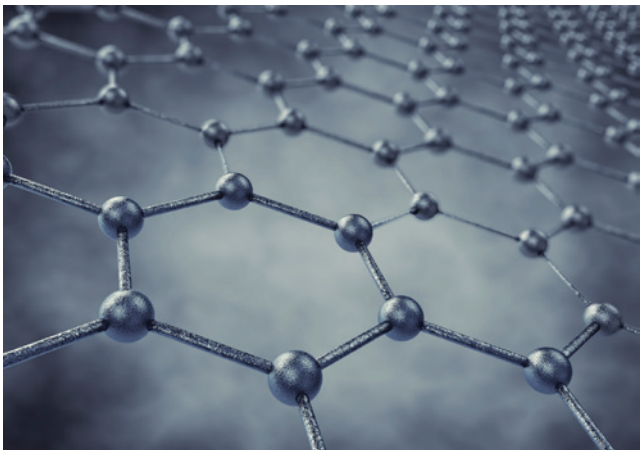
- Availability of renewable energy resources – the Atacama has one of the highest levels of solar irradiance on Earth, and Chile's coast offers great opportunities for wave power generation.
- Existing government targets for non-conventional renewable energy.

Risks and challenges associated with this scenario

- Costs associated with environmental compliance and community investment cause Chilean mining companies to lose cost competitiveness relative to companies in lower-cost regions like Central Africa and Southeast Asia.

Collapse of Copper

Chile's copper industry fails to remain globally competitive as domestic labour and energy costs rise. Lower cost competition emerges in developing countries and the rise of recycling and potential substitutes squeezes out demand for raw copper.

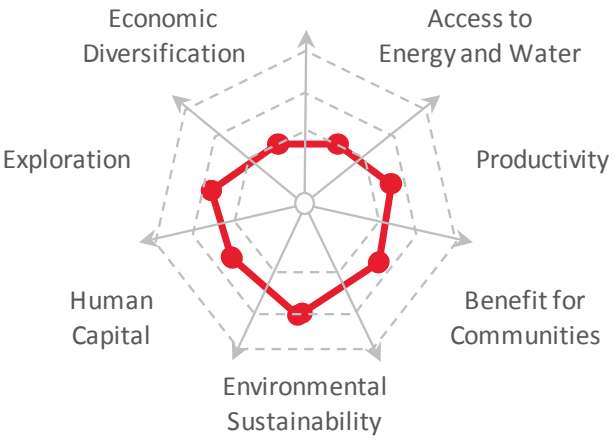


KEY CHARACTERISTICS

Three possible sub-scenarios:

1. External demand-driven
   - Due to economic growth lagging expectations, growth in global demand for copper slows, driving down prices and making many of Chile's mining operations unprofitable.
   - Copper substitutes (e.g., graphene) become feasible in certain applications and contribute to decreasing demand.
2. External supply-driven
   - Chile's mining industry continues to struggle with low productivity relative to more developed mining countries. Cultural and structural barriers hinder the adoption of technology innovations that could improve productivity.
   - Chilean miners continue to face some of the world's highest costs for energy and water. Climate change reduces output from southern Chile's hydro-power stations and improved efficiency of other renewable energy sources is slow to materialise, leaving Chile dependent on increasingly expensive energy imports.
   - Increased environmental regulation and investment in local communities impart additional cost on Chilean miners.
3. Internal cost-driven
   - Chinese investment in Africa pays off, and copper mines in Zambia and DR Congo are producing metal at a fraction of the cost of Chilean mines. China itself continues to be the world's largest producer of minerals and metals.

OPPORTUNITIES AND CHALLENGES



KEY SUPPORTING MEGATRENDS

- The Asian Century
- Era of Accountability
- The Rise of Recycling

Collapse of Copper

Indicators that support this scenario

- Delays in the mining investment pipeline due to lower copper prices and declining ore grades .
- Current policies on exploration rights discourage new exploration.
- Reliance on foreign investment for access to capital.
- R&D expenditure still relatively low (0.3% of GDP in 2012).
- Low level of business R&D and innovation, a lack of commercial-oriented research and low levels of industry-researcher collaboration.
- Chile relies heavily on energy imports and volatility in relationship with Argentina threatens the availability of natural gas.

Other risks and potential opportunities associated with this scenario

- Large declines in copper production will increase unemployment and create an urgent demand for training and workforce redeployment. This could lead to a nation “brain drain” as skilled labour looks for better opportunities overseas.
- Declining revenues in mining significantly impacts expenditure on social services, education, healthcare, and infrastructure in mining regions.
- Decreasing mining activity may result in lower environmental impact from mining operations, although there is a risk that insolvent mining firms will not have sufficient capitalisation to cover the cost of mine clean-up and rehabilitation.
- Even with a declining domestic industry, Chilean mining services and knowledge can be exported to other lower-cost developing mining regions.
- There is an opportunity for Chile to move into specialised services in copper recycling.

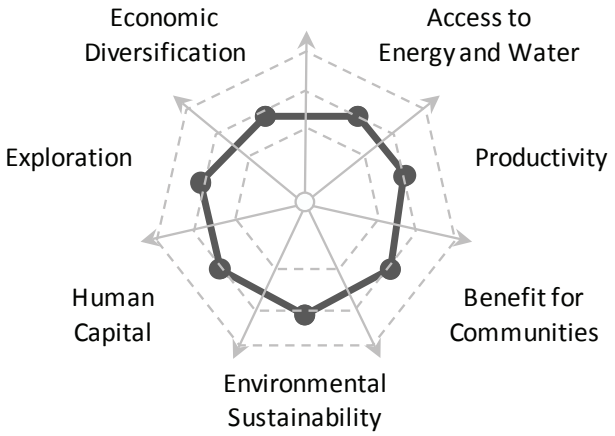
BASELINE: Uncertain Future

Chile's economic growth levels off as demand for copper stabilises and costs continue to rise. Chile's mining services industry grows slowly and mining companies continue to import labour, technology and services. Efforts to develop a thriving national innovation system are hampered by cultural and structural issues.

KEY CHARACTERISTICS

- Chile's efforts to develop a domestic innovation-driven knowledge and services economy are slow to deliver and the country remains heavily import-dependent for mining equipment, technology and services.
- Collaboration between Chilean research universities and Chilean mining companies delivers limited results due to differing priorities and cultures.
- Costs and productivity remain issues for the mining industry, and research and development produces limited solutions to solve these issues.
- The World Class Providers Program continues to incubate small support firms, but does not capitalise on the potential to develop world-leading mining technology and service innovators.
- Energy and water costs remain high as Chilean miners remain dependent on imported coal and oil and desalinisation plants for water.
- Labour costs remain higher than in many other mining nations leading mining companies to explore options such as conducting mine-site management from international hubs via remote operation or shifting investment to other countries.
- Environmental sustainability remains a major issue and Chile faces increasing tension between mining companies and mining communities over land use, water use, and tailings disposal.

OPPORTUNITIES AND CHALLENGES

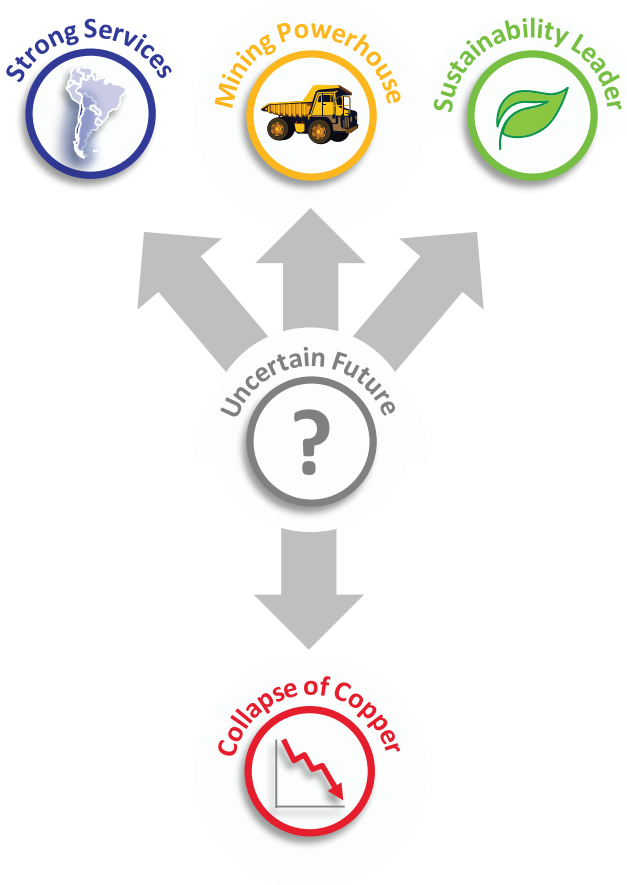


KEY SUPPORTING MEGATRENDS

- The Asian Century
- Innovation Imperative
- Knowledge Economy
- Era of Accountability
- The Rise of Recycling

Using Scenarios for Strategy Development

How to Use the Scenarios for Strategy Development



1. IDENTIFY ACTIONS TO DRIVE POSITIVE SCENARIOS

Each of the positive scenarios includes a set of high-level "key actions" to drive the associated positive outcomes. These actions can feed directly into strategy development.

2. IDENTIFY AREAS OF OVERLAP ACROSS SCENARIOS

The desired future state will likely contain components of several scenarios. There are strategies that can drive outcomes associated with multiple positive scenarios.

3. MITIGATE RISKS ASSOCIATED WITH THE NEGATIVE SCENARIO

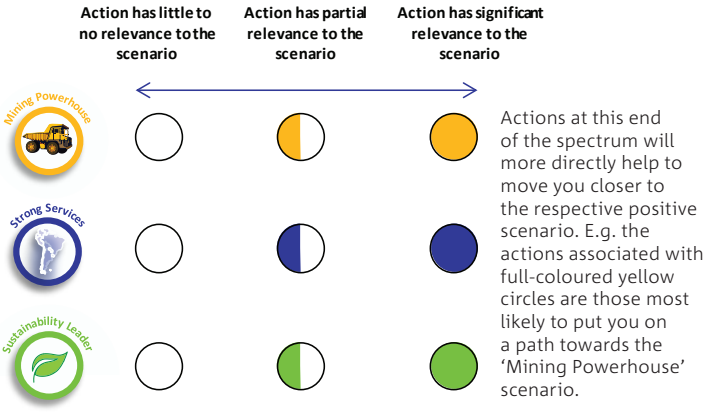
The "Collapse of Copper" scenario instead looks at the current weaknesses and indicators that must be addressed in any strategy in order to avoid the consequences of this scenario.

Key Actions to Drive Positive Outcomes

The key actions identified in the positive scenarios can help to drive positive outcomes by capitalising on the major opportunities and addressing the major challenges currently facing Chile's mining industry. Specifically, these positive outcomes are:

- Increase the security of supply and reduce costs associated with two of the mining industry's most important inputs: energy and water.
- Generate the exploration and new project investment required to sustain long-term growth for the industry.
- Improve mine productivity.
- Ensure the mining industry has access to the skilled labour it needs to remain globally competitive.
- Reduce the negative and/or increase the positive environmental and social impacts of mining in Chile.
- Increase economic diversification through the development of a globally competitive services industry.

As shown on the following pages, each key action that has been identified will have a varying degree of relevance to each the different scenarios. Analysing the actions in this way helps to identify the areas of overlap between the different positive scenarios.



As well as having varying degrees of relevance for different scenarios, each action will also require different levels of involvement from the different stakeholder groups:

Mining industry (including industry bodies and service providers)

- Government
- Universities
- Research organisations
- SMEs
- Community organisations

Positive Outcome: Increase the security of supply and reduce costs associated with two of the mining industry's most important inputs: energy and water.

	KEY ACTIONS	PRIMARY STAKEHOLDER/S	Mining Powerhouse	Sustainability Leader	Strong Services
Innovation and R&D initiatives	Reduce water feedstock requirements through research in dry processing techniques, seawater processing, water reuse, and water conservation methods.	Mining industry Universities Research organisations	●	●	◑
Innovation and R&D initiatives	Fund research into desalination efficiency and sustainable desalinisation technologies – such as using wave energy to power reverse osmosis desalinisation – that decrease energy requirements for production water.	Mining industry Universities Research organisations	●	●	◑
Innovation and R&D initiatives	Partner with international research teams and suppliers to develop pilot programs in a number of promising renewable energy sources – solar thermal, wind, wave, and geothermal – that can then be developed into large-scale renewable energy facilities.	Mining industry Universities Research organisations	○	●	◑
Innovation and R&D initiatives	Co-locate large solar-thermal generation plants with mine operations and conduct research in the area of advanced in energy storage to allow mining operations to use 100% solar energy.	Mining industry Universities Research organisations	◐	●	◑
Other actions for consideration	Review the existing policy on energy regulation to identify whether a new model could help to facilitate market-driven energy solutions.	Government	●	○	○
Other actions for consideration	Explore the potential impact of integrating the central electrical grid (SIC) and northern electrical grid (SING) in order to give northern mining operations access to the south's hydropower.	Government	●	◑	○

Positive Outcome: Generate the exploration and new project investment required to sustain long-term growth for the industry.

	KEY ACTIONS	PRIMARY STAKEHOLDER/S	Mining Powerhouse	Sustainability Leader	Strong Services
Innovation and R&D initiatives	Develop a national pre-competitive geo-scientific database.	Mining Industry Government Research organisations	●	○	◑
Innovation and R&D initiatives	Implement hyperspectral core analysis (using tools such as CSIRO's Hylogger) to allow for more rapid development of new resources.	Mining Industry Universities Research organisations	●	○	◑
Innovation and R&D initiatives	Explore the potential for deep-drilling technology, advanced drill sensors, large-scale geophysical analysis and 3D resource modelling to allow for exploitation of deeper and more difficult deposits.	Mining Industry Universities Research organisations	●	○	◑
Other actions for consideration	Further explore the development of a resources bourse to encourage greater domestic investment.	Government Mining Industry	●	○	◑
Other actions for consideration	Review existing policies on exploration rights to understand if they are effective for encouraging industry growth.	Government	●	○	○

Positive Outcome: Improve mine productivity.

	KEY ACTIONS	PRIMARY STAKEHOLDER/S	Mining Powerhouse	Sustainability Leader	Strong Services
Innovation and R&D initiatives	Increase the levels of automation on mine sites.	Mining industry Universities Research organisations	●	○	◑
	Develop remote operations centres in major metropolitan areas that are capable of controlling mine sites and operations nation wide.	Mining industry Universities Research organisations	●	○	◑
	Develop a single integrated mine model (e.g. Common Mine Model) to drive operations across the value chain.	Mining industry Universities Research organisations	●	○	◑
	Implement intelligent processing across operations to analyse ore content in real time.	Mining industry Universities Research organisations	●	○	◑

Positive Outcome: Ensure the mining industry has access to the skilled labour it needs to remain globally competitive.

	KEY ACTIONS	PRIMARY STAKEHOLDER/S	Mining Powerhouse	Sustainability Leader	Strong Services
Innovation and R&D initiatives	Invest in the development of multiple world-class (top 100) science and research universities.	Government	●	●	●
	Create a researcher and skilled labour exchange program with other countries with common industries and challenges, such as Australia, Canada and South Africa.	Universities Research organisations	●	◐	●
	Foster a cultural shift that encourages more PhDs to move into industry and facilitates a stronger relationship between the university research community and industry research groups	Mining industry Universities Research organisations	●	●	●
Other actions for consideration	Develop a national vocational training program to develop human capital in mining-related skilled labour.	Mining industry Government	●	○	◑
	Take an innovative approach to community engagement to increase the quality-of-life in mining regions and make it easier for companies to attract top-tier skilled labour to these regions – both Chileans and skilled migrants.	Mining industry Community organisations	◐	●	◑

Positive Outcome: Reduce the negative and/or increase the positive environmental and social impacts of mining in Chile.

	KEY ACTIONS	PRIMARY STAKEHOLDER/S	Mining Powerhouse	Sustainability Leader	Strong Services
Innovation and R&D initiatives	Develop a strong 'cleantech' sector to address challenges in areas such as energy and water management, emissions and waste – particularly in support of mining operations.	Government Research organisations SMEs	○	●	●
Innovation and R&D initiatives	Establish a renewable energy research precinct to support collaboration between major universities, energy companies, and mining companies on technologies that support Chile's unique environment – marine (wave) power, solar thermal power, and geothermal power are particularly promising.	Government Universities Research organisations SMEs	○	●	●
Innovation and R&D initiatives	Develop in-situ mines that allow for the access of deeper resources with less environmental damage.	Mining industry Research organisations	●	◐	○
Innovation and R&D initiatives	Develop an innovative project model that sees mining companies become directly involved in community planning and investment.	Mining industry Community organisations Government	○	●	○
Other actions for consideration	Explore the potential for a stronger environmental framework and greater environmental transparency to understand if this could lead to greater benefits in the long-run through improved public trust in the mining industry.	Government Community organisations	○	●	○
Other actions for consideration	Analyse the potential for Chile to differentiate itself on the global stage through the development of a 'GreenChile' brand and increased trade in environmentally and socially sustainable goods and services.	Government SMEs	○	●	◐

Positive Outcome: Increase economic diversification through the development of a globally competitive services industry.

	KEY ACTIONS	PRIMARY STAKEHOLDER/S	Mining Powerhouse	Sustainability Leader	Strong Services
Innovation and R&D initiatives	Develop Antofagasta as a world-leading mining research, education, and innovation precinct. Create a "living mine" research centre where industry, SMEs and researchers are co-located and collaborate on fundamental *and* mission-directed research.	Mining industry Universities Research organisations SMEs	●	○	●
Innovation and R&D initiatives	Develop a series of other industry precincts or collaborative research centres that act as innovation hubs and bring together industry, university researchers, government, and SMEs in core Chilean industries: agriculture, forestry, aquaculture, winemaking.	Government Universities Research organisations SMEs	○	◐	●
Innovation and R&D initiatives	Expand BHP Billiton/Codelco's World Class Providers program into more innovative and technology-oriented services.	Mining industry SMEs	◐	◐	●
Innovation and R&D initiatives	Create an ICT services incubator in Santiago that provides common facilities, support, funding and mentorship for entrepreneurs.	Government SMEs	◐	○	●
Other actions for consideration	Build programs that provide incentives to staff and students at universities to commercialise research.	Government Universities	●	●	●
Other actions for consideration	Leverage existing strengths in copper production to develop copper recycling services that can be exported to major copper consumers in Asia and elsewhere.	Research organisations SMEs	○	●	●
Other actions for consideration	Create a vocational program that prepares workers for the transition from resources to service-related jobs.	Government	○	●	●

Mitigating Risks Associated with the Collapse of Copper Scenario

Naturally, the actions that drive towards the positive scenarios will simultaneously mitigate against risks associated with the Collapse of Copper scenario:

- Actions that drive towards the Mining Powerhouse scenario will help Chile to remain cost competitive in the global mining industry. For example, investing in improved desalination technologies can help to solve the energy and water challenge, reducing input costs for the industry and allowing Chile to remain a key player in the global copper market.
- Actions that drive towards the Strong Services scenario will reduce Chile's sensitivity to fluctuations in the global copper market. For example, the development of world-class service providers across a range of industries (from primary industries such as mining and agriculture through to IT) can help to provide a source of economic growth even if copper demand and/or prices decline in the future.
- Actions that drive towards the Sustainability Leader scenario will help to give Chile a comparative advantage against other mining nations. For example, an investment in the development of non-conventional renewable energy sources will help lead to greater energy security and lower energy costs for the mining industry and the nation. It will also put Chile in a prime position to capitalise on the growing international demand for technology and services in the renewable energy field.

There are also other actions that should be considered independent of the identified scenarios. These actions can help to stimulate ongoing growth in the worldwide copper market and, as a result, can help to ensure that copper mining remains an important part of Chile's economy:

- Actively promoting copper and its benefits over other alternatives and substitutes will help to stave off any drop in demand.
- Developing new uses and applications for copper can create new opportunities for demand growth.

The Way Forward

A new way forward is required if Chile is to continue to enjoy growth in its mining industry and the wider economy. The current trajectory leads towards an uncertain future where Chile's ability to remain globally competitive is unclear. However, innovation can play a central role in helping to forge a new growth trajectory for the industry and the nation. This potential for innovation spans across all areas of the mining value chain and can help to drive the positive outcomes needed to ensure Chile remains on a path towards greater prosperity.

The required approach to innovation, however, cannot be realised without coordination and collaboration across stakeholders in industry, government and the research community. A common vision and strong public-private partnerships will be crucial in ensuring that innovation efforts provide the maximum possible impact.

The intention of this report is to provide a starting point for the creation of this common vision and to initiate conversation across diverse stakeholder groups. While there will be much debate around what the ideal future for Chile should look like, based on the positive scenarios identified, there will no doubt be a consensus around the need to avoid the potential outcomes associated with the negative scenarios outlined in this report. This consensus provides a great starting point for the development of strategies that provide a future direction for mining in Chile.

The scenarios in this report should be used as an input to strategy development with a particular emphasis on the specific actions that can help to move Chile away from the negative scenarios and towards a more positive future path.

While it is impossible to predict what the future will hold, strategic consideration of the different possible scenarios provides a level of foresight that can help to ensure full consideration of future risks and a greater realisation of future opportunities.

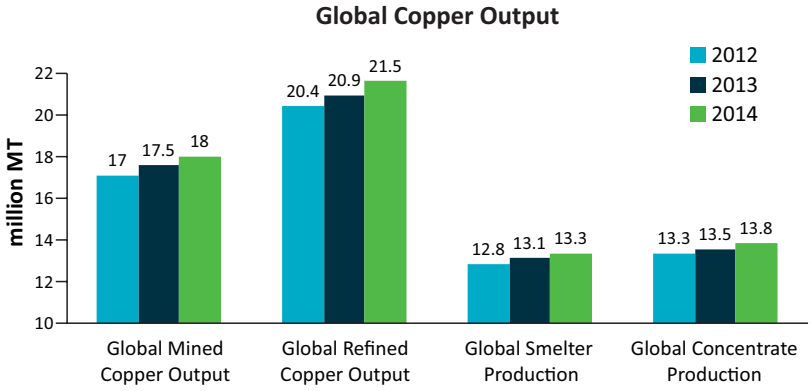
This will ensure that Chile remains prepared and proactive and that the mining industry remains a key pillar of growth for the nation for generations to come.

Appendix: Global Copper Market Overview

A look at current and forecast statistics across copper production, consumption and prices

Global Copper Market: Production

- Cochilco predicts that global copper output will increase by around 4-6% between 2012 and 2014 across mined copper, refined copper, smelter and concentrate production.[1]
- Growth in mined copper output is expected to be led by increases in Mongolia, Congo DR, Brazil, and Indonesia. During the period 2013-2025, the global mined copper output should grow from 17.8 to 27.4 million MT, an average of 3.7% a year.[1]
- The Americas are the dominant region in concentrate production, with a 51% share of global production in 2012, followed by Asia with a 26% share.[1]
- 82% of global refined copper production in 2012 was from primary sources.[1]
- Asia accounts for the bulk of growth in smelter production as China is continually expanding its smelting capacity. Asia accounted for around 53% of global copper smelter production in 2012, while the Americas accounted for just 23%.[1]

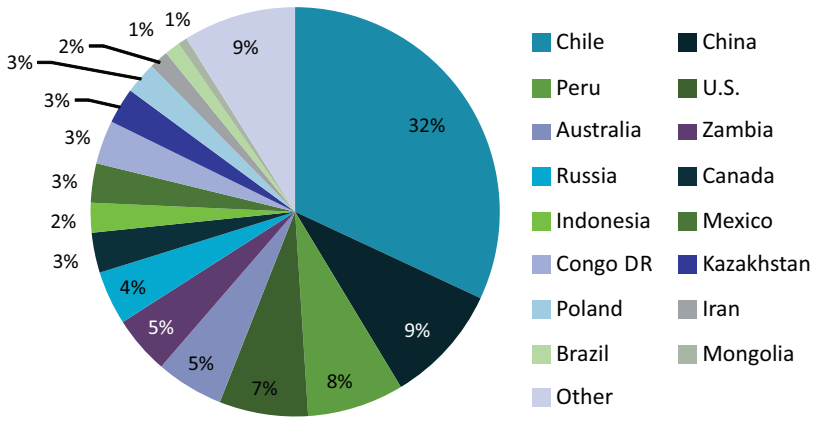


Source: Cochilco, 2013

Global Copper Market: Production - Chile

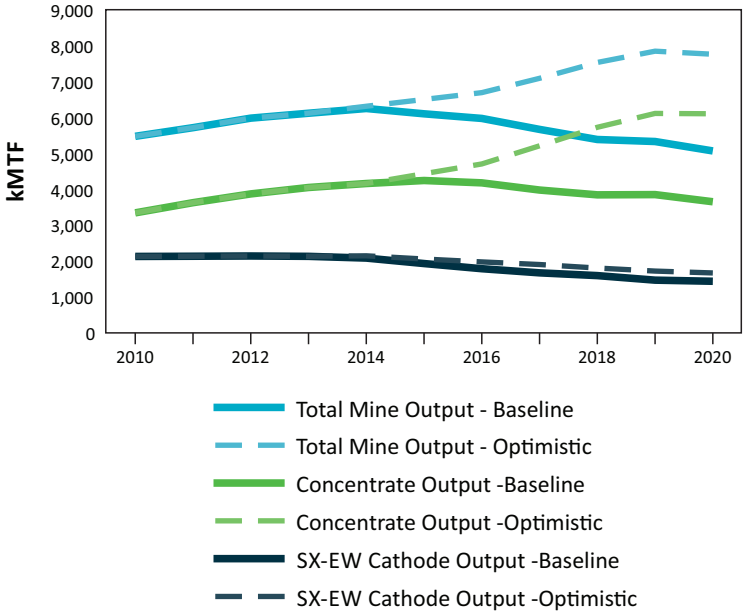
- Chile is responsible for around one-third of global copper output. It is responsible for less than 5% of global gold and silver output.[2]
- Chile has the world's largest copper reserves, holding 28% of the world's reserves, more than twice the remaining reserves of Peru.[3]
- Optimistic estimates (including baseline, probable, possible and hypothetical projects) show that total mine output in Chile could increase from 5.4 million MT in 2010 to 7.8 million MT in 2020.[4]
- The expected growth will be driven by concentrate output, with 2020 concentrate output representing an 83% increase on 2010 levels. SX-EW cathode output is expected to decline by 20% between 2010 and 2020 as the natural depletion of surface leachable oxides and sulfides leads to few new leaching projects.[4]
- A comparison between optimistic estimates and baseline figures highlights the importance of new projects in achieving long-term growth in the industry.[4]
- Mining investment in Chile is expected to reach US$112 billion by 2021, of which, $86.7 billion will be spent on copper mining, $21.7 billion on gold and silver mining, and $3.6 billion on iron and industrial minerals mining. The northern region of Antofagasta will receive the most investment, with $43 billion, followed by the northern region of Atacama, with $34 billion.[5]
- Antofagasta is expected to remain the primary region for mine copper output but the Atacama and Tarapacá regions are expected to grow their respective shares of the country's mine output, thanks to the incremental growth generated by new concentrate projects in these regions.[4]

Mined Copper Output by Country, 2012



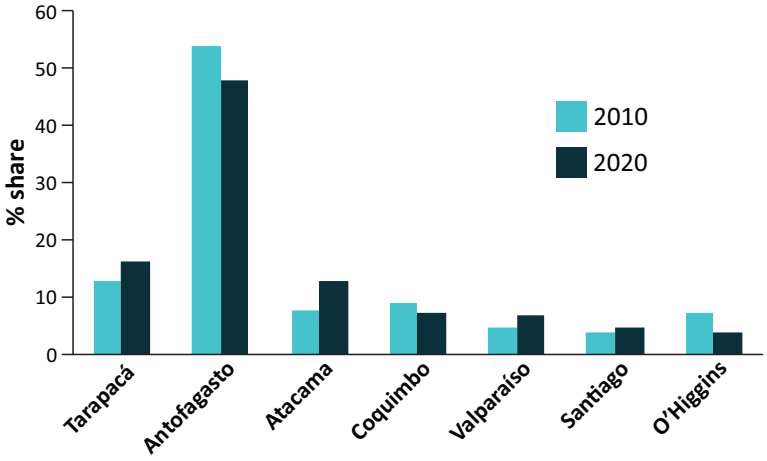
Source: Cochilco, 2013

Chile's Potential Mine Copper Output Through 2020



Source: Cochilco, 2010

Chile's Mine Copper Output by Region

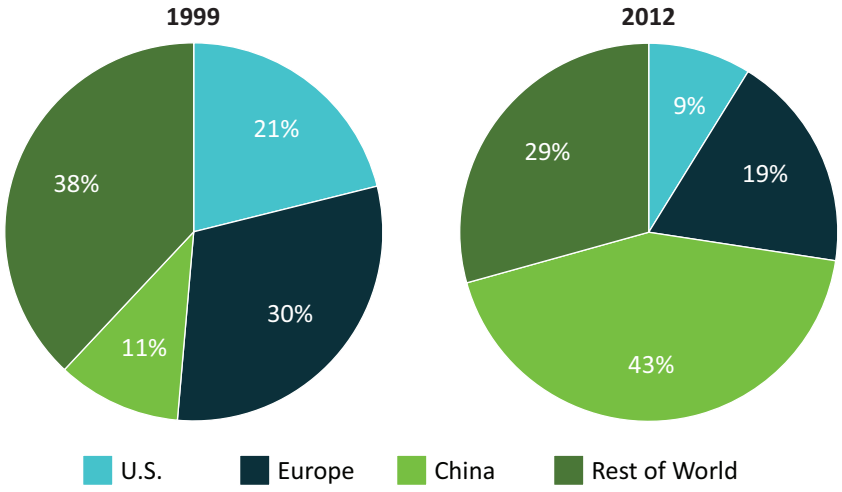


Source: Cochilco, 2010

Global Copper Market: Consumption

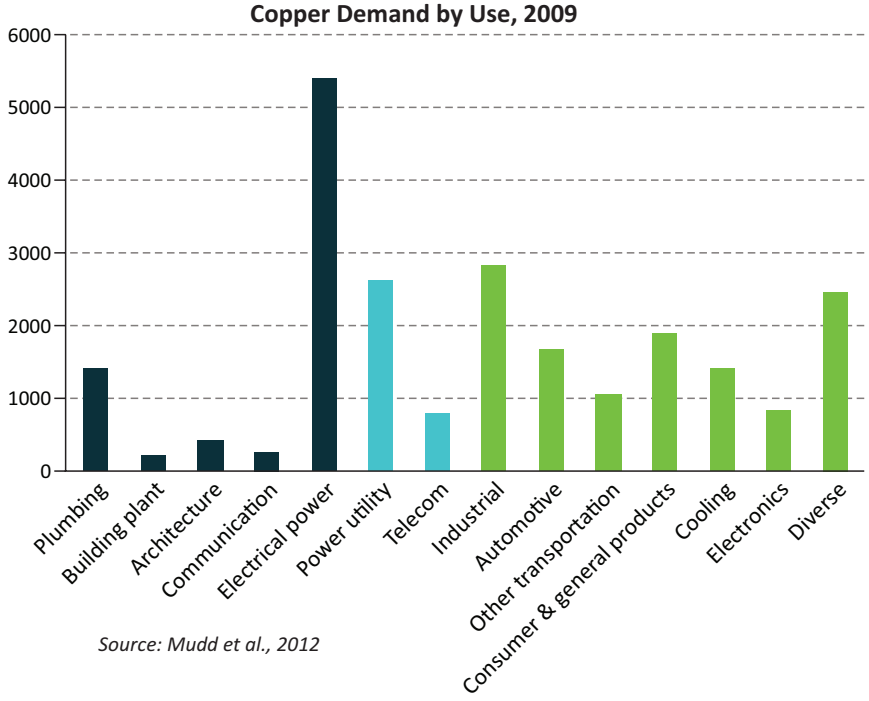
- Overall, the equipment manufacture industry is the main end-use sector for copper, representing 52% of total demand in 2009. Electrical power (part of the construction sector), however, represents the largest specific end-use of copper, accounting for 24% of total demand in 2009.6
- China is now the world's largest copper consumer, responsible for 43% of consumption in 2012, up from just 11% in 1999.1
- Between 2013 and 2025, demand in Europe is expected to rise from 3.8 to 4.2 million MT; U.S. consumption should drop from 1.8 to 1.65 million MT; consumption in Japan and South Korea should fall 0.5% a year; and in Brazil consumption will grow by 4.9% a year to reach 780 kMT in 2025. However, these changes are insignificant compared to the growth that is expected in Chinese copper consumption. By 2025, China is expected to be responsible for over half of global copper consumption.1

Global Copper Consumption by Region, 1999 vs. 2012



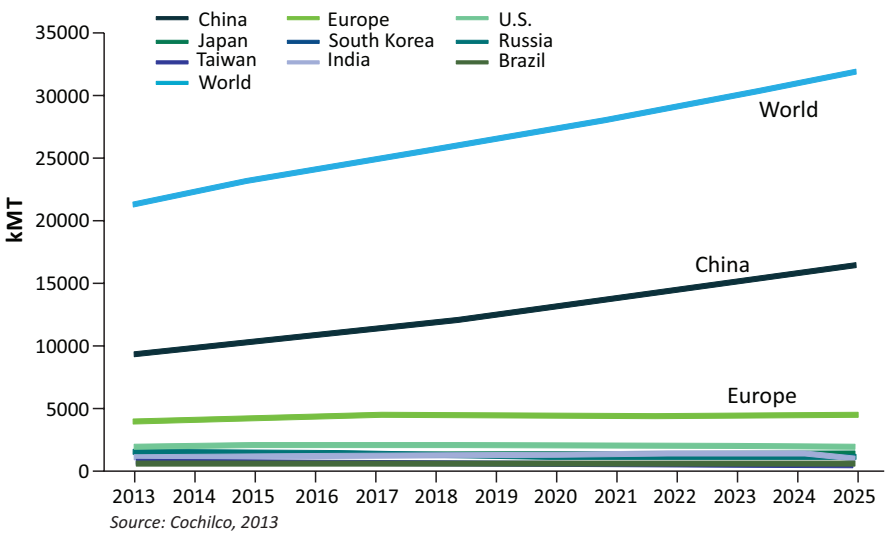
Source: Cochilco, 2013

Copper Demand by Use, 2009



Source: Mudd et al., 2012

Forecast Global Copper Consumption by Region, 2013-2025

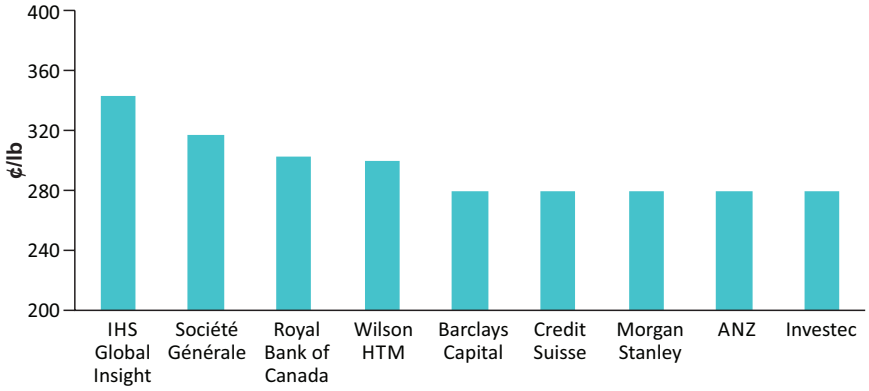


Source: Cochilco, 2013

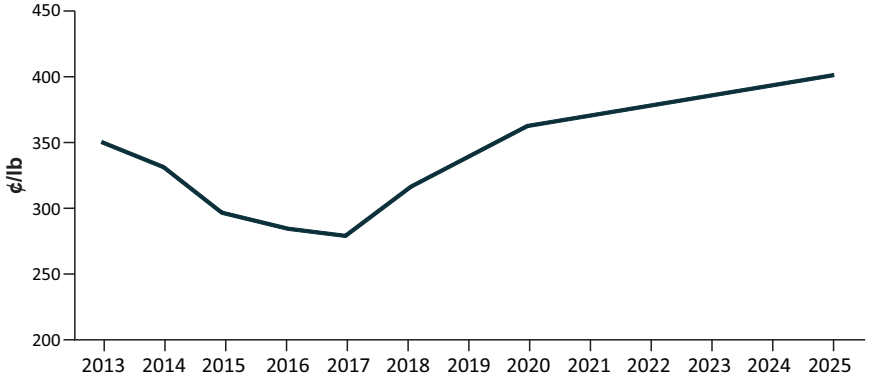
Global Copper Market: Prices

- The copper price peaked at around 460¢/lb (US$) in 2011 and Cochilco expects prices to average 332¢/lb in 2014. Some analyst predictions, however, estimate prices of up to 432¢/lb in 2014.1
- Long-term prospects remain positive as the world's largest copper consumer nations (China and India) continue with large-scale urbanization plans. As a result, markets expect prices to stay above 280¢/lb (US$) through the next decade. Wood Mackenzie estimates a price of 300¢/lb by 2020 and beyond, while analysts polled by Consensus Forecast expect an average of 291.8¢/lb for 2018-2022.7
- Cochilco forecasts a low point to occur in 2017, after which prices will begin to rebound.7

Long-term Copper Price Estimates, 2018-2022



Copper Price Projection

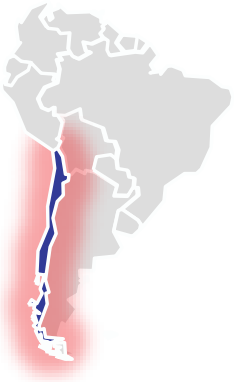


Source: Cochilco, 2013

Appendix: Project Methodology

Report Methodology

This report was developed by CSIRO Futures in collaboration with CSIRO Chile. The report draws on CSIRO's research experience in mining, mineral processing, energy, and water. Additionally, the project team conducted a widespread review of existing research literature and a number of interviews with key Chilean industry, government, and university stakeholders.



KEY CHALLENGES AND OPPORTUNITIES FACING THE CHILEAN MINING INDUSTRY

This stage of the process involved interviews with a range of stakeholders in Chile across industry and government in order to draw on their vast knowledge and expertise. It also involved an extensive review of existing data and literature from sources such as Cochilco, Gobierno de Chile, CNIC, Fundación Chile and the OECD.

GLOBAL MEGATRENDS SHAPING THE FUTURE OF MINING AROUND THE WORLD

The global megatrends were defined based on consultation with a range of scientific experts across CSIRO. This was combined with an extensive review of global literature from sources such as the IMF, the United Nations, the OECD and the World Bank. A number of stakeholders were given the opportunity to review and provide input to the development of the megatrends.

CONCEPTUAL SCENARIOS FOR THE FUTURE OF MINING IN CHILE

The findings of the first two stages (challenges and opportunities and megatrends) were used as inputs into the development of the scenarios. The scenarios combine qualitative and quantitative evidence from the first two stages with a sense of imagination for what the future could look like. Stakeholders were once again engaged at this stage of the process and given the opportunity to review and provide input to the development of the scenarios.

Addressing Opportunities and Challenges: Detail By Scenario

Opportunity / Challenge	Metric	Uncertain Future	Mining Powerhouse	Strong Services	Sustainability Leader	Collapse of Copper
Energy and Water	Improves energy efficiency	3	5	3	4	1
	Increases non-conventional renewable energy production	3	3	3	5	2
	Improves water efficiency	3	5	3	4	1
	OVERALL	**3**	**5**	**3**	**5**	**1**
Human Capital	Improves education and vocational training programs for mining	3	4	5	4	2
	Helps companies attract skilled labour	3	4	4	3	1
	Increases size of labour pool	3	3	4	3	2
	OVERALL	**3**	**3**	**5**	**4**	**2**
Productivity	Automation and other advanced technologies decrease production cost	3	5	4	3	2
	Technology enables deeper mining	3	5	4	4	1
	In-situ mining lowers costs	3	4	3	5	1
	OVERALL	**3**	**5**	**4**	**4**	**2**
Environmental Sustainability	Increases transparency and reporting	3	2	3	5	2
	Reduces emissions and by-products	3	1	4	5	4
	Increases oversight and regulation	3	2	3	5	1
	OVERALL	**3**	**2**	**4**	**5**	**3**
Economic Diversification	Increased mining services	3	2	5	2	1
	Increased environmental services	3	2	4	5	1
	Decreased reliance on copper exports	3	1	5	5	1
	OVERALL	**3**	**1**	**5**	**3**	**1**
Exploration and Capital	Exploration technology	3	5	4	3	2
	Improved exploration rights	3	4	3	2	2
	Improved access to foreign capital	3	5	3	4	1
	OVERALL	**3**	**5**	**3**	**3**	**2**
Benefit for Communities	Increased investment in regional development	3	4	3	4	1
	Increased social license and community perceptions	3	3	4	5	1
	OVERALL	**3**	**3**	**4**	**5**	**1**

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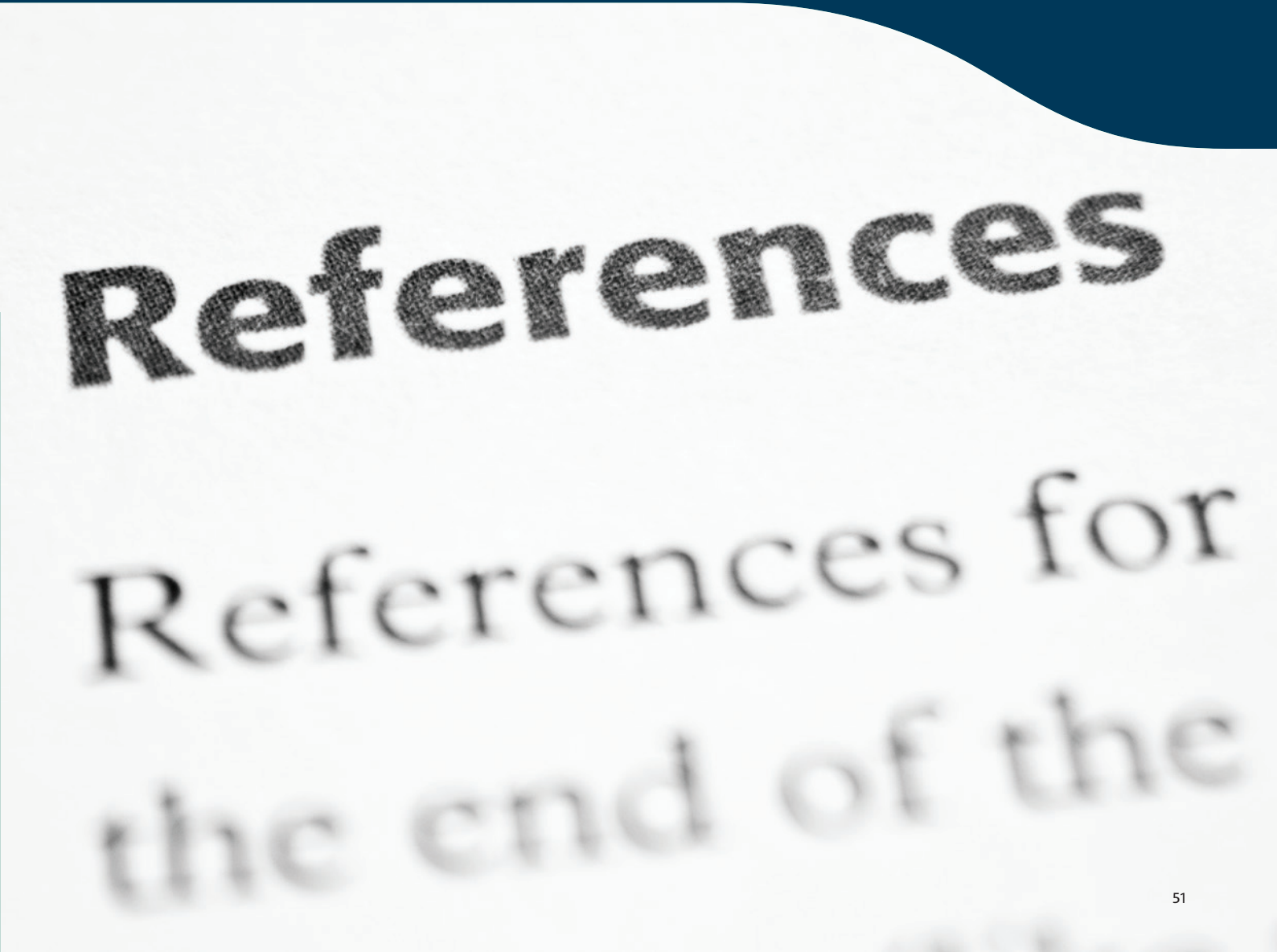

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