Refined copper

A good business for Chile

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This work is in response to Cesco's desire to address subjects we consider important for the future of mining. With this objective, we have divided into work groups to discuss and prepare specific proposals, as applicable.

We firstly thank the authors of this document, as well as many others who felt motivated by the subject and contributed to the work and discussion with questions, information and very enriching ideas. In particular, we would like to thank Gerardo Alvear, Carlos Risopatrón, Osvaldo Urzúa, Leopoldo Reyes, Jorge Bande, Roberto Parada, Juan Cariamo and Patricio Aguilera, for their very useful comments and critiques.

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1.-Introduction.

One of the important issues that the Chilean copper industry must resolve this decade is whether the country will export more copper concentrate or more refined copper in the future. In 2020, refined copper exported by Chile represents 52% of the total, a market share that could fall in the next 15 years to 21% if the trend is not reversed[1], which had been marked by a 12% reduction in concentrate smelting[2] and 25% in electrowinned cathodes[3] between 2010 and 2019.

The primary motivation for this article is to answer the question: What is most suitable for Chile from a strategic perspective, to export more concentrate or more refined copper in the future? Our proposal is that the outcome for either option is very different.

A **strategic perspective** is different from a traditional economic evaluation since it considers criteria that are not evaluated by the latter. In the case of smelters, **first**; a factor that will be critical in the future must be achieved, that of environmental excellence, which involves collecting most of the harmful elements that enter smelters in the concentrate, avoiding its maritime transport, where close to 75% of its mass is waste, emitting less greenhouse effect gases globally, and reducing lifecycle indicators regulated by ISO and the United Nations. In summary, open the path to a green and circular economy. A circular economy implies bringing producers and end clients closer, which is more feasible to achieve between a refinery - smelter than between a mine and said client. **Secondly,** to generate technologies and know-how to treat and store the harmful elements contained in the increasingly complex minerals from our mines and to recover the valuable elements contained in the minerals, to enhance the multiple factors that allow a refinery-smelter to achieve profits in line with an industrial business, create jobs that are more quality and highly-specialized than current ones regarding operation and management, and incentivize research teams in these areas at companies, universities and institutes nationwide. In summary, progress towards a knowledge-based economy. **Third**, to develop competitive smelters globally, developing the country as a significant negotiating pole facing the dominant power of the Chinese concentrate market. **Fourthly**, the idea of having excellence

[1] Future Chilean copper mining production 2035, UC Minerals Economy Program, 2019.

[2] Concentrate smelting in Chile reached a peak in 2010, of 1.65 million tons of copper contained in anodes produced by the smelters.

[3] In 2010, 69.8% of the copper exported by Chile was refined in-country, whether by traditional means (smelting and refining) or by hydrometallurgical means.

smelters should be a fundamental criterion to supplement mining production growth strategy, above all considering the weakness detected in such strategy as a primary driver of Chilean economic growth. **Fifthly**, that this segment of the production chain recovers its place as an important contribution to the national economy. And lastly, to improve the reputation of smelters, and therefore, that of mining as a whole.

The question we ask in this document is important, since copper exports continue to be by far the country's largest, exceeding 50% of the national total. Therefore, it is crucial to look at its future composition and segmentation.

The increase in exports of concentrate became a very marked trend over these years, due to the progressive depletion of oxide – or in general, leachable – minerals in large Chilean operations, and to the emergence of Chinese smelters that in a short time achieved hegemony in this business, making smelters and refineries located elsewhere in the world less competitive, particularly Japanese and Chilean ones that used to be the primary ones. In light of this, Chilean and many international mining companies prioritized the extractive part of the mining business, which is clearly distinguishable from the smelter business, seeking to reinforce the most profitable part of their business. This decision implied relegating an essential element of the copper value chain, such as smelters and refineries, to a secondary priority in the national industry, leaving this segment for development in other countries.

Investment in smelters in Chile over the past 30 years was mainly used to attempt to maintain operating capacity and meet environmental obligations, but without a defined business model. This caused the progressive deterioration of competitiveness, safety and sustainability, particularly in state owned smelters, which resulted soon in ruling out the idea of having world-class smelters capable of competing with Europe, North America and Asia.

These events changed the course of Chilean smelters, which as a whole were not only those with the highest production worldwide in the 90s (Figure 1), but were also among the most competitive. In 1990, Chile led smelters' production, with a 14.6% global market share, followed by the USA with 12.9% and Japan with 11.6%. In 2018, Chile had 7.9%, following Japan with 8.7% and China with 35.3%.

Figure 1 shows the meteoric rise of smelters' production increase in China that took place shortly before the start of the super cycle, reaching 4.1 million tons of copper production in 2019. This Figure also shows the increased production in Chilean smelters between 1992 and 2005, and the higher production these had with regard to Japanese smelters. After 2005, a marked decline of smelters' production in Chile[4] is noted.

Concentrate treatment by the seven Chilean smelters, 5 of them state-run (Chuquicamata, Potrerillos, Hernán Videla Lira or Paipote, Ventanas, and Caletones), and 2 private (Altonorte and Chagres), is shown in Figure 2 for the period 1993-2018.

[4] The increase noted to 2005 took place in Altonorte (Glencore) and Chagres (Anglo American) smelters, while production decrease beginning in 2005 took place primarily at Chuquicamata's smelter. The marked decrease in production in 2018 and 2019 was primarily due to Chuquicamata being inactive for several months due to the installation and start-up of two new acid plants.

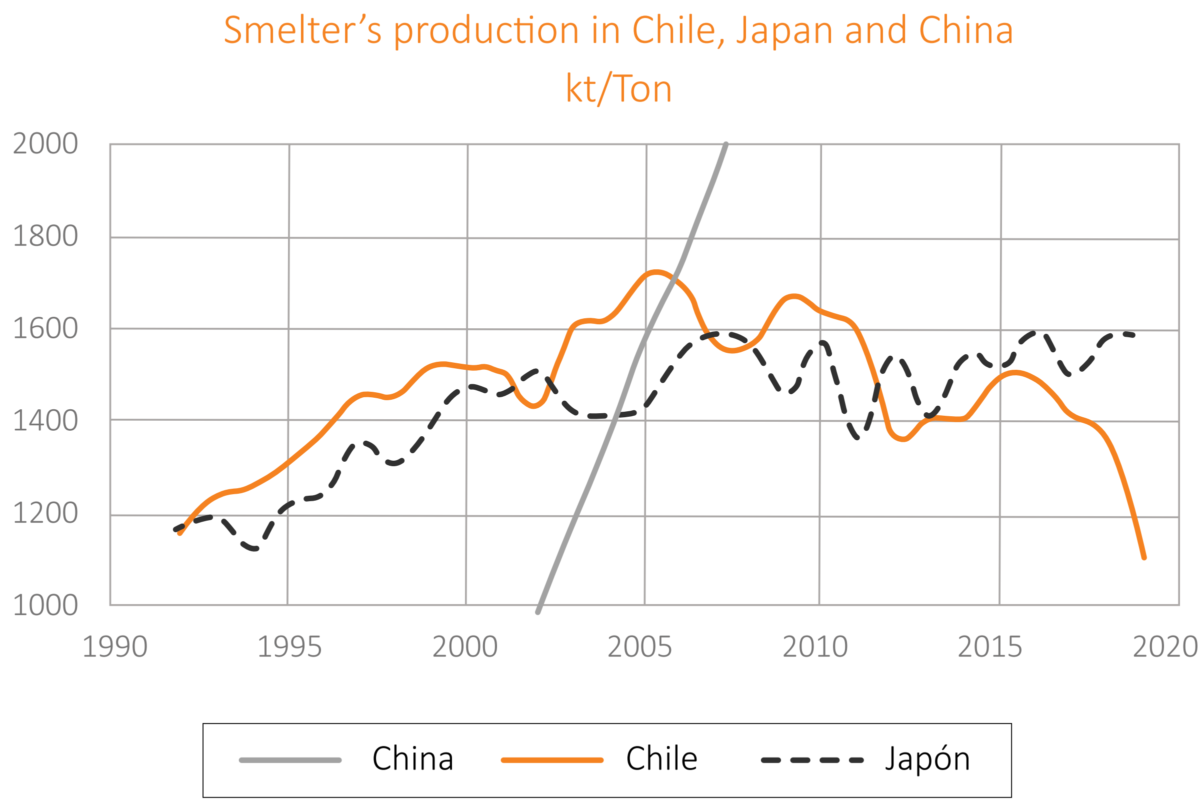

Figure 1: Smelters production in China, Japan and Chile. Source: Wood Mackenzie.

It is rather shocking that in this period of almost 30 years, the capacity of Chilean smelters remained practically the same. Two smelters increased their capacity, but the national net effect was zero due to the reduction in smelting capacity at Chuquicamata.

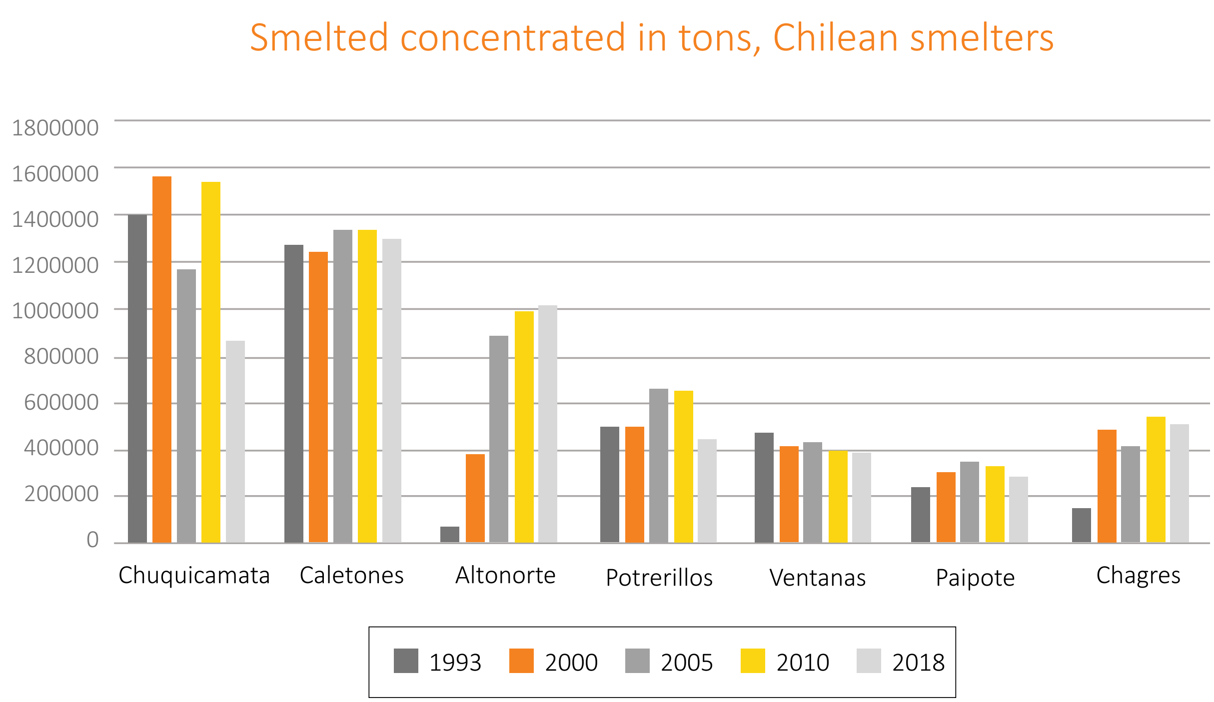

Figure 2: Smelted concentrate (tons) in Chilean smelters. Source: U. Concepción database, UC Mineral Economy Program.

Furthermore, there are three refineries[5] in Chile. These facilities refine the anodes produced by a smelter, creating copper cathodes, which constitute refined copper. This document refers to the smelter/refinery set, although these can operate separately, together they constitute an economically more robust unit than a smelter alone. This is based on the fact that the recovery of the valuable elements (which can be close to 20, depending on the concentrate) is generated at the refinery, which is key for increasing the business' profitability.

Section 2 of this document addresses the development trends and scenarios for copper mining production in Chile, showing that it is not possible or advisable to support a strategy based only on the growth of mining production, and certainly not based only on the export of concentrate.

Subsequently, section 3 analyses what has occurred with smelters since 1990, showing their loss of significance and drop in competitiveness.

Section 4 constitutes the central part of the document, showing that, despite the bad aggregate behavior of smelters in Chile over the past decade, a well-managed business can be economically and environmentally sustainable. We show successful smelters around the world, with technologies similar to Chilean technologies, which are capable of competing with Chinese smelters. We also conduct a rigorous evaluation of a project for the construction of a new Smelter-Refinery in Chile. The numbers show profits and risks, and despite these differing from those that are inherent to mining, they should be acceptable for an industrial business. We indicate that investment in new smelters has not been made in Chile primarily due to the lack of signs of interest by the State, and of commitments to guarantee the supply of concentrate.

The final part of the document contains our proposal for generating a new smelter capacity in the country. Here we indicate that the effort must be led by the State as public policy, to coordinate efforts that would be very difficult to achieve if left to the market alone. Investment is made by private investors, not necessarily by the mining companies existing in the country, which must provide concentrate under market conditions, in order for third parties to be willing to invest. For the latter to occur, the proactiveness of the State is essential, noting that there are examples of bankruptcies of private smelters worldwide due to lack of supply.

This proposal is necessary for Chile to progress in changing its mining development strategy, accepting that it is no longer possible to expand production at historic rates, and that generating more value necessarily comes from having a more complex, diversified and sophisticated productive chain, which has not yet been achieved, despite some isolated efforts.

2.- Trends and scenarios for mining production.

Here we analyze the most probable growth scenarios for mining over the next decades, incorporating what has occurred over the past 30 years.

Chile at one point had 37% of mine copper production, but in 2020, it only has 28%, and it is probable that this figure will continue to decrease. This is explained in part, because the depletion of the oxide deposits has begun, and it is expected

[5] The three refineries belong to Codelco and they are Chuquicamata, Potrerillos and Ventanas.

that in 2035 they will generate less than 5% of copper production, while in 2019 they represented 28% of such.

Thus, the growth of future copper production will be based on the extraction and processing of copper sulphides, which generate concentrate[6]. Now, if the current course of mining is not modified[7], refined copper exported by Chile in 2035 could drop to 21% of the total, and the rest would be exported in concentrate, as indicated in Figure 3.

This figure shows the stagnation of smelting capacity between 1990 and 2019, the growth of production through hydrometallurgy until 2010, and its subsequent decline due to the progressive depletion of copper oxide deposits. It also shows the growth of concentrate exports, especially at the end of the 90s.

Projections of future production scenarios were prepared by Cochilco and by the UC. They are based on economic information (costs, profits) obtained from Wood Mackenzie databases during engineering studies, on the probability of obtaining approval of the environmental impact studies, on obtaining social license, and on several other factors.

Figure 3 confirms that it will not be possible in the next 15 years to repeat the growth rate of the 90s to 2004, which was an annual average of 9.2%. The highest projected growth rate for the future is that of Cochilco (2019 report), with 8.1 million tons of copper in 2030, with an average annual growth rate of 3.5% in 2020-2030. It is however, more likely that the annual growth rate will actually be in the range of 1.4% to 2.1%, as indicated by the most probable Cochilco and UC scenarios. Geological, technological, economic and environmental reasons make annual growth of more than 2% difficult over the next two decades, thus, extractive mining cannot benefit from the growth boom, as has occurred since the 90s.

The morphology of large deposits, frequently vertical, often impedes in many cases faster mining. This is particularly evident in underground mining such as El Teniente and Chuquicamata, where the extraction rate cannot be increased with current technologies, since this would involve developing extraction levels at greater depth, which would be mined simultaneously with the New Mine Level levels at Teniente and of the first level of Chuquicamata underground mining. Something similar occurs with the Andina and Los Bronces deposits, which additionally have environmental obstacles to increase the extraction rate (production). It is important to remember that the Andina-Los Bronces copper deposit is the largest in the world with respect to reserves and resources. Nor does it seem feasible for now to mine the Escondida deposit faster, due to technological limitations because of the extremely high rate of material extraction, which exceeds 1.5 million tons daily in 2020. In addition, Escondida is not the only deposit that is limited by this factor; this is also the case for some of the other large Chilean deposits. In summary, although Chile has

[6] Copper minerals are primarily treated in one of two ways worldwide, depending on their composition. Copper sulphides are treated using flotation, which generates concentrate. These must be smelted and then electrowinned to obtain cathodes. This is called the traditional method. Oxide minerals, however, are treated using a hydrometallurgical method, consisting of leaching, following by solvent extraction and by electrowinning, giving rise to cathodes of the same quality as those obtained using the traditional method. In 2020, the traditional method represents close to 80% of the refined mine copper worldwide, while the hydrometallurgical method represents close to the remaining 20%.

[7] Which consists of maintaining smelting capacity constant in the best case, or reducing it by closing some smelters.

by far the best copper resources and worldwide reserves, and several of its large deposits have up to 100 years of future life at the current extraction rate, the speed of extraction cannot increase much more than planned over the next two decades.

Mining production growth strategy was without a doubt very successful from 1990 to 2004, as indicated in Figure 3. From 2004 to 2019, however, Chilean copper production grew on average 0.38%[8] per year, despite the fact that 8 new large mines were developed in this period, including Esperanza, Gabriela Mistral, Spence, Sierra Gorda, Caserones, Antucoya, Ministro Hales, and Andacollo. Without the development of these mines, the country's production would have fallen by 885 thousand tons, or 15% of Chile's production. These figures indicate that the most optimistic growth that could be expected for the 2004-2035 period would be an annual average of 1.03%.

We anticipate that the obstacles identified (geological, economic, technological and environmental) for future expansion to exceed the growth rates indicated in Figure 3 over the next 15 years are practically inevitable with current technology. Thus, here we see a serious difficulty to expand production of existing mines, despite having extensive reserves.

The fact that copper mining in the country has a certain ceiling for its growth over the following 15 years, associated to its poor behavior in

Copper production in Chile, 1990-2019, future scenarios, UC- Cochilco – 2020-2035

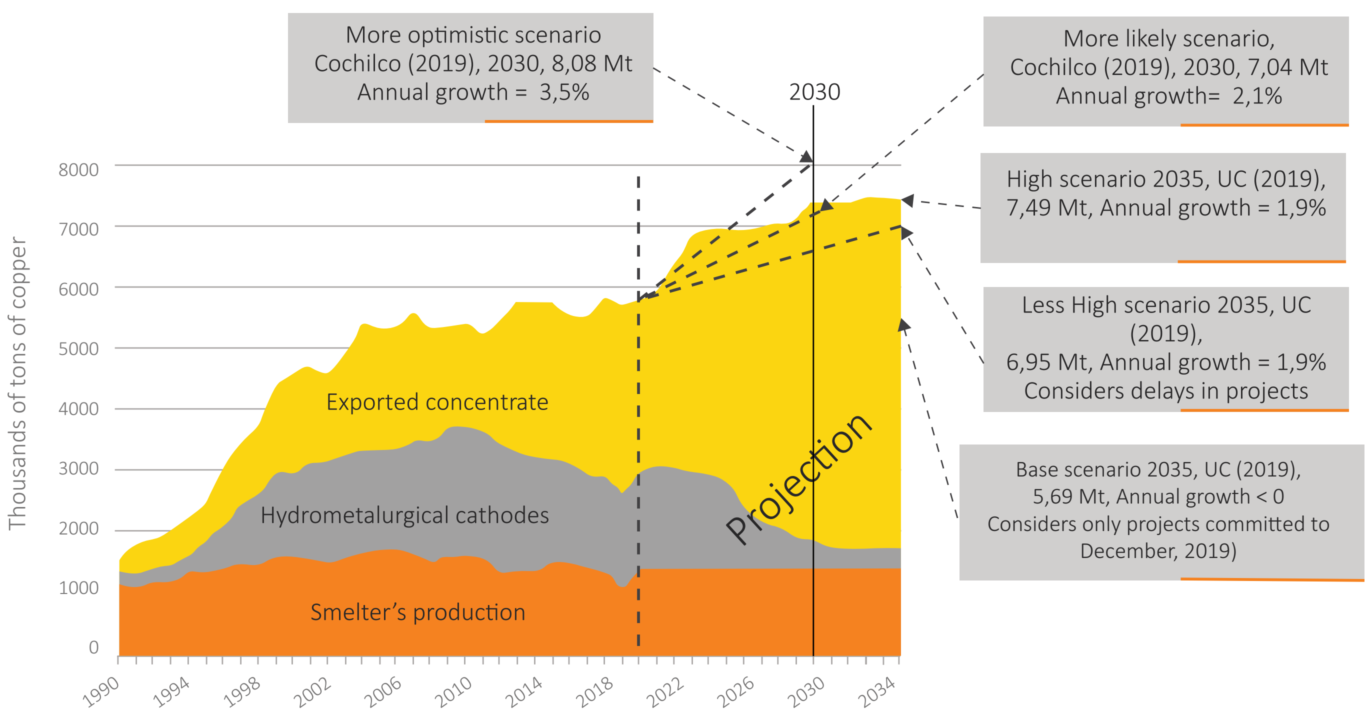

Figure 3: Historic production of smelted concentrate in Chile, exported, and leached copper (hydrometallurgical). It also includes several future production projections prepared by Cochilco and UC in 2019. Sources: UC Minerals Economy Program, Cochilco.

[8]Growth of Chilean copper production 2004-2018 was 0.5%, because production in 2019 decreased with respect to 2018.

productivity vis a vis the rest of productive sectors, leads us to think that it will be difficult for mining to continue being the country's engine of growth as it was in the 90s and in the super cycle[9].

Growth projections of Chilean economy up to 2027, 2037 and 2050 by the Central Bank of Chile in its "Trend growth: medium-term projection and analysis of its determinant factors" dated September 2017, tend to confirm the aforementioned. The natural resources sector[10] (RRNN) grows considerably less than the "Rest" of the economy. In its projection to 2027, it considers that in the base scenario, while the rest of the economy grows 3.4%, RRNN grow 2%, making a total of 3.2% for the set. (See Table 1).

This concern regarding the sector's dynamism and its impact on the economy as a whole has been raised for some time. In 2014, the National Innovation Council for Development published Mining and Chile's Sustainable Development: Towards a Shared Vision, where it proposed future mining that were "Virtuous, Inclusive and Sustainable". The Alta Ley Program[11], created in 2015, pursuant to the previous effort, already mentioned the need to introduce changes to the sector's dynamics to progress in such "mining of the future". Its 2015-2035 Road Map contained three primary targets: i) for Chile to produce 7.5

Table 1: Chilean GDP growth projections by the Central Bank, September 2017.

Trend growth projection
Production function method, 2017-2050

	Capital	Labor Force	Worked Hours	Quality Index	**Work Factor**	**PTF**	**Rest GDP**	**RRNN GDP**	**Total GDP**
Pessimistic Scenario									
2017-2026	**3,0**	**1,1**	**-0,7**	**-0,7**	**1,1**	**0,9**	**2,9**	**2,0**	**2,8**
2017-2036	2,6	0,8	-0,6	0,6	0,8	0,8	2,6		
2017-2050	2,4	0,6	-0,4	0,5	0,5	0,9	2,4		
Base Scenario									
2017-2026	**3,4**	**1,3**	**-0,4**	**0,8**	**1,6**	**0,9**	**3,4**	**2,0**	**3,2**
2017-2036	3,0	1,0	0,4	0,7	1,3	0,9	3,0		
2017-2050	2,7	0,8	-0,4	0,6	1,0	0,9	2,7		
Optimistic Scenario									
2017-2026	**3,7**	**1,4**	**-0,2**	**0,9**	**2,1**	**0,9**	**3,8**	**2,0**	**3,6**
2017-2036	3,4	1,2	-0,2	0,8	1,8	0,9	3,5		
2017-2050	3,0	0,9	-0,2	0,7	1,3	0,9	3,1		

Source: Central Bank of Chile.

[9] Due to price increase.

[10] RRNN is comprised of mining, electricity, gas and water.

[11] "a public-private initiative created in 2015 as a Strategic Intelligent Specialization Program of Corfo", and was managed by Fundación Chile until it became the Alta Ley Corporation, which is now an independent public-private partnership.

million tons of copper annually by 2035, ii) to move from 40% production in the first cost quartiles worldwide to 80% and iii) to quadruple thenumber of world-class export suppliers, achieving exports for US$ 4,000 million annually.

Due to this, we state that it is extremely important for national mining to develop a strategy that is supplementary to the growth of copper production. One aspect of this supplementary strategy consists of developing its entire value chain, up to refined copper and even further.

We are not the first to conduct an analysis of this nature.

With 5 years having passed since the launch of this policy, no clear progress can be seen in meeting any of the aforementioned targets. The coronavirus situation could make this even more difficult.

On the other hand, the Large-Scale Copper Mining Productivity Report (GMC) prepared by the National Productivity Commission (2017) concluded, "total factor productivity (TFP) of the Chilean economy as a whole decelerated from 2.3% annually in the 1990s to 0.1% annually in the 2000s. The fundamental, albeit not exclusive cause, was the drop in mining productivity. This drop was fundamentally due to the reaction that copper prices super cycle induced companies to assume, which led to prioritizing production levels over other criteria". We know, however, that production progressed marginally during the super cycle, that is, although the industry attempted to significantly increase production, it did not achieve this. The Productivity Commission concluded that in the 15 years between 2000 and 2014, copper production rose 19%, but for this, an additional 79% of energy was required, an additional 157% of labor, and an additional capital investment of 178%.

Thus, GMC Productivity Report supports our statement that mining requires thorough changes in order to be able to transform the tremendous Chilean geological potential into value and wealth. It is clear that continuing to do the same thing is no longer sufficient. It is not a coincidence that the aforementioned Report concludes with a significant number of recommendations (53) for the public and private sectors, which it considers to be the basis for a mining strategy that ensures the continuity of the sector, its expansion and its adaptation to new technological challenges and social demands. That is, this report recognizes that there is a problem in the sector's development strategy and proposes relevant modifications to it.

Aware that the subject is very complex and has multiple aspects, our approach is to focus on one specific aspect of this new path that is required. The proposal to create a new refining - smelter generates a set of signals, all of which are in line with the new strategy required by the sector

3.-Evolution of Smelters in Chile: 1990-2019.

Beginning in the 90s, three periods could be distinguished in the development of smelters.

The first, between 1992 and 2002, was determined by the need to comply with new environmental standards contained in Decree 185 of 1992, which involved an average investment of US$ 170 million per year (2018 currency) between 1990 and 2002, in the 5 state owned smelters.

In 1990, the 5 state owned smelters collected very little of the sulphur that entered them, which in turn resulted in extremely high emissions of sulphurous anhydride into the atmosphere. In 1990, Paipote smelter collected 24% of the sulphur, Ventanas 18%, Chuquicamata 36%, Potrerillos 4% and Caletones less than 6%.

This is what motivated the creation of the decontamination plans. The emission of sulphur in the form of sulphurous anhydride leads to the acidification of the atmosphere, of rain and eventually of the ground, water courses, infrastructure, flora and fauna.

As the result of the investments made at the beginning of the 90s, the collection of sulphurous anhydride increased sharply, close to 72% at Potrerillos in 2002 and at maximums of 87% at Ventanas and Paipote. This collection continued to increase in all smelters up to close to 90% on average in 2009, except for Chuquicamata.

Figure 4 shows the collection of sulphur as a proportion of total sulphur input in smelted concentrate[12]. All smelters are seen to have significantly reduced their sulphur emissions (as well as arsenic emissions).

The second period, between 2004 and 2013, was characterized by the super cycle of commodity prices, and by there being no new environmental requirements regarding emissions. Between 2003 and 2013, investment in the 5 state owned smelters was reduced to two thirds of that of the previous period, US$ 121 million per year (2018 currency), and additionally, investment by mining companies focused almost exclusively on increasing production of concentrate.

During the super cycle, the strategy of mining companies worldwide was to increase mine

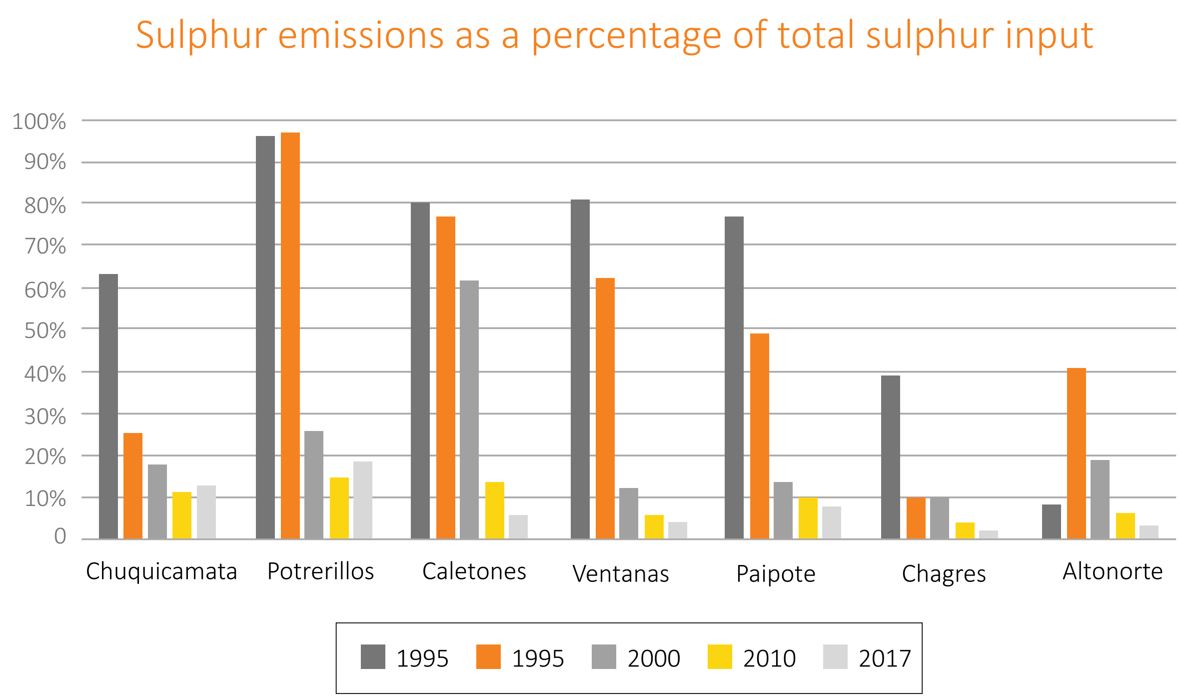

Figure 4: Sulphur emissions by Chilean smelters as a percentage of total sulphur input in concentrate in selected years: 1990, 1995, 2000, 2010, 2017[13]: Source: PEM database, UC, company annual reports, and Cochilco.

[12] SO2 in emissions may also be expressed as sulphur content. One ton of sulphur is equivalent in weight to two tons of SO2.

[13] Data is shown for 2017 since 2018 and 2019 were anomalous due to significant stoppage of Chuquicamata smelter, which was replacing its two acid plants. This meant a very significant reduction in production, which is also noted in Figures 1 and 2.

production, since this segment of the value chain increased greatly in value. Most mining companies neglected or even attempted to leave the smelting and refinery segment, since this is primarily managed by the amounts of smelting and refining charges (rates), which move almost entirely independently of commodity prices[14]. The huge growth of smelting capacity in China (see Figure 1) led spot treatment and refining charges to close to zero in 2007 and 2008, resulting in economic losses for practically all smelters worldwide, excluding some Chinese smelters that received significant subsidies and developed new technologies that allowed them to have lowest operating costs in the world. In any case, this boom of the Chinese smelters industry deteriorated profit margins of this industry for a long time and favored profit margins of the concentrate producers. Figure 5 shows treatment (smelting) and refining charges between 2001 and 2020.

Fed by exceptional copper price conditions in the super cycle, two things occurred that show the change in strategy that occurred in the development of state owned smelters.

The first was the abandonment of one of the most important innovation efforts in Chilean mining, the Teniente Converter (CT), which originated in the mid-70s and culminated in the 80s and 90s with the installation of CTs in all the state owned smelters, in Mexico, Zambia and Thailand. In 2005, however, Codelco decided not to continue to develop the CT and decided to focus on mining business, ending the development program for this equipment and disbanding the team of professionals and

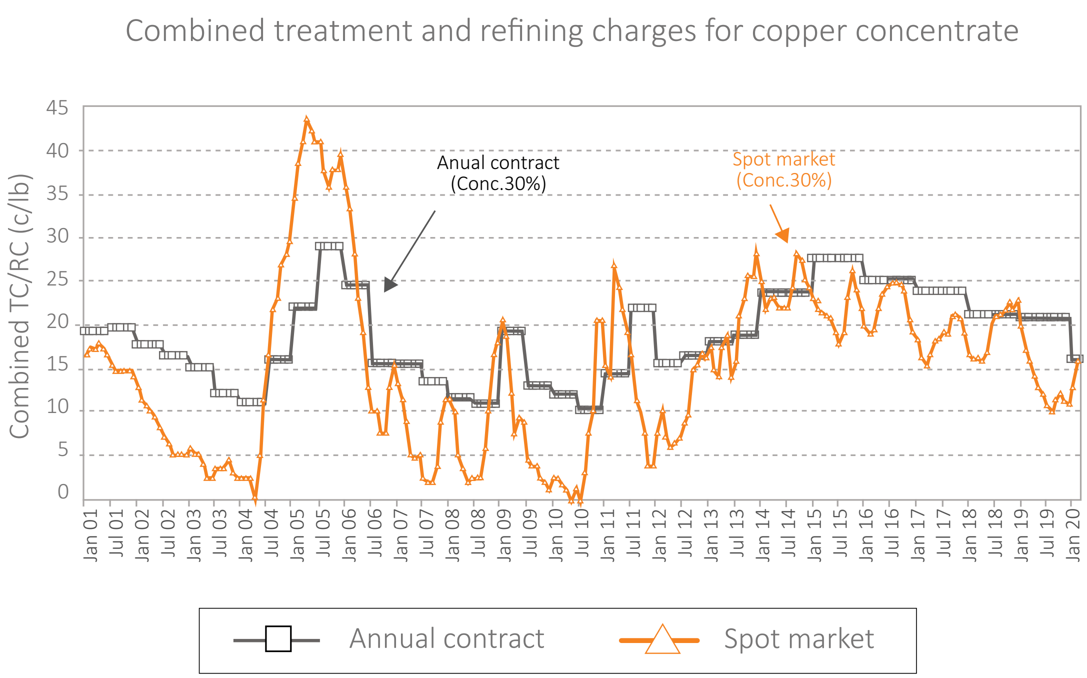

Figure 5: Treatment (smelting) and refining charges for concentrate with 30% copper, price of annual contracts and spot price. Source: CRU, Incomare, Minerals Economy Program Database, UC.

[14] The treatment or smelting charge is paid by the seller of concentrate to the smelter-refinery. It sells the cathode to the end client. The treatment charge or rate is low when there is excess smelting capacity in relation to concentrate available for treatment. Said charge is high when there are large amounts of concentrate in relation to the existing smelting capacity.

academics who had been working on it.

The second event was in 2003, when Codelco abandoned the Mejillones Smelter and Refinery project, which it had been developing since the end of the 90s. The decision was made despite the fact that basic engineering established the project's feasibility and there was a good investor and controlling partner (Nippon Mining).

The decisions to end these two developments was a shock to the design and engineering capacity of the national industry. Beyond its economic significance, this represented a professional and technological setback for the country, a loss that has remained invisible until now.

The two private smelters, however, continued forward with their development plans, increasing their capacity (Figure 2), reducing their emissions (Figure 4) and maintaining their competitiveness.

The Chagres smelter invested in increasing the collection of gases beyond that required by decontamination plans, possibly driven by its multinational condition and its location in the agricultural valley of Catemu, achieving 95% in 2006 and 97.4% in 2017. For this, it had installed an Outokumpu flash furnace in 1995. This smelter constructed a building around its fusion reactors in the following years, in order to increase collection to 99% or more.

Altonorte smelter began operations under the name Refimet Smelter in 1993, with old technology (Reverberatory Furnace). Later, when it was acquired by Noranda, a Canadian company, it installed a Noranda converter in 2000, fairly similar to Teniente Converter, but of superior technology since it had been transformed into a continuous reactor, which implied a reduction in fugitive emissions. The installation of this unit was paired with a significant increase in smelting capacity (Figure 2). Subsequently, Noranda was acquired by Glencore, which continued investments to emit less sulphur than the levels required by Decree 28, and reached sulphur collection of 97.3% in 2018.

The third period, between 2014 and 2019, was determined by the requirements of Decree 28 of 2013, which defined that Chilean copper smelters should collect to December 2018 at least 95% of the sulphurous anhydride they generated. Although this was significant progress, it was a timid target compared with the 97% average SO_2 collection that smelters worldwide achieved in 2016. Decree 28 began being prepared in 2011 by the nascent Ministry of the Environment (MMA) and emerged with force, justifiably, due to the lack of environmental progress in copper smelters once decontamination plans were complied with in 2002.

Codelco's investment was US$ 2,200 million (2018 currency) between 2015 and 2018. Enami invested US$ 54 million in Paipote smelter during this period in order to comply with Decree 28.

In this third period, average investment per year exceeded that of any other period in state owned smelters by more than double. We do not yet know if this will translate into greater competitiveness.

In summary, this information shows that investment in state owned smelters was focused almost exclusively on meeting environmental regulations in effect in the country from 1992 onwards. The super cycle led to a loss of importance of the competitiveness of state owned smelters, but this was not the case for both private smelters. This aspect will be discussed in section 4.

The following section describes the economic and environmental evaluation performed for a new smelter-refinery. It also shows relevant and reference economic indicators for Chilean smelters for the period 1993-2019, which suggest the feasibility of recovering the economic standard of smelter business in the country. Finally, it discusses a set of advantages arising from the installation of a new smelter-refinery in the country.

4.-A new, modern and clean smelter in Chile is necessary and possible.

4a- It is a profitable business.

The economic study performed shows that a new smelter-refinery has a profitability (IRR) of 12.9%, with the assumptions indicated in Table 2, which is a very acceptable value for a long-term industrial business. The smelter has a capacity of one million tons of concentrate, which is 280 thousand tons of copper, which places it close to Altonorte regarding capacity. The refinery has sufficient capacity to treat all anodes produced by the smelter. Direct costs are assumed to be 21.5% higher than the direct cost of reference smelters in 2019. The charges for treatment and refinery are 23.8 c/lb combined (smelting + refining), higher than market value, which was close to 20 c/lb at the end of 2019 and dropped to 16 c/lb in March 2020. The future trend, however, is that the excess of smelters will decrease until TCRC value is about 24 c/lb in the long-term.

The study assumes that the smelter saves 50% of the cost of maritime transport of concentrate to China. The other 50% savings is captured by the mining company that sells the concentrate. An aspect that is not evident in Table 2 is that the higher the toxic impurities of the concentrate, the higher the profitability and NPV.

Electrolytic refining produces cathodes and anode slimes. The latter contains gold, silver and other 15 additional elements that when recovered

Table 2: Assumptions for the economic evaluation of the smelter-refinery:

Treated concentrate (millions of tons/year)	1	Transport savings for smelter-refinery located in Chile (%)	50
Concentrate copper grade (%)	28.5	Smelter operating cost (c/lb)	23
Discount rate (%)	8	Long-term price of sulphuric acid (US$/ton)	50
Recovery of copper in smelter (%)	98	Refinery operating cost (c/lb)	5
Recovery of copper in refinery (%)	99.95	Smelter investment (MUS$)	1000
TC clean concentrate (US$/ton of dry concentrate)	90	Refinery investment (MUS$)	700
Refining charge (c/lb)	9	Price anode slime (US$/kg)	125
Combined treatment and refining charge (c/lb)	23.8	Net Present Value (NPV), concentrate 80% clean (MUS$)	704
Maritime transport to China (US$/ton moist concentrate)	50	Internal Rate of return (IRR), concentrate 80% clean (%)	12.9

Source: U. de Concepción, Cesco, UC.

competitively, improve the profitability of the business. We did not include plants to recover gold, silver or other elements in this evaluation.

4-b It is possible to install a new, competitive smelter-refinery in Chile.

We also asked ourselves whether in the context of dominant Chinese smelters, it is economically viable to establish a new smelter located in Chile. For this purpose, we conducted a comparative analysis of Chilean smelters against a group of international excellence smelters.

As a criterion for the comparison, smelters with good environmental economic behavior were chosen, with standard technologies, and that face market costs (due to this, Chinese smelters were disregarded). The comparison included the smelter in Huelva, located in the city of Huelva in Spain, the smelter of Aurubis, located in the city of Hamburg, Germany, the smelter of Garfield, located near the Bingham Canyon mine in Utah, United States, and the smelter of Tamano, located in Japan. Three of these four smelters have the same technologies as those of Chuquicamata and Chagres smelters, and only Garfield smelter has more advanced technology. The four smelters of reference collect over 99.8% of gases and are profitable.

The evidence from these smelters, all profitable and environmentally sustainable, shows that smelters can be attractive in a very competitive context. That is, that in a competitive business, marked by significant commercial aggressiveness of Chinese competitors, with traditional and non-cutting-edge technologies like some Chinese smelters, and facing market conditions for all their costs, they can generate positive results, in economic as well as environmental terms. Management of technology is key, and automation of transport of materials between units, continuity of operations, maintenance of the units, the timely addition of concentrate and reagents, suitable mixes of

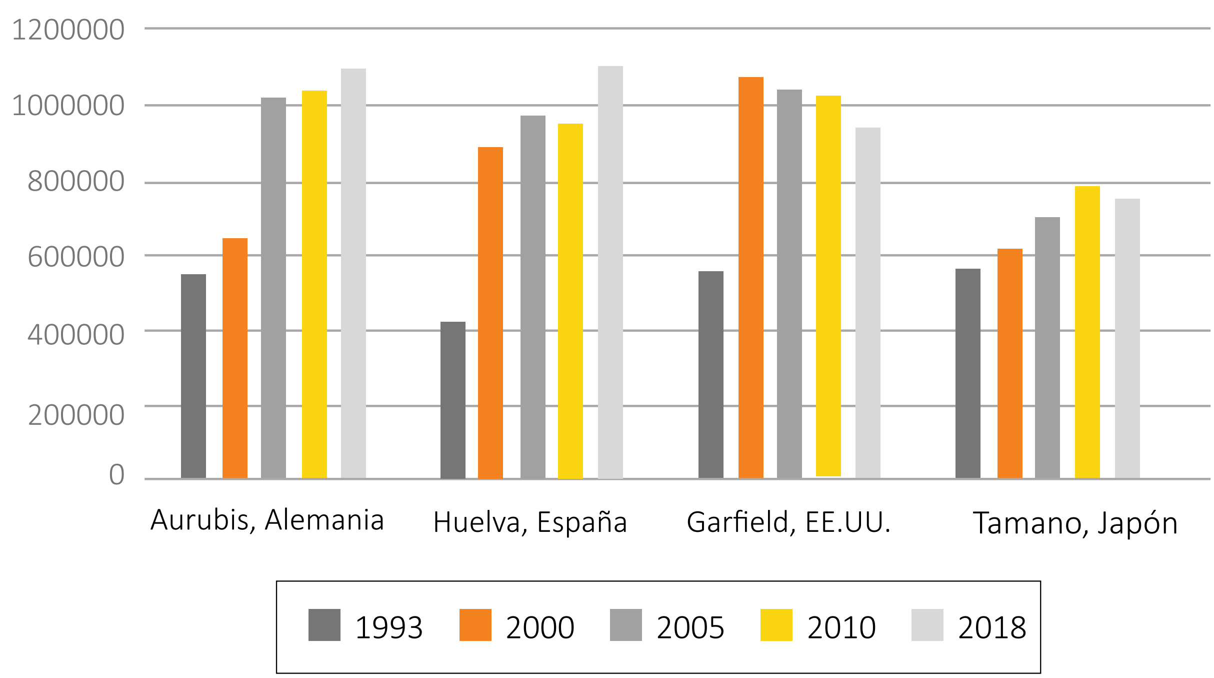

Figure 6: Treatment of concentrate by reference smelters (tons)[15], Source: U. Concepción database, UC Minerals Economy Program.

[15] One ton of concentrate contains between 25 and 26% copper; the rest is sulphur and iron.

concentrate and scrap to meet environmental regulations and economic targets, labor discipline in operation by workers and engineers, knowledge and experience of operators, are key variables, among many others. A smelter can enter into a zone of economic losses if it does not have concentrate that use close to 90% of its capacity during the year. Due to this, the availability of sufficient concentrate is key for its economic sustainability, and teams of business experts who negotiate and purchase concentrate are crucial.

It is interesting that in thirty years, from the beginning of the 90s until 2019, the capacity of the Chilean smelters has remained practically the same, while as a whole; the international smelters analyzed doubled their production (Figure 6).

Figure 7 shows the evolution of average direct costs[16] of the Chilean smelters, for the three best Chilean smelters and for the four reference smelters, between 1993 and 2018. Beyond costs pressure for energy and labor and the reduction in rates faced by all companies, there were smelters that were capable of containing costs and achieving economic profits. That is, the management factor was determinant.

We can see two much differentiated groups in Figure 7. One, integrated by three Chilean smelters, with positive results in both dimensions (blue line in Figure 5), although lower than the international ones; and a second group that constitutes the average of Chilean smelters (orange line in Figure 7), with poor economic results.

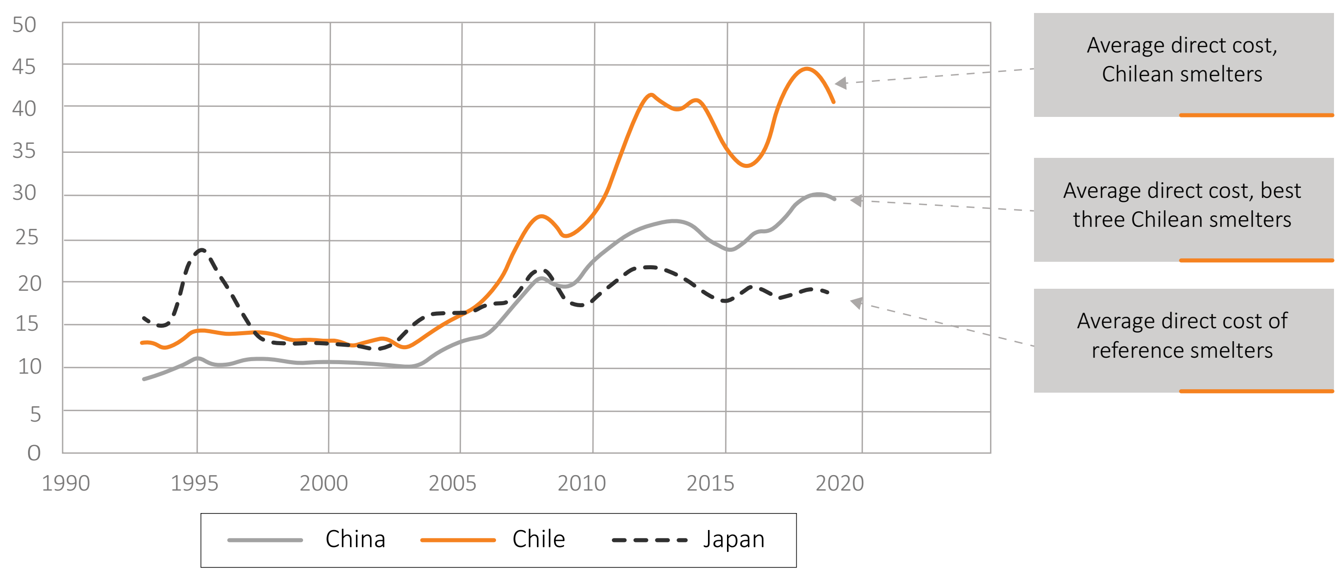

Figure 7: Average direct costs of Chilean smelters, of the best three Chilean smelters and of four reference smelters (Aurubis, Tamana, Huelva, and Kennecott). Source: Brook Hunt and Wood Mackenzie, U. de Concepción database and UC Minerals Economy Program.

[16] Direct costs include salaries, power, operating supplies, maintenance and other site costs.

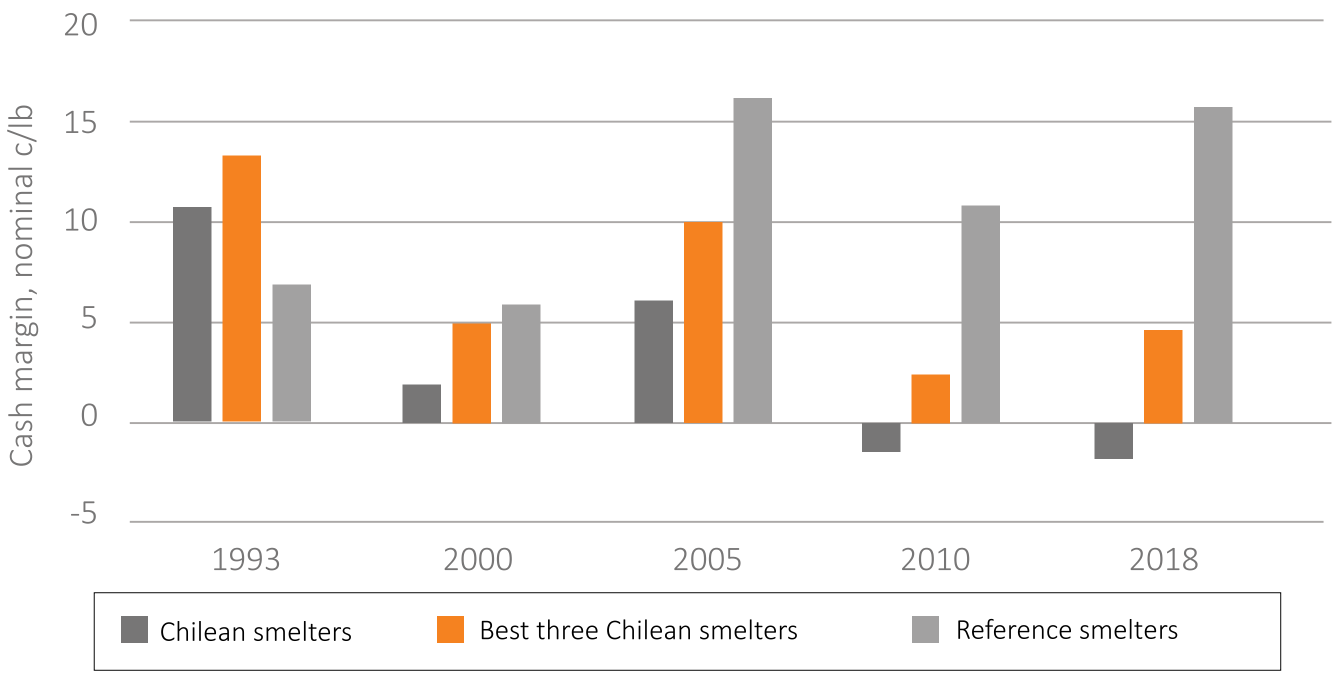

Figure 8: Operating margins (cash) obtained by Chilean smelters, by the best three Chilean smelters (from the economic perspective) and by reference smelters. Source: Brook Hunt, Wood Mackenzie, U. Concepción databases, UC Minerals Economy Program.

Figure 8 shows the operating margins (cash) achieved by Chilean smelters, by the best three Chilean smelters (from the economic perspective) and by reference smelters.

Figure 8 shows that on average the best Chilean smelters had positive results, despite the fact that one of them is much smaller in size than is required to be competitive.

In summary, whether from the analysis of profitability of a new smelter using all market parameters, or from what occurs with the operation of international and some Chilean smelters, the conclusion is that the business can be good and that this depends fundamentally on the management of investment, operations and very especially, commercial management.

4c- It is a contribution to the environment

Reduces greenhouse gas emissions

A smelter-refinery located on the coast of China near Shanghai that imports concentrate from Chile would emit 27% more greenhouse gases (GHG) globally than an identical facility located on the coast of the regions of Atacama or Antofagasta. This is because smelting in China signifies using an energy matrix that is more fossil-fuel intensive (70.1% in 2018) than in Chile (55.7% in 2018, with a strong downward trend). We also add the contribution to greenhouse gases (GHG) by the maritime transport of concentrate, which contains approximately 75% waste, which implies emitting 4 times more greenhouse gases (GHG) than when transporting cathodes. That is, carbon footprint of a smelter installed in Chile is less than a similar one currently installed in China, and will have a larger difference due to the large potential for renewable energy in the Chilean desert and the technological (and price) revolution that is underway in the production of solar energy and fuels.

This has a high probability of continuing to provide Chile with an advantage over China, in accordance with projections known of the progress of Chinese and Chilean energy matrix. This shows the importance of making use of the huge advantage of solar radiation in the north of Chile, which would increase environmental benefits of Chilean matrix with respect to China not only in the emission of greenhouse gases (GHG), but also other environmental indicators that are indicated further below.

Figure 9 shows the emission of greenhouse gases (GHG) per ton of treated copper, for a smelter-refinery located on the coast of China, and a smelter-refinery located on the coast of Chile. In order to obtain this value, as well as others indicated further below, we performed a lifecycle assessment (LCA) in accordance with ISO 14044:2006.

The same comparison makes the potentials for acidification, eutrophication, photochemical ozone and the demand for primary energy 73%, 103%, 80% and 11% higher, if the smelter were located in

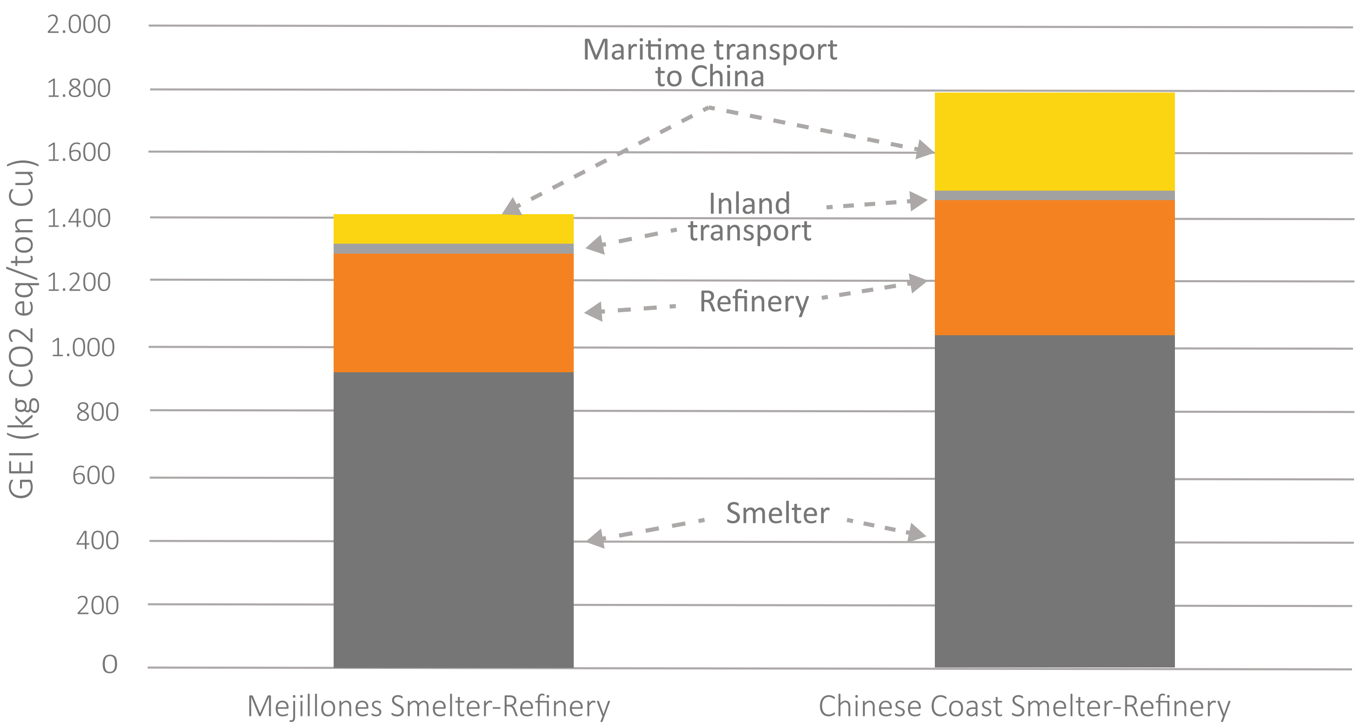

Figure 9: Greenhouse gases (GHG) emitted per ton of copper treated in smelters located on Chilean coast and on the Chinese coast. Source: Gabi 9.2.0.58 software, schema 8007 database, modelled in accordance with CML 2001, ISO 14044:2006 protocols, UC Minerals Economy Program.

China. Table 3 shows the results of modelling in the Gabi 9.2.0.58 software.

Lifecycle Assessment and the indicators originated by this methodology generate traceability of processes and materials used. These criteria are applied with increasing frequency by a wide range of product manufacturers worldwide. There is already legislation in Europe and Asia that recommends, and even requires, certain standards when selecting materials that comprise the fabricated products. This is part of the green economy that is booming, and that in the future is expected to systematically prohibit the use of products that do not meet standards given for the indicators obtained using the Lifecycle Assessment (LCA). This single factor favors the installation of more smelters in Chile, provided they meet high environmental standards.

4d- It is a technological contribution to improve mining's value chain and progress in the circular economy, the basis for future industry.

A smelter with the capacity to smelt one million tons of concentrate would create 570 direct, permanent, highly-specialized and quality jobs[17], as well as around 1,500 additional jobs due to the productive chain. Suppliers of this new smelter would have more specialized and higher-quality requirements than those currently offered in Chile.

(CML 2001 – Jan. 2016) Lifecycle Assesment (LCA) Indicators	Chile SEN 2018, with acid credit with credits	China 2018, con with acid credit
Potential for acidification (AP) [kg SO2 eq/ton Cu]	7.57	13.15
Eutrophication potential (EP) [kg Phosphate eq/ton Cu]	0.62	1.26
Greenhouse gases (GWP 100 years) [kg CO2 eq/ton Cu]	1,408	1,784
Ozone depletion potential (ODP, steady state) [kg R11 eq/ton Cu]	2.64E-11	1.97E-11
Ozone creation photochemical potential (POCP) [kg Ethene eq/ton Cu]	0.40	0.72
Total demand for energy (gross cal. value) [MJ/ton Cu]	23,199	25,836
Primary energy from non-renewable resources (gross cal. value) [Mj/ton Cu]	17.642	21.988
Primary energy from renewable resources (gross cal. value) [MJ/ton Cu]	5.558	3.848

Table 3: Lifecycle Assessment (LCA) environmental indicators of smelters (per ton of treated copper) located on Chilean coast and on Chinese coast. Source Gabi 9.2.0.58, schema 8007 database, modelled in accordance with CML 2001, ISO 14044:2006 protocols, UC Minerals Economy Program.

On the other hand, a modern smelter is part of the efforts to improve mining competitiveness, which faces serious challenges to lower its costs, along with having to adopt increasingly less-polluting technologies and processes.

Access to markets in the future will be with traceable, recyclable raw materials and products that are part of clean production chains (circular economy), due to regulatory requirements as well as due to

[17] Assuming that labor productivity (ton/person) at the smelter will be double the average of current productivities in Chilean smelters.

demands of end clients or of intermediate value chain (for example, electric vehicles, household electric goods, mobile phones, etc.). Without modern metallurgy and progress in understanding new materials, and the insertion of mining in the logic of these new trends and knowledge chains, our country will have an increasingly peripheral role in the worldwide market. Along with other efforts, maintaining metallurgical activity in Chile will generate a more diversified and dynamic critical mass of businesspeople, professionals and workers that are capable of discussing, influencing and participating in the emerging economic activities in this new economy, contributing to the growth of the export mining technology sector, which unfortunately has not been very productive in the past two decades. If this is achieved and if copper reserves and resources grow at lower rates, there will be an important industry in place that could pick up the economic slack left by traditional mining. Large Chilean copper deposits have many decades of life still, but this cannot delay the decision to progress more quickly with building a strong export mining technology sector, such as Australia's. It is unthinkable to think of significant technological developments that move the needle, without such an important and historically excellent area, as smelters were, playing a leading role.

Contribution to the recovery of sub-products

Sub-products are exported in concentrate. The content of minor elements constitutes an opportunity to optimize the business. In fact, Chinese smelters state that at least 15% of their profits come from selling 15 different types of sub-products associated with minor elements. In the same way, many smelters are opening to the treatment of e-waste, getting ahead of what is foreseen to be a worldwide trend: the reuse and recycling of valuable elements in the economy. Also, the use of slag in civil engineering works or as an additive for cement let us anticipate that smelters with the best business indicators today will generate minimum waste in upcoming years, making the circular economy a (highly) profitable practice.

The increase in smelting capacity increases generation of sulfuric acid.

This will make mining of multiple low-grade and high-acid-consumption mining resources that today cannot be treated for economic reasons possible. Chile has over 20 thousand million tons of waste rock, a large part of which has significant copper content, which could be extracted through hydrometallurgy if there is abundance of acid at a low price. This would make use of the enormous capacity of these hydrometallurgical plants that would no longer be used when copper oxides are depleted, which seems to be inevitable.

4e- Management of country risk

Another advantage of building a new smelter-refinery is that Chile would stop losing global market share in concentrate smelting, as has occurred over the past two decades. The great Chinese boom in worldwide smelting capacity (with 35.3% in 2018) implies a strategic risk for Chile, which will increasingly depend on the export of concentrate. China already has market power to increase treatment and refinery charges. Furthermore, its smelters act as a cartel when negotiating these charges each year. Although this threat is eventual and even if it occurs it would not have a lasting effect, it cannot be ruled out. Due to this, the report by the Presidential Commission on the future of smelters that was issued for 2015-2016 indicated that the country should not, under any circumstances, reduce its smelting capacity. Although this report remained on the desks of the ministers of the time, its recommendations remain valid.

The fragility of logistic chains, demonstrated by the coronavirus crisis, shows the need for countries to take certain safeguards that appeared to be absolutely unnecessary prior to this crisis.

4f- Risks of maritime transport of concentrate

Export of concentrate has a potential risk in the case of the temporary suspension of sales due to market problems (such as coronavirus), specific low prices (such as a financial crisis) and maritime restrictions, such as new regulations of the International Maritime Organization. Any of these restrictions could result in the stoppage of mine sites that export concentrate, since storage capacity and time is very limited (3 to 4 weeks), while the capacity for storing cathodes (refined copper) is very high. This is what happened in China in January and February 2020, when the coronavirus pandemic stopped supply chains, but allowed concentrate to arrive at smelters in the country. These smelters processed concentrate and refined it to cathodes, which could not be transported to clients until March-April and therefore had to be stored in the yards of electrolytic refineries. This, however, was not a problem that permanently threatened the industry; it only signified a delay in deliveries to end clients.

4g- Reputation effect.

An evident result of productive and environmental undermining of most Chilean and particularly state owned smelters, was damage to the country's perception of these facilities, which are seen as old-fashioned and polluting. As a consequence, the general public has difficulty believing that a smelter could be a modern, clean and safe facility, as in other countries, there is reputational damage that tends to affect the mining activity as a whole.

If we had smelters such as those of Aurubis or Huelva, both located in the centers of large European cities (Hamburg and Andalusian port of Huelva), the Chilean copper industry as a whole would enormously improve its image in the country.

These smelters are not only profitable, but also have very high environmental and community standards, that even go beyond what is mandatory.

When an industry is systematically responsible, it gains credibility with the general public and also with the regulator; but if part of its value chain has significant environmental failings, like Chilean smelters, communities and regulators are mistrustful and assume that the entire industry operates negligently elsewhere.

5.-Our proposal

This proposal does not intend to resolve all current problems in mining, but instead to provide a powerful signal of change towards green mining, of progress towards a circular, more technological, and knowledge-based economy.

Our proposal is to build a cutting-edge smelter-refinery, of environmental excellence, financed and operated privately, and that in principle would be independent of any particular mining company. It should be located on the coast, or near the coast in the Region of Atacama or Antofagasta.

Closing or abandoning smelters without replacing their productive capacity with economically and environmentally sustainable smelters, in addition to negative impacts on qualified labor, would mean the end of a significant part of extractive metallurgy in Chile. Key knowledge would be lost, that could not only be used to bring us closer to the value generation nodes linked to end uses of copper, to new materials and alloys, but to capacities for developing solutions for competitive mining with increasingly complex technological challenges, some of which are precisely linked to the development of new pyro and hydrometallurgical processes.

There are many advantages for an independent smelter-refinery that is not integrated to a mining company. Firstly, its success depends on its own operational management and on the annual investment flow not subsidized by a mine; secondly, it must seek additional sources of income, for example, using recycled copper, recovering heat to improve its energy efficiency, recovering sub-products and processing impurities; thirdly, the financial risk of operating a smelter is less than the risk of having a copper mine. And lastly, salaries of an industrial facility are lower than those of a large mine. In fact, the increase in labor costs recorded during the mining super cycle was replicated in integrated smelters, although these were not profitable.

Due to this, Codelco's announcement in January 2020 that it would create a Vice-Presidency of Smelters is a promising sign, since it suggests that these facilities could become more competitive by mines business being managed separately in the company. Until now, Chuquicamata, Potrerillos and Caletones smelters have answered to Chuquicamata, Salvador and Teniente divisions, respectively. Thus, we have the paradox that these divisions have 2 businesses under the same executive, one which produces concentrate (mine-plant operation) and another that produces cathodes (smelter-refinery operation), with the former being very manageable and highly profitable, and the latter complex with losses. It is obvious that the executive will prioritize the profitable business and avoid becoming involved in the business that always generates losses.

We propose that the new smelter-refinery be preferably developed by a company with international experience, with the capacity to operate it profitably and in an environmentally sustainable manner. We propose that this be done now, in order to quickly surmount the negative reputational load generated by the decline of state owned smelters over the past decades. This will contribute to look ahead a new path for more complex, diversified and environmentally friendly mining.

There is sufficient concentrate in Chile and in its neighboring countries to feed this smelter, and there will be more in the future.

There are significant advantages in the location of this project, which signify a lower transport cost of between 8 and 10 cents per pound of copper, which is the difference between exporting cathodes and concentrate. This will favor mining companies that operate in the country, since it will also contribute to the reduction of their costs. In terms of size, given the existence of important economies of scale, the smelter-refinery should have a capacity similar to that of Caletones or Chuquicamata in order to be profitable.

We propose a proactive and consistent action by the State to catalyze a decision of this type. What always occurs, when a new government arrives, undoing what has been done, should not happen. We propose that the government develops this project by creating a group of highly prestigious professionals, comprised of technicians, economists and lawyers, who can successfully materialize an international bidding process, or achieve negotiations with invitations to companies of excellence in this area. This "Taskforce" should be chosen transparently, favoring competition in its selection.

We propose that agreements be implemented with Codelco and with private mining industry in Chile, and possibly in Peru, to ensure the supply of concentrate for the new smelter-refinery at market prices. **A detailed analysis of concentrate available in Chile indicates that this would have positive economic externalities for private mining and also for Codelco. The participation of large Chilean mining companies as investors, while desirable, should not be a critical requirement for the business to be viable.**

We propose that the government have a state-owned property or one acquired from third parties for this, in Atacama or in Antofagasta, with an environmental authorization, with clear and transparent information for the public on the benefits and impacts, which also includes a shared value proposal. The proactiveness of the State in this area is crucial to ensure that the site selected for the new smelter obtains a social license.

We hope that this proposal strengthens the implementation of other technological activities that are downstream from the production of cathodes, for example; recovery of metals and valuable elements, development of new processes for the treatment of increasingly complex minerals in our deposits, and other technological aspects associated with the extraction of copper.

In particular, we hope that this proposal strengthens the relationship between Chilean copper producers and their end clients, to understand and satisfy the increasing demands of the latter for the supply of copper from green and circular mining. Along these lines, it appears key to strengthen the bond in the Chilean copper value chain with renewable energy, electromobility and technologies that mitigate the effects of copper extraction on climate change.

6.-In summary

We propose that the State drive, but does not finance or operate, the construction of a smelter-refinery with cutting-edge technology and the highest environmental standards, since it will generate a set of economic, technological, environmental, human capacity, strategic and social benefits for the mining industry and for the country, and at the same time does not involve costs for the mining industry.

That the State create a high-level technical working group to drive this business.

Mining companies can participate in the ownership of this business if they so choose, noting that their main contribution will be the commitment to sell concentrate in a long-term. The smelter-refinery business must be managed by a company that is world-renowned in the area of copper smelters and refineries.

The State must guarantee that all conditions indicated are met regarding the location of the project, environmental assessment and protection, supply of concentrate and consultation with communities and other stakeholders, so that it can be implemented successfully in a short period of time.

7. Epilogue

Many years ago, specialists in the area considered the idea of a new smelter as they watched the country move backwards in an area in which it had accomplished much. At Cesco, we accepted that challenge and analyzed the subject from a more global mining perspective, considering new market developments. We asked two questions:

- Does the country need modern, clean and competitive smelters?

- Is this industry viable in economic terms?

The discussion on smelters is very relevant, since it opens a discussion on the future of mining in our country, after over 30 years during which mining strategy has pointed primarily towards one single objective – increasing copper production, and exporting concentrate.

The conditions in which mining is carried out have changed drastically in this period. Large deposits have reached their maturity, with a significant reduction in their grades and without significant discoveries. Furthermore, environmental, social and economic demands have increased significantly, which, linked to the pressure of costs, puts the industry in a new and difficult scenario.

One single indicator regarding competitiveness that illustrates the aforementioned: In the 90s, copper production in Chile was in the second cost quartile, while towards 2017, it was in the fourth quartile*.

Mining, the traditional engine of Chilean economy, is losing its dynamism, due to lower growth rates (0.38% annually since 2004) and productivity that is growing less than economy's average. Future perspectives do not look promising. According to Central Bank forecasts, by 2027, the natural resources sector will grow at 2% compared with the "Rest", which will grow at 3.4%.

We are far from the times when copper production grew at annual rates of 9% with productivities that pushed the economy as a whole. To continue growing and contributing value in accordance with its resources, mining needs a new viewpoint, no longer exclusively based on increasing tonnage of produced concentrate. The challenge is to generate more value for the country per unit of copper produced. As we will see further below, the growth of Chilean mining in terms of production of fine copper has important limitations and therefore, in order to maintain its potential for growth and deploy all of its virtuous effects, we must think of the entire value chain. This has been suggested in several documents over recent years: Minería, Una Plataforma de Futuro para Chile y Roadmap Tecnológico para la Minería, version 1.0 and 2.0 (Mining, a Future Platform for Chile and Technological Roadmap for Mining, versions 1.0 and 2.0)

Clearly, there is a problem of consistency in a country with a mining industry that continues to be "world class" but has third-world smelters,

* Chilean Copper Mining Costs. Jorge Cantallopts. Chilean Copper Commission, Dec. 2017.

which has strong reputational impacts that affect the entire sector. It is surprising that, in almost 30 years, the capacity of Chilean smelters has stalled, while the country's production of concentrate has more than tripled.

When we speak of smelters, we are not going back to the past, thinking of cathodes production. The technical revolution we are witnessing, with new market requirements and the environmental issue as a challenging driver, leads to a new way of mining. Integration in productive chains is imperative, especially in that related to the value chain of renewable energy, electromobility, metallurgy and new materials, among others.

Access to markets, a requirement of the new competitiveness, will increasingly require more raw materials and traceable, recyclable and clean production chain products (circular economy). This requires a productive, technological and knowledge base that allows the above concepts to be implemented, which are precisely those that generate value. Thus, for example, and thinking of a new smelter 2.0, in addition to concentrates, processing of sub-products, scrap, including electronic scrap and other materials that can integrate the productive flow is required. It should be indicated that mining success in the future will require increasingly more complex metallurgical knowledge along with the development of new materials and alloys. Without this, we will become increasingly more circumscribed to exporting concentrates and become increasingly distanced from intermediate and final markets, which is where most of the value generated by the activity is obtained.

Along these lines, the proposal for a new smelter is a starting point for discussing the future of mining in our country. Is there anything that is different', is anything better possible? If conditions are changing radically, do we have to continue to do the same thing?. All we are certain of is that it is not possible to repeat the production growth rate of the 90s up to 2004, which was an annual average of 9.2%. We need to think differently and think big.

We have been stationary to a certain extent for a long time. The country demands more from mining. Is this discussion about green mining, circular economy, only words, or are they tectonic movements that are underway for which we have to prepare as a country?

We know that changes are not easy. For any decision, there are thousand conditions. But in the case of Chile, there are many arguments for high-standard facilities located close to the deposits. From the risk of depending so critically on one single market and of possible interruptions in the logistics chain, to savings in transport, access to strategic commercial and technological knowledge. Not to mention the environment: are we going to continue to transport by sea and road millions of tons of concentrate containing only 25% copper, with the rest being waste?

The importance of the exercise carried out at Cesco is that, beyond how necessary a new smelter is for our future as a country, it seems to be economically viable. For this, we have looked at the experience of international smelters that compete successfully against their Chinese counterparts. In addition, an assessment of a new smelter/refinery project located in Chile was conducted, with attractive rates of return for industrial investors. A clear competitive advantage is the location near the deposits, which means significant savings in transport, estimated at around 10 cents per pound of copper. To this, we add lower environmental impacts and the favorable result in the fight against global warming by the Chilean energy grid, which is turning at great speed towards renewable energy when compared, for example, with that of China.

In this vision of efficient and environmentally clean smelters that recover sub-products and recycle scrap, with the incorporation of capital and cutting-edge technology, there is a broad field of cooperation with large mining companies that export concentrate. It is without a doubt to their advantage to be able to process their concentrate near their facilities, at market conditions, without needing to transport it by road, or store or load it, especially when there are impurities.

Progress along these lines requires proactive and consistent actions by the State, as the initial coordinator and catalyst of a decision of this type. Financing for an industrial project such as this must come from private investors interested in attractive long-term profits, with lower risks than those involved in the mining business, and with operators experienced on the world stage.

In summary, we must continue to progress and speak with potential interested parties and investors, but we believe that this is a worthwhile adventure. It requires pioneering investors, capable of acting in the complex current business environment, who want to do important and groundbreaking work.