Comisión Chilena del Cobre
Ministerio de Minería
Gobierno de Chile

Water consumption forecast in copper mining 2017-2028

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Abstract

Every year, the Chilean Copper Commission carries out the water consumption forecast in copper mining in Chile for the next ten years, based on the production forecasts of copper and the consumption surveys from mining companies. This forecast differences water according to its source (fresh or seawater), region, processing type, project condition, development type and environmental permit status. The consumption forecast for the 2017-2028 period was prepared using data from 2016.

Regarding the source, the forecast for seawater consumption predicts an increase, reaching 11.2 m^3/sec in 2028, which accounts for 289.9% growth compared to the 2.9 m^3/sec consumed in 2016. Fresh water is expected to decrease from 12.3 in 2016, to 11.5 m^3/sec in 2028, which accounts for a 6.3% reduction.

As for regional consumption, the one with the greatest variation in both fresh and seawater, is Antofagasta, which is calculated to decrease the use of fresh water by 55%, as well as O'Higgins by 13.4%. On the contrary, Tarapacá is expected to increase it by 82%, Atacama, Coquimbo, Valparaíso, and the Metropolitan Region by 21.7%, 52.3%, 20.1%, and 19.3%, respectively. Antofagasta stands out again in terms of the seawater consumption due to its estimated 8.28 m^3/sec rise for 2028, which translates into 248.5% more than in 2016. In second place is Atacama. This region is expected to use up to 1.57 m^3/sec in 2028, 222% more than in 2016.The concentration process, which demands the highest consumption of water, is expected to show a sharp increase by 2028 (almost 75%), while the hydrometallurgical process will reduce its total use of water by 51.7%. Regarding the projects status, almost half of the seawater consumption projected for 2028 correspond to probable, potential or possible projects, this is, projects with uncertain materialization. The same trend applies to the seawater consumption depending on the development stage of the projects, whereas 42.8% of the consumption projected by 2028 alone can be justified on the ground of projects in operation. Regarding the use of water by environmental permit status, for 2028, 61% of the consumption represents projects that are up-to-date with their environmental proceedings.

There are differences regarding last year's water consumption forecast mainly due to unexpected strikes, the entry of new projects to the portfolio (both mining and desalination plants) and the closing of some hydrometallurgy sites.

It is important to point out that although the use of seawater solves the scarcity problem in the large northern zone (Norte Grande) of Chile, it does not solve the problem of water quality arising from mining waste, and therefore, proper management and efficiency in water usage are necessary, regardless of its source.

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1 Introduction and Purpose

Mining is one of Chile's main economic activities, contributing with approximately 13.1% of the GDP, 14.3% of the collected taxes, and with 60% of exports between 2007 and 2016. In addition, it is responsible for 3% of direct and 10% of indirect jobs. Copper mining is the main mining activity in Chile and is responsible for approximately one third of the world's copper production (COCHILCO 2017). Water is an essential resource for this activity, because it is necessary in several stages of the productive process. Compared to other productive sectors, with only 3% of the national water consumption, mining would not be one of the main actors. However, the biggest part of the mining sites are located in the large northern zone (Norte Grande) of Chile (78% of copper extraction companies), with only 0.13% of national water run-off. In this region, there is a semi-arid climate with 87 mm of rain per year, and it has the presence of plains and wetlands, which are unique, fragile ecosystems of great ecological value at a national level (DGA 2016). On the other hand, water is an essential resource for people and the environment. It is fundamental for human survival and health, for sustaining crops, animals and sensitive ecosystems.

Therefore, the correct management of water in mining areas is necessary for a sustainable development in the region. In this context, this "Water Consumption Forecast in Copper Mining 2017-2018" report intends to be a useful tool for planning and decision-making, water-consuming companies and sectorial public authorities.

This report is aimed at generating estimates of water consumption forecasts between the years 2017 and 2028 for the copper mining industry in Chile. The projections of the future use have been carried out with assumptions that could be denominated as uncertain, since production is subject to the decisions companies make regarding the feasibility of the projects. The scope has been limited to the water consumption forecast for copper mining between the regions with the highest mining presence, that is to say, Arica y Parinacota and O'Higgins regions, comprised in the 2017-2028 period, and considering real data from 2016.

The detail of the results is provided at a national level and establish a difference between fresh and seawater according to region, process type for ore treatment, status of the different projects or operations, development stage and progress of the environmental permits.

2 Methodology

The methodology for estimating the value for water consumption in copper mining in Chile consists of a four consecutive stage process: (i) update of the copper production forecast for both concentrated and fine copper in the period of study, (ii) determination of the unit consumption of water per mining process and company, (iii) determination of the occurrence probability of the production forecast, making a difference between a maximum, most probable and minimum scenario, and (iv) therefore, the modeling of the water consumption forecast for the determined period.

The aforementioned proposed stages are further detailed here bellow.

i. First stage: production forecast

The project registry that COCHILCO creates each year with updated information of operations and new projects for 2028 was used to determine the production forecast. In this projection, copper production is estimated, for both concentrated and SxEw cathodes (solvent extraction and electro-winning), and in foundry and refinery (COCHILCO 2017) of the different mining sites, according to the project's status: base, possible, probable or potential. This also specifies their location (region), project type, development stage, environmental permit status, and commissioning year (effective or expected).

ii. Second stage: unit water consumption

Secondly, companies obtain the unit consumption of fresh and seawater of the copper mining industry from the survey annually carried out by COCHILCO. With this information, the unit consumption coefficients of fresh and seawater are calculated for the different processes in the different processing types. That is, extraction in sulfide and oxide mines, in processing of concentrates and in hydrometallurgy, in other consumptions in the different facilities (mainly human services and in camp), in foundry and refinery, and its other consumptions (services). To establish the coefficients of operations and projects, the following criteria were used:

- For sites in operation, the fresh water consumption coefficient reported for 2016 is used (last year with real available data), which remains constant over time.
- For expansion projects, the coefficient used is the same as the one for the main operation or for operations of analogue characteristics.
- For new projects, unit coefficients of similar operations are considered, as well as the average of the industry.
- In the case of seawater, coefficients similar to those of real operations with seawater are established, and in addition, its consumption is associated with the capacities of the desalination plants and pumping systems.

iii. Third stage: probability matrix

In third place, based on the background information on the materialization of investment projects, the probability of occurrence for the production expected in the stipulated dates is determined, with which, three water consumption scenarios are created: maximum, most probable and minimum, and then grouped into a probability matrix. The values of these scenarios are determined under the following criteria.

- **Maximum production scenario:** it considers that operations continue according to the plan, all projects are commissioned on the real date, and production capacity estimated by their owners.

- **Most probable scenario:** it weighs the copper production profiles expected and reported by mining companies with values smaller than the unit, since there is a high probability that projects will go through variations and will not be carried out on the date and productive capacity initially estimated. This weighing has been determined by COCHILCO based on the background information (gathered since 2005) on the behavior of materialization of mining projects, obtained from the historic projects' registry published by COCHILCO.
- **Minimum production scenario:** it adjusts the most probable scenario with lower figures within a reasonable technical criterion.

iv. Fourth stage: water consumption forecast

In fourth place, the probability matrix is multiplied (third stage) by the production forecast (first stage) and the unit water consumption (second stage) to generate the maximum, minimum and most probable probability scenarios, which will be subject to a Montecarlo simulation, in order to determine the expected value of the forecast.

The value of water consumption for *t* year is calculated as shown in equation (1):

$$\boldsymbol{Consumption\_Water_t} = \sum_i \boldsymbol{E}\left[\boldsymbol{f}(\boldsymbol{X_{ijkt}}; \boldsymbol{Y_{ijkt}}; \boldsymbol{Z_{ijkt}})\right] \qquad (1)$$

Where,

- *i*: Mining site considered
- *j*: Type of final product considered
- *K*: Condition/status of the mining project considered[1]
- *t*: Year considered in the forecast period
- *f*: Distribution of probability describing the range of values that the electricity consumption could take and the probability assigned to each value in accordance to the entry variables.
- Z_{ijkt}: Corresponds to the maximum production of fine copper in site *i*, in process *j*, in accordance to the *k* condition/status of the project, in year *t*. The unit of measure is ktpa.
- Y_{ijkt}: Corresponds to the most probable production of fine copper in site *i*, in process *j*, in accordance to the *k* condition/status of the project, in year *t*. The unit of measure is ktpa.
- X_{ijkt}: Corresponds to the minimum production of fine copper in site *i*, in process *j*, in accordance to the *k* condition/status of the project, in year *t*. The unit of measure is ktpa.

On the other hand, regarding the weighing factors for the capacity of the operation or project, they depend on the status and condition of the project and the situation that was generated.

From this generation of scenarios, three values of annual consumption are obtained for the aforementioned process, one for each scenario, which are subject to the Montecarlo simulation

[1] The condition/status of the projects established in this report is: Base, Probable, Possible-feasibility, Potential-feasibility and Potential-prefeasibility.

with the purpose of creating a probability distribution of its annual consumption, which is calculated for the expected statistical value.

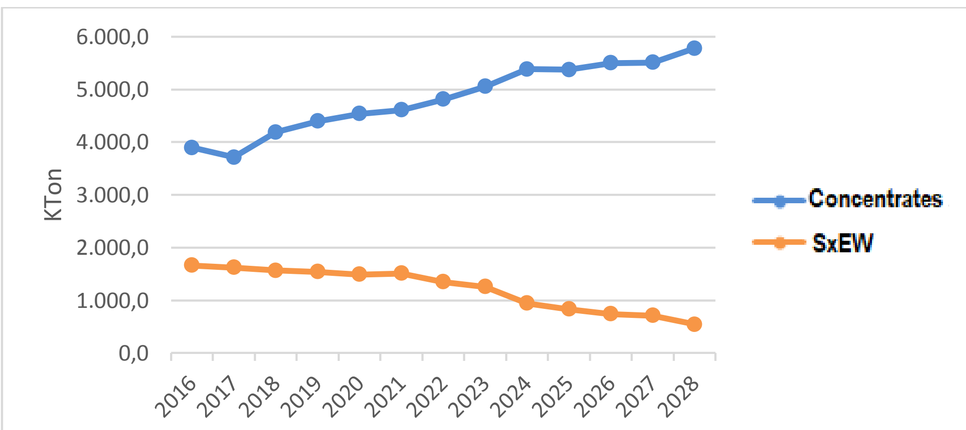
3 Results: Water consumption forecast for 2028

The results obtained for the first three parts of the methodology are shown here below, in addition to the results of stage 4, which corresponds to the water consumption forecasts. Said results are shown by their source, region, and process, condition of project, development stage and environmental permits status.

3.1 Main findings for the forecast

In stage 1, the copper production forecast, it is possible to see that it indicates an upward trend regarding the production of concentrated, and a downward trend in terms of SxEw cathodes. See Figure 3-1 where real data from 2016 and forecast of 2017 to 2028 are shown.

Figure 3-1: Concentrated and cathode production forecast 2016-2028



Source: Cochilco, 2017

As concluded in the copper production forecast in Chile 2017-2028 report, since 2016 (real data) and until 2028, the production of SxEw cathodes is reduced by 67.2% (8.2% annual on average), while the fine copper production by concentrates increases by 48.5% (with an annual rate of 0.31%). This clearly expresses the evolution that copper deposits are having in Chile, which are becoming old and containing dwindling amounts copper oxides, are closer to the surface and more leachable, and each time more sulfides, which are in greater depth and can be processed, generally, through the flotation-concentration process. At a national level, copper production for 2028 is expected to grow by 13.9%, relative to 2016.

In stage 2, the unit consumption of water is obtained through the survey to mining companies, the unit water consumptions for each one of them according to stage and process. The values of these unit consumptions cannot be provided separately since they are confidential. However, the consumption in the concentrating plant and in hydrometallurgy is delivered as cubic meters of water per ton of ore processed in the second table (COCHILCO 2017).

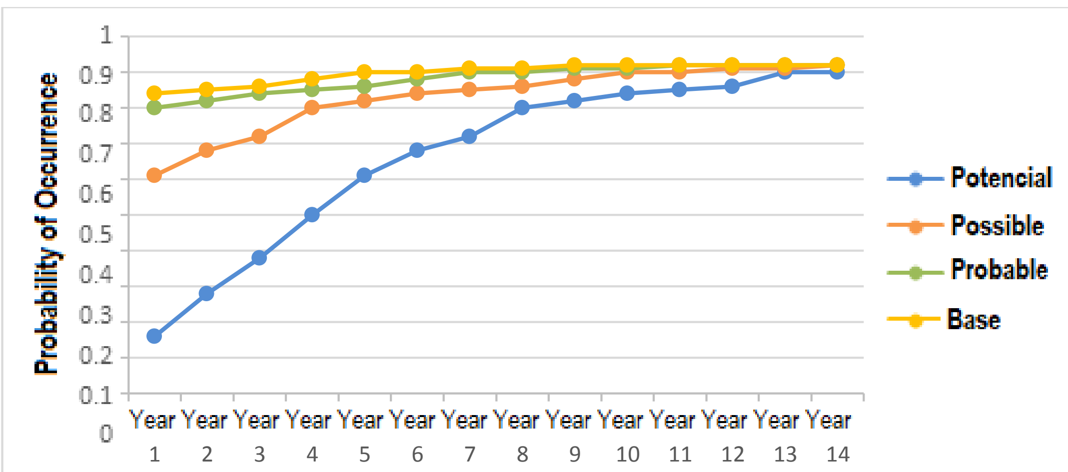
Table 3-1: Unit water consumption per processes in 2016

Process	Unit	Fresh water
Concentration	(m^3/ton_min)	0.5
Hydrometallurgy	(m^3/ton_min)	0.1

Source: Cochilco, 2017

In stage 3, the probability matrix is carried out for base, probable, possible, and potential projects, defining a minimum, most probable and maximum scenario for each one them. The next graph shows the occurrence probability in the scenario defined as "most probable", for the four types of projects. Figure 3-2 shows that the estimations are carried out in such a way that over time (2028 in this case), the four types of projects have a high probability of materialization (over 0.9). It can also be seen that projects defined as those to be hard to materialize (such as potential) start in year 1 with very low probability of occurrence, which increases over the years.

Figure 3-2: Occurrence probability according "most probable" scenario"



Source: Cochilco 2017

In the case of the maximum scenario, the most optimistic situation is considered, which would be that all projects have probability 1 of occurrence at the end of the time horizon. On the other hand, the minimum scenario is a more pessimistic one where occurrence probabilities remain low over the years. For more details on the probability matrix and to know the maximum and minimum values see Annex 1: Probability matri

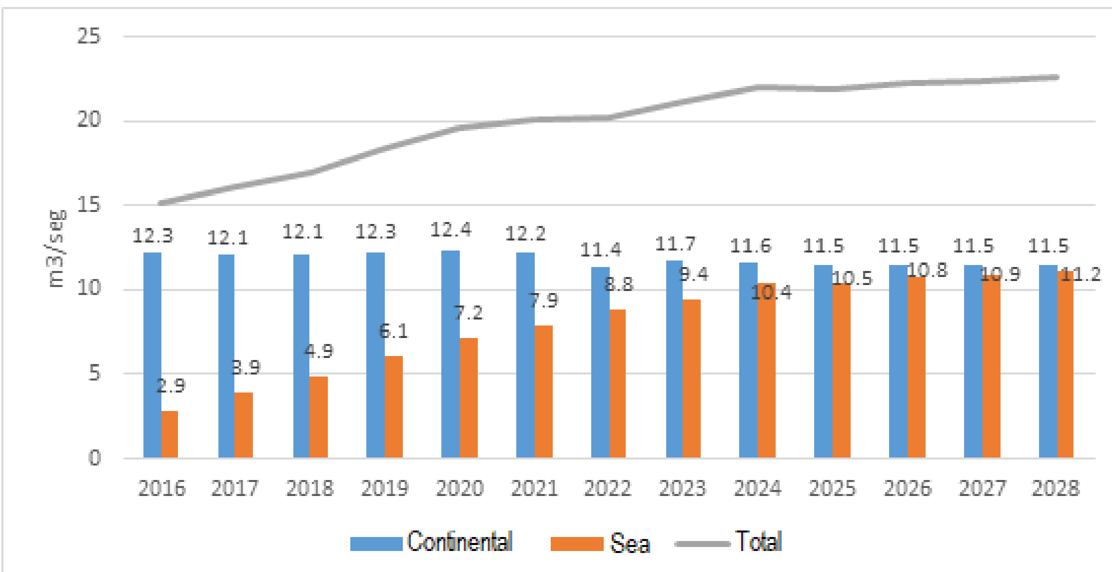
The stage 4 results are described here below. They correspond to water consumption forecasts from different points of view. It is worth noting that the following results show real data from 2016 and the projections for the 2017-2028 period.

3.2 Water consumption forecast according to source

Water sources can be two, fresh water, which encompasses surface, underground water and also water purchased from third parties, or seawater, which includes desalted and salt water. Forecasts according to source can be seen in Figure 3-3. This figure also shows that the use of seawater is expected to have a significant increase (around 289.9%), while the use of fresh water presents a small reduction (of 6.3%) in the 2016-2028 period. The total water consumption experiences a 49.7% rise in the same period.

The growth in seawater consumption is explained by a series of desalinization plants that are planned to be built. Among them, the following plants stand out: BHP, Escondida Water Supply and Spence Growth Project for 2017 and 2019, respectively, as well as North Codelco, North District, for 2021 and Teck, Quebrada Blanca phase 2 for 2021.

Figure 3-3: Water consumption forecast according to source 2016-2028



Source: Cochilco, 2017

From the previous figure it is important to highlight the stability of fresh water consumption until 2022, where the Chuquicamata pit stops operations and Chiquicamata underground will be commissioned, which includes the use of seawater. In addition, that same year RT Sulfide Phase I will stop its operation, in order to begin Phase II of RT sulfide, which also contemplates the use of seawater.

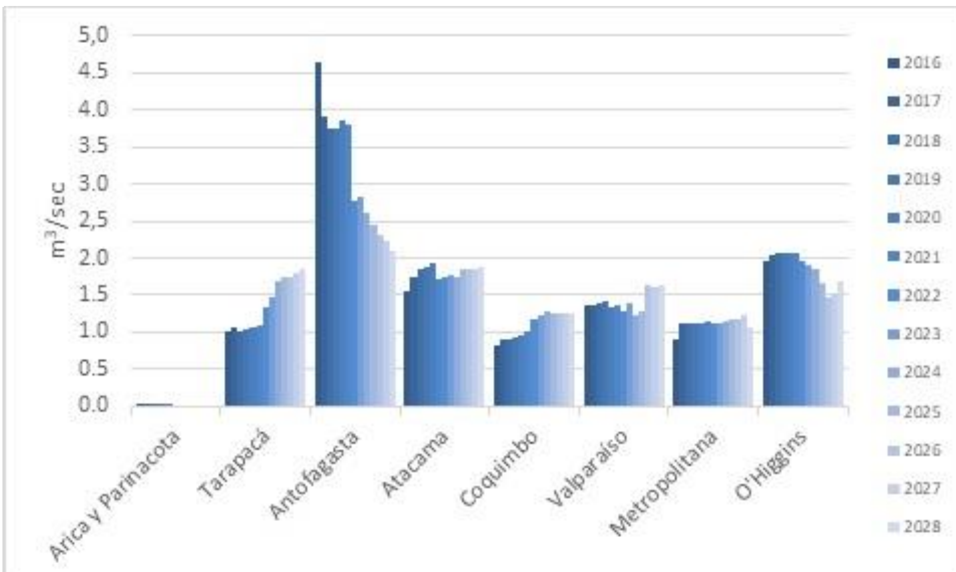
3.3 Water consumption forecast per region

At a regional level, there are great differences in terms of the water consumption forecast. While some regions have upward trends in fresh water consumption (such as Tarapacá, Coquimbo and Valparaíso), others have a downward trend in water from this source and an increase in seawater consumption, such as the case of Antofagasta.

3.3.1 Fresh water per region

The following figure indicates a strong reduction in fresh water consumption by Antofagasta from 2016 (real data) to 2017, which can be explained by the commissioning of the Escondida desalinization plant. However, this decrease can be overestimated due to the fact that the strike and halt in activities that Escondida suffered at the beginning of 2017 were not considered. Then, it is possible to see a significant drop from 2021 to 2022, which is due to the end of activities of Chuquicamata pit. Chuquicamata underground begins activities gradually in 2020, which is why one consumption type does not replace the other. Also, this forecasts an improvement in the efficiencies of the use of water in processes and the use of seawater. The total decrease from 2016 to 2028 is expected to be 55%.

Figure 3-4: Fresh water consumption per region 2016-2028



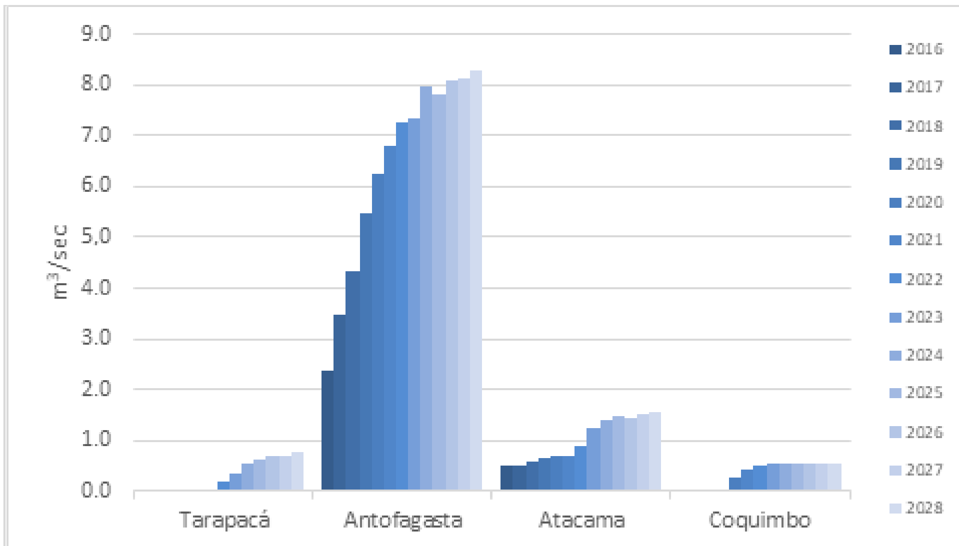
Source: Cochilco, 2017

As for other regions, it is possible to see that both Tarapacá and Coquimbo have an upward trend in fresh water consumption. Tarapacá has the commissioning of the Quebrada Blanca Hipógeno project for 2022, while Coquimbo has the start of the expansion of Los Pelambres same year, both sites will use both fresh and seawater. We see in the case of Valparaíso, it is expected to show an increase in 2026, which is explained by the expansion of Andina projected for that year. Regarding the O'Higgins region, it reflects a downward trend, explained by higher efficiencies in the use of water of the New Level Mine project of El Teniente and the end of the old operation, in addition to the fact that New Level Mine does not reach the productions calculated in previous years.

3.3.2 Seawater per region

The following figure shows that the rise in the use of seawater is mainly explained by initiatives in the Antofagasta region, especially between 2017 and 2024. In that period the commissioning or expansion of several desalting plants, such as BHP Escondida and Spence, North District of Codelco, Sentinel plant to supply water to the Sentinel District of Antofagasta Minerals, and the extraction of seawater for the possible expansion of Sierra Gorda of KGHM took place. Between 2016 and 2028 a 248% growth in the use of seawater in this region is expected, with an annual average of 11.7%.

Figure 3-5: Seawater consumption per region 2016-2028



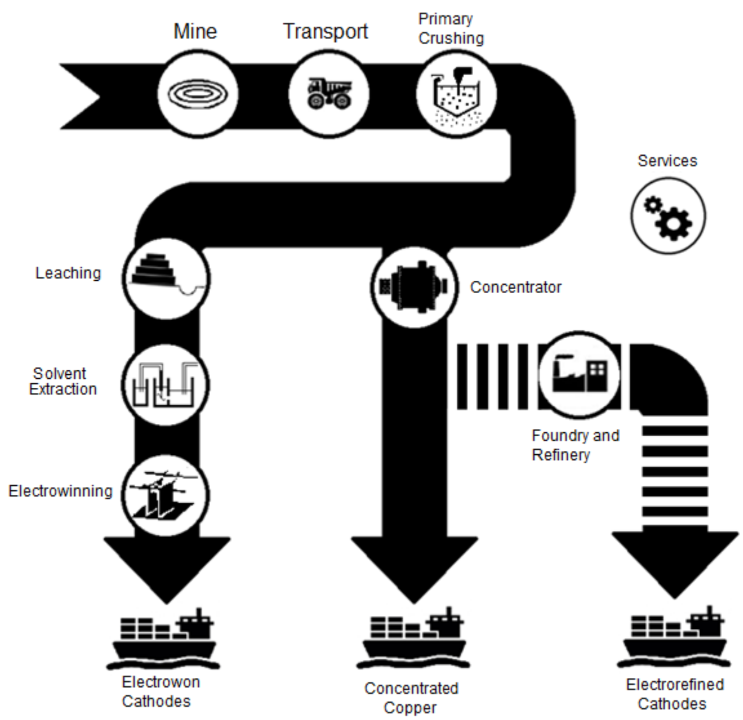
Source: Cochilco, 2017

The Tarapacá, Atacama and Coquimbo region will also use seawater, but in a smaller proportion. Important projects that include the use of seawater in this region would be Nueva Unión and Santo Domingo projects. The other regions, however, do not have plans to use seawater in the period of study.

3.4 Water consumption forecast according to type of process

The use of water in the mining process is described briefly in the following figure. Nevertheless, the division of processes was carried out in three large groups depending on the ore to be processed. These are uses of water in mine and processes, among others. For the case of copper oxide, in hydrometallurgy, the point “process” refers to leaching, extraction by solvent and electro-extraction (LIX-SX-EW). Meanwhile, for the processing of sulfide, the process refers to the floating and concentration process. The item “others” in both cases refers to services, human consumption, etc. As for refinery foundry, the use of water is divided into foundry, refinery, etc. In summary, there are three independent activities with three processes each: (1) SX-EW cathode production, (2) Concentrated production, both with use of water in mine, in processes and others; and (3) Cathode production in foundry-refinery (FuRe), with water consumption in foundry, refinery and others. Now well, there are certain facilities that extract oxides and sulfides from the mine, where water used for it is not differentiated. In cases where mine water was only counted in the concentrated production activities (since in proportion concentrated production is higher), therefore, the total mine water in the SX-EW cathode production, is underestimated, contrary to the total mine water used in the two activities.

Figure 3-6: General diagram of copper mining processes



Source: Cochilco, 2017

In the case of the mine area, this includes the mine, whether open pit or underground and the transport of the material until the primary crushing. In this area, the water is mainly used for the removal of dust in roads, and the extraction and pumping from underground tasks.

The area of the concentrating plant includes the processing of ore. This area involves the comminution of the ore, then floating, classification and thickening processes. According to the distance between the concentrating plant and the facilities for filtering and storage, waste water can or cannot be re-circulated to the process. An important part of the water used in floating becomes part of the tailings, which are shipped to the thickening stage to recover a part of the water they contain.

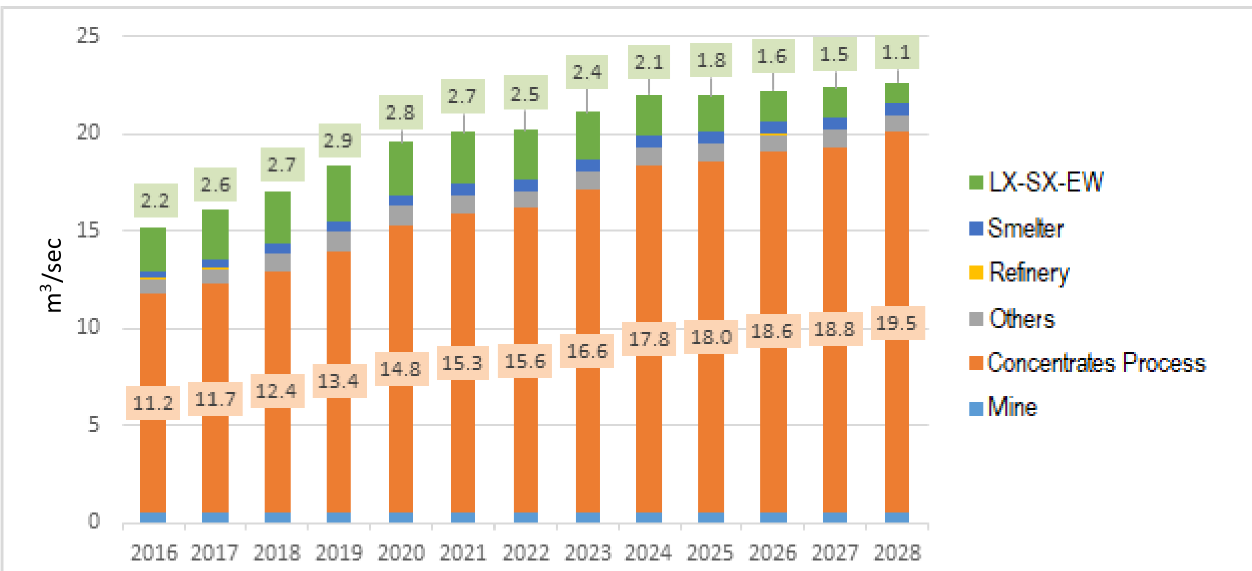
In the hydrometallurgical plant, the main water consumptions are the result of the evaporation of the leaching piles where an acid solution (water with sulfuric acid) is poured on the surface of the piles. This solution is planted in the pile, dissolving the copper contained in the oxidized ores.

In fourth place is foundry and refinery. The dry concentrate undergoes a pyro-metallurgical process, in order to obtain thick plates, in the form of anodes. This is commercialized directly or sent to the refining process, which is carried out in the electrolytic cells in a sulfuric-acid solution. An electric current is applied, which solves the copper of the anode and to deposit in the initial cathode, reaching high purity cathodes.

Finally, the area of others or services, includes those activities with insignificant water consumption volumes in comparison to the total consumed in a mining operation. The main use of water is for drinking, cooking, washing, irrigation and restrooms in camps, molybdenum plants in operations they may carry out and other minor consumptions.

The following graph shows the total water consumption per process. As expected, the water consumption per concentrates process increases, while the water consumption per hydrometallurgical process (LxSxEw) decreases.

Figure 3-7: Total water consumption per process 2016-2028



Source: Cochilco, 2017

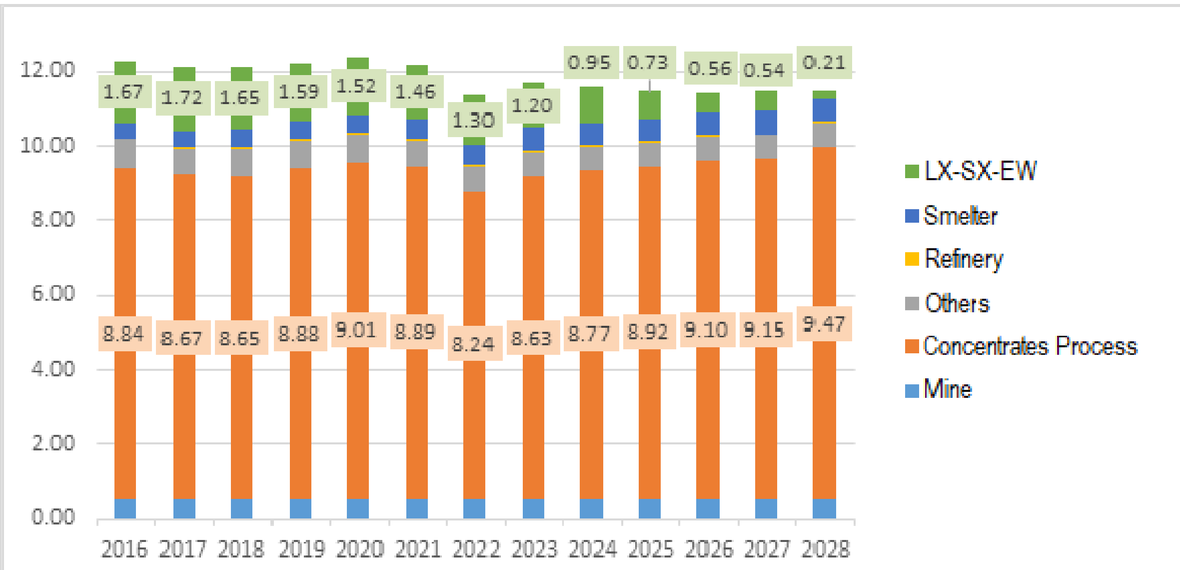
The water consumption per concentrating plant experiences a 74.7% growth from 2016 to 2028, while in the same period, the consumption by SxEw goes down by 51.7%. The use of water in mining is reduced by 3.5%. In foundry, it increases by 56.4%, in refinery 7.4%, and in other processes by 9.8%.

The concentration process is the one using the most water, with a 78.3% average in the period of study, which goes from 74% in 2016 to 86.3% to 2028. Nonetheless, the LxSxEw process uses 11.5% of total water in the period of study, which varies from 14.4% in 2016 until its reduction to 4.6% in 2028.

3.4.1 Consumption of Fresh Water Based on Process Type

In regards to consumption of freshwater, the process that leads the consumption is concentration, which consumes 75% of fresh water on average during the study period, starting with 72% in 2016 and increasing by 82.2% in 2028. In second place it is the LxSxEw process with 9.7% on average in the study period, starting with 13.6% in 2016 and ending with 1.9% in 2028, which is mainly explained by the reduction of oxide extraction in Chile over the following years. Figure 3-8 shows the absolute flows calculated per process until 2028.

Figure 3-8: fresh consumption per process 2016-2028



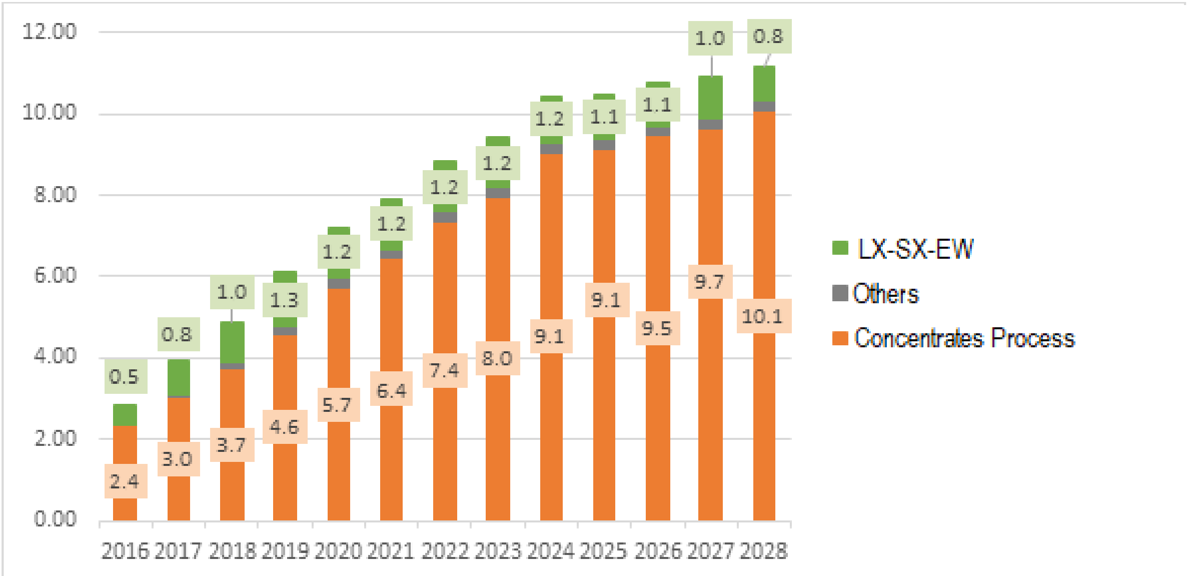
Source. Cochilco, 2017

In respect to the other processes represented, currently, 14.4% of fresh water use, reaching 15.7% in 2028. In the period from 2016 to 2028, the refinery and other processes (services) have an increase of 7.1 and 7.4%, respectively, while water used in mines will decrease by 3.5%. The foundry process, on the other hand, will increase its water usage by 56% during this period, which is mainly explained by the new Paipote plant that is being planned and should start its operations in 2021.

3.4.2 Seawater Use Based on the Process Type

The use of seawater forecasted for the following ten years is mainly to supply the concentration process. In 2016, of the 2.86 m^3/s of seawater used in mining, 82.1% was for the concentration process. The total amount of seawater consumed in 2028 would rise to 11.16 m3/s, of which 90% would be for the concentration process. That is to say, the use of seawater for concentration would increase by 328.8% over the next 10 years. The rest of the processes that use seawater are hydrometallurgy, with an average of 14.5% of seawater consumption in the forecasted period, and other processes (or services) with an average use of 2.4% in the forecasted period.

Figura 3-9: Seawater Consumption per 2016-2028 Process



Source: Cochilco, 2017

As seen in previous sections, in 2028 seawater will represent approximately half of the water consumed in mining in that same year. It is worth mentioning that today mining recirculates a high percentage of water (above 70%) due to the scarcity in the north of the country. This causes positive externalities because the tailings that are discarded have lower content humidity content, which makes the volumes lower and more stable. Because seawater is an abundant resource, it is necessary for it be adequately managed to not decrease the level in recirculation by current processes, because in and of itself, although using seawater solves the problem with the amounts of water, it does not solve problems related to the deterioration of water quality.

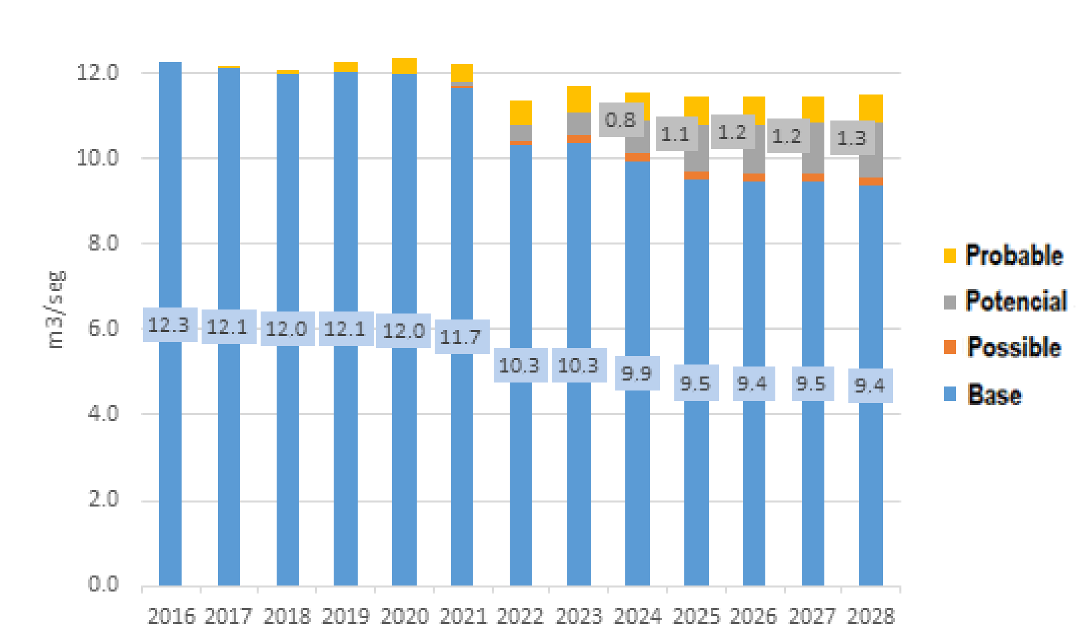
3.5 Water Consumption Based on the Projects Status

In regards with production calculation, four statuses are defined: base, probable, possible, and potential, associated with specific attributes of project types, the progress stage it is in, the stage of processing in the Environmental Impact Evaluation System (SEIA, by its Spanish initials) and the estimated date of implementation. When each one of these attributes is combined, the status of each project can be determined, which indicates its feasibility.

3.5.1 Consumption of Fresh Water Based on the Condition of the Projects

The distribution of the projects, based on their status, regarding the use of fresh water, tends to be marked by projects in base status, which is to say, the ones that are operative. They transit from being 100% in 2016 to 81.4% in 2028. The projects in potential status also have an important percentage of fresh water use starting in 2022. Among these projects, the ones that stand out are Rajo Inca of Codelco, Quebrada Blanca Hipógenos of Teck, and Expansión Andina of Codelco. All of them are in the pre-feasibility stage and have not yet been presented to the Environmental Impact Evaluation System.

Figure 3-10: Water Consumption per Project Status 2016-2028



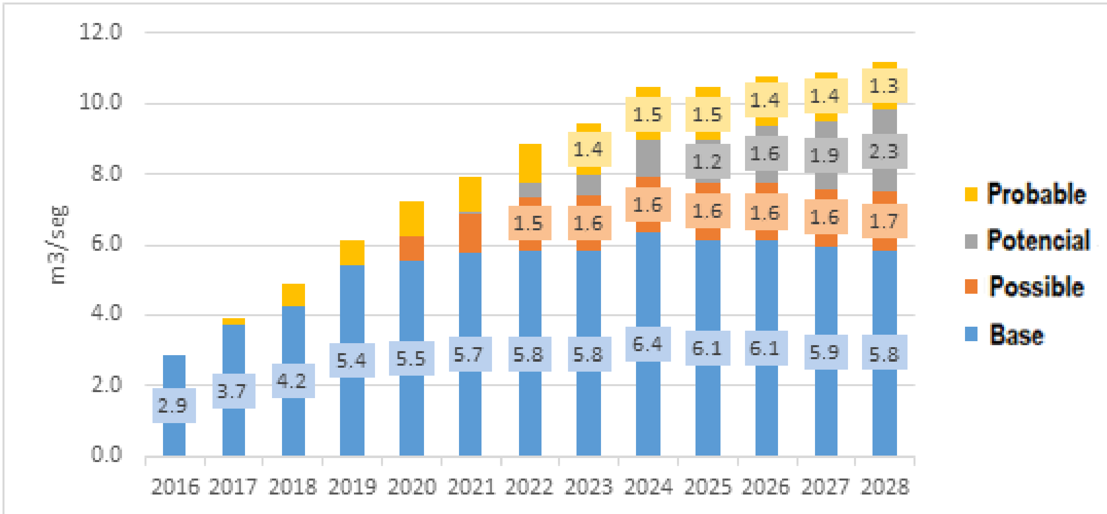
Source: Cochilco, 2017

The probable projects (that have the second highest probability to materialize after the base projects) are, generally, expansion projects.

3.5.2 Seawater Consumption Based on the Condition of the Projects

The projection of seawater tends to be more homogeneous in time with regard to the different project conditions. In 2016, as expected, 100% of the use of seawater belongs to base projects. It is estimated that in 2028 the projects in this status will only represent 52.4%, while in this year the possible, potential and probable projects are predicted to reach 14.9%, 20.6%, and 12%, respectively. This clearly proves that half of the projects that are forecasted to consume seawater in 2028 might not materialize.

Figura 3-11: Consumo de agua de mar por condición de proyecto 2016-2028



Source: Cochilco, 2017

3.6 Consumption of Water Based on Based on Development Stage

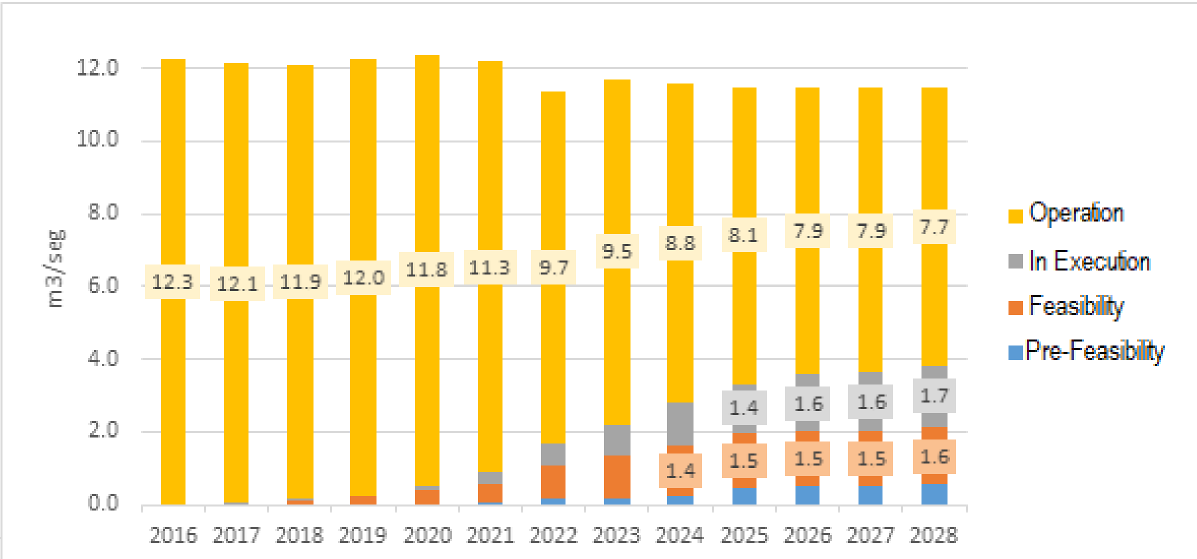
In order to analyze the forecasted demand of freshwater in copper mining Based on based on the state of progress of the projects in the investment cadaster, four development stages were defined; pre-feasibility, feasibility, in execution, and in operation. The progress of a project can be affected by any type of suspension, whether due to situations internal or external to the desires of the company. When the project is suspended, the project stops its progress and in some cases it must return to its previous state to re-do studies and thus resolve the difficulties that can arise internally or externally.

Pre-feasibility corresponds to the stage of generation and selection of project alternatives, also known as conceptual engineering. The feasibility corresponds to the stage of development of the alternative selected or basic engineering. The projects in execution are those that are under construction, assembly, and implementation of the new asset, where there is an intention to capture the promised offer privileging the aspects term, cost, quality, and sustainability. Finally, the operations are those that are currently in production.

3.6.1 Fresh Water Consumption Based on Based on Development Stage

In regards to the fresh water used in projects in operation, it is estimated that over the next 10 years it will diminish by 37.5%, reaching 100% in 2016 and 66.7% in 2028. This is mainly due to the closing of Chuquicamata Rajo and Salvador, which will be replaced by new projects. On their part, the projects that are currently in execution stage will represent 14.7% of consumption, and the feasibility projects, 13.7% of consumption. Meanwhile, the projects in pre-feasibility status will only use 4.9% of the fresh water in 2028.

Figure 3-12: 1.1.1 Fresh Water Consumption Based on Development Stage 2016-2028

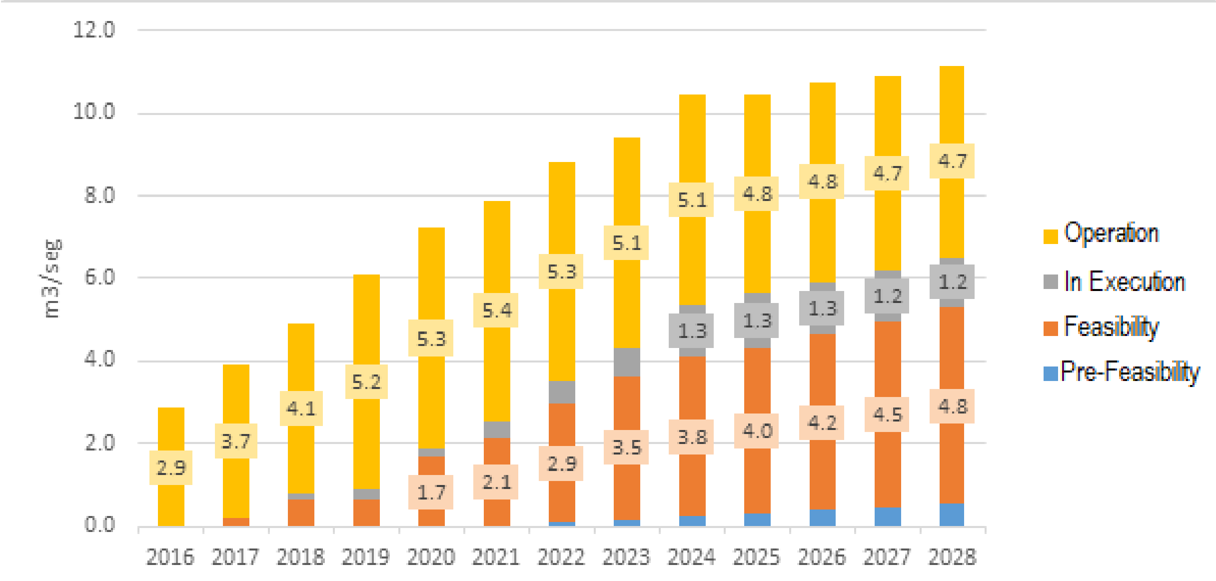


Source: Cochilco, 2017

3.6.2 Water Consumption Based on the Stage of Development

In regards to seawater, the projects in operation will increase their consumption from this source by 63.4%. On the other hand, water consumption predicted for 2028 is 42.8% explained by projects in feasibility, 10.5% by projects in execution, 4.8% by projects in pre-feasibility, and 41.9% by projects in operation.

Figura 3-13: SeaWater Consumption Based on Development Stage 2016-2028



Source: Cochilco, 2017

3.7 Consumption of Water Based on Based on the State of Environmental Permits

All the projects must contain a favorable Environmental Qualification Resolution (RCA, by its Spanish initials) to operate, which is obtained after undergoing the Environmental Impact Evaluation System (SEIA, by its Spanish initials), Based on that established in Law 19300 of General Environmental Principles. This process ensures that the project complies with current environmental norms, as well as having a correct and social environmental management, which proposes prevention, mitigation, and/or compensation measures, as appropriate, because of the impacts associated with production activities. The environmental evaluation can be carried out by an Environmental Impact Study (EIA, by its Spanish initials) or an Environmental Impact Declaration (DIA, by its Spanish initials), depending on the magnitude and nature of impacts associated to it. Due to the above, three states from highest to lowest certainty of materialization.

- EIA or DIA approved
- EIA or DIA presented (in evaluation process).
- Without EIA or DIA presented

Meanwhile, there are also projects that these categories do not apply to (identified by N/A) because its construction was prior to Law 19300 entering into force, which is why they did not have to undergo the environmental impact evaluation in their time, or rather, the project represents only minor changes to the operation, which are not relevant for SEIA.

It should be noted that having the environmental approval of a project does not guarantee its materialization because it must always be accompanied by a "social license," which is not a legal permit, but a fictional permit that is "granted" by the community if it is satisfied and in agreement with the projects. Said license is dynamic and impermanent, which is why the owner of the project must work to obtain and preserve it.

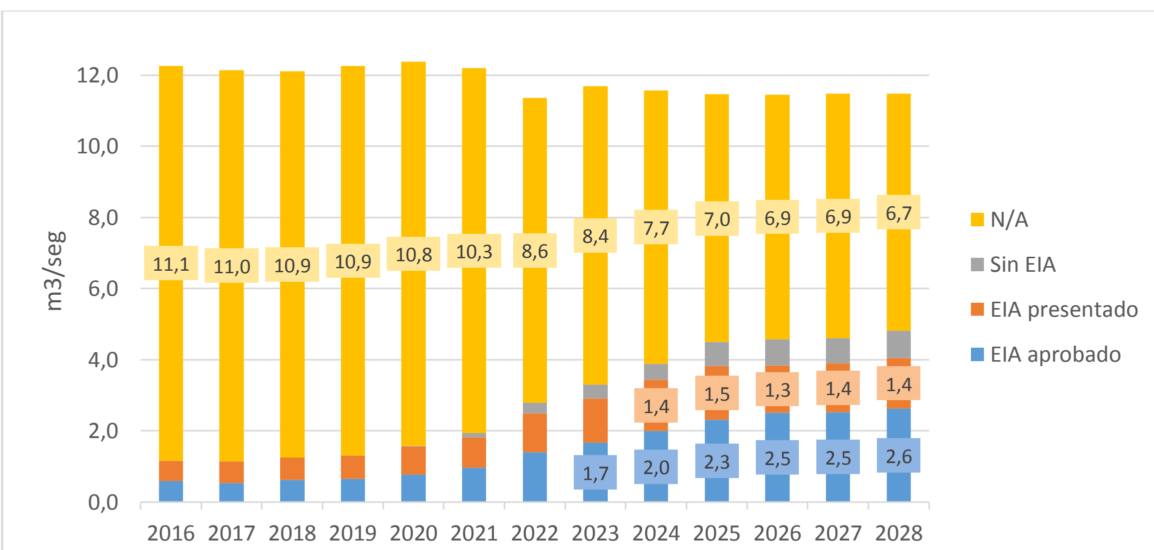
Statistically, close to 50% of the mining projects presented are approved, and it takes on average between for them to obtain a favorable RCA. However, only 2% of projects are rejected, and the remaining percentage are projects that were not admitted for processing, under evaluation, or withdrawn (Cochilco 2017).

3.7.1 Consumption of Fresh Water Based on Based on the State of Environmental Permits

The projects that are in the category “N/A,” mostly projects that started operating before Law 19.300 entered into force, represent the majority of water consumption in 2016. However, if some of those projects desires to undergo modification of a certain magnitude in an upwards sense, it must undergo SEIA and obtain an approved RCA. The same goes for new projects. This is why the projects in the N/A category are expected to decrease over time, and therefore their water consumption will also diminish. If the year represented 90.5% of water consumption, by the year 2028 it is expected that it will represent only 58.1%. That same year, it is expected that the projects that now have an approved EIA represent 22.8% of the consumption of fresh water, while those with EIA and without EIA represent 12.5 and 6.6%, respectively.

Figure 3-14 shows the projection of water consumption in each of the categories defined based on their state of environmental permits.

Figure 3-14: Consumption of Fresh Water Based on Based on the State of Environmental Permits 2016-2028



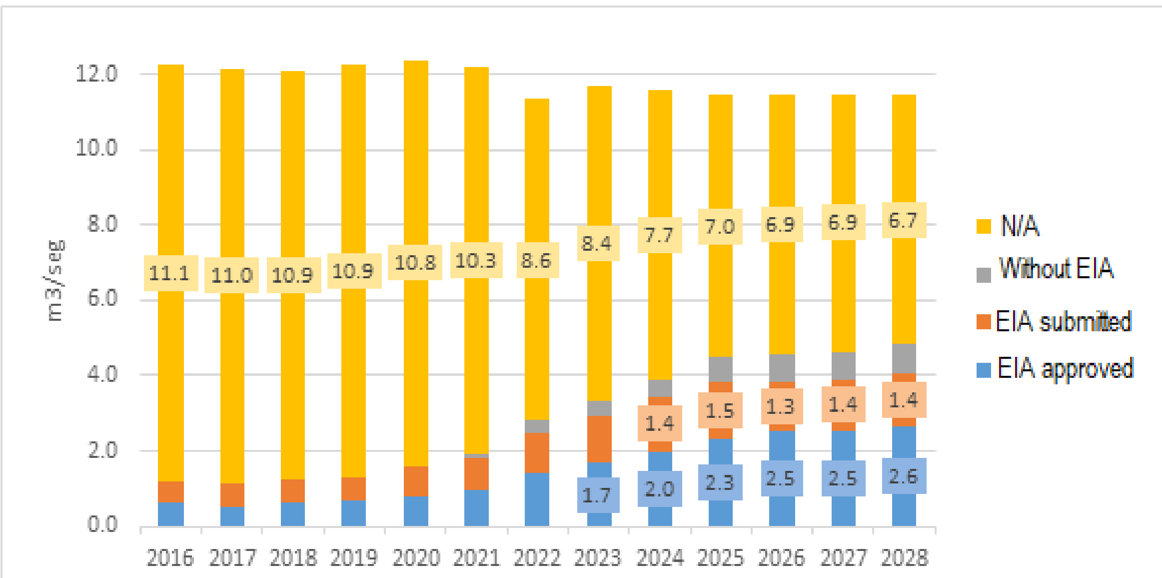
Source: Cochilco, 2017

3.7.2 Consumption of Seawater Based on Based on the State of Environmental Permits

In contrast to fresh water, in 2016, the number of projects in the N/A/ category and with EIA approved is grater because the popularization of industrial-scale desalting plants is relatively new. Although they are not defined in Law 19300, the submarine outlets are part of it, which is why they must undergo an environmental evaluation. In 2016, the N/A category represented 62% of consumption, and the remaining 38% being projects with approved EIA. In 2028, the distribution between the four categories is expected to be much more homogeneous, with 24.9% of the consumption to be by projects in the N/A category, 36.2% of the consumption by projects with approved EIA, 26.6% by projects that have presented EIA, and 12.3% by those that have not yet presented EIA or DIA.

The Figure 3-15 below shows the estimation of seawater consumption Based on Based on the State of the environmental permits of the projects.

Figure 3-15: 1.1.1 Consumption of Seawater Based on Based on Based on the State of Environmental Permits



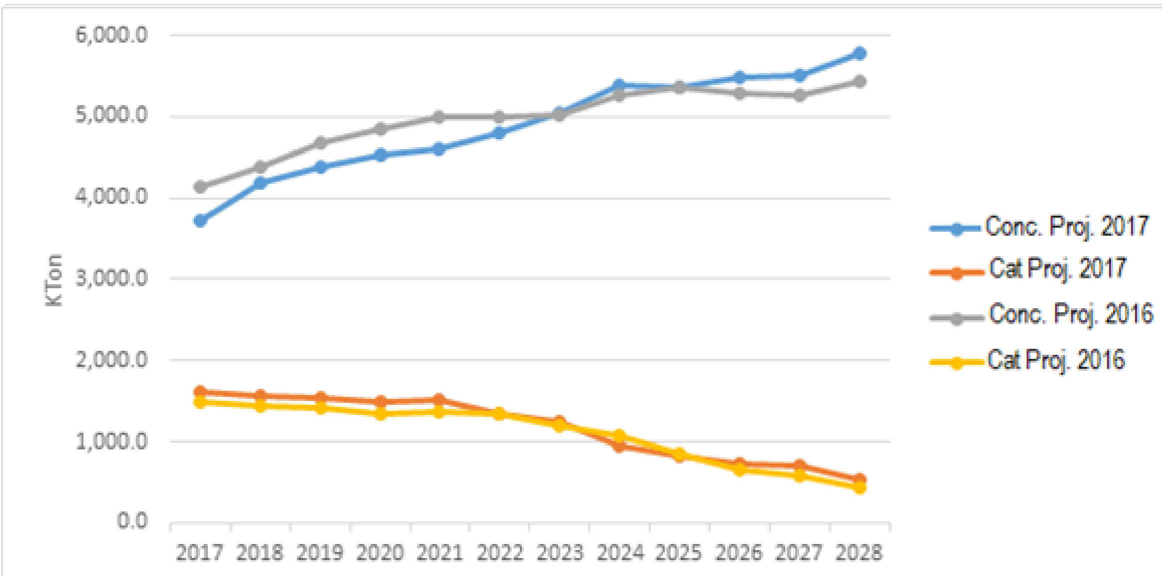
Source: Cochilco, 2017

4 Analysis of the Results

The projection of water consumption in Chilean copper mining is a task that is performed annually, and in order to have a continuous improvement process, it is fundamental to compare the results of previous forecasts with current projections and data, so as to understand the differences, why these exist, and which variables that determine these differences can be controlled and which cannot.

In the first place, we can observe that there are differences in regards to the projection of the production in the year 2016, which are mainly due to delays in initiatives, operational projects and strikes in active operations, reformulation of Codelco projects, entry of new concentrate projects (such as the Sierra Gorda, Desembotellamiento Mantos Blancos, Optimización Collahuasi, El Abra Mill Project, and Nueva Unión project expansion), and some operational continuities (Andacollo lix. Ripios, Radomiro Tomic, and Chuquicamanta), and the closing of hydrometallurgical operations (Cerro Dominador and other medium-sized operations). Figure 4-1 shows the differences between the production projection of last year (2016) and this year (2017) both for concentrators and SxEw cathodes, together with the percentage difference each year.

Figure 4-1: Difference between the production projection between 2016 and 2017



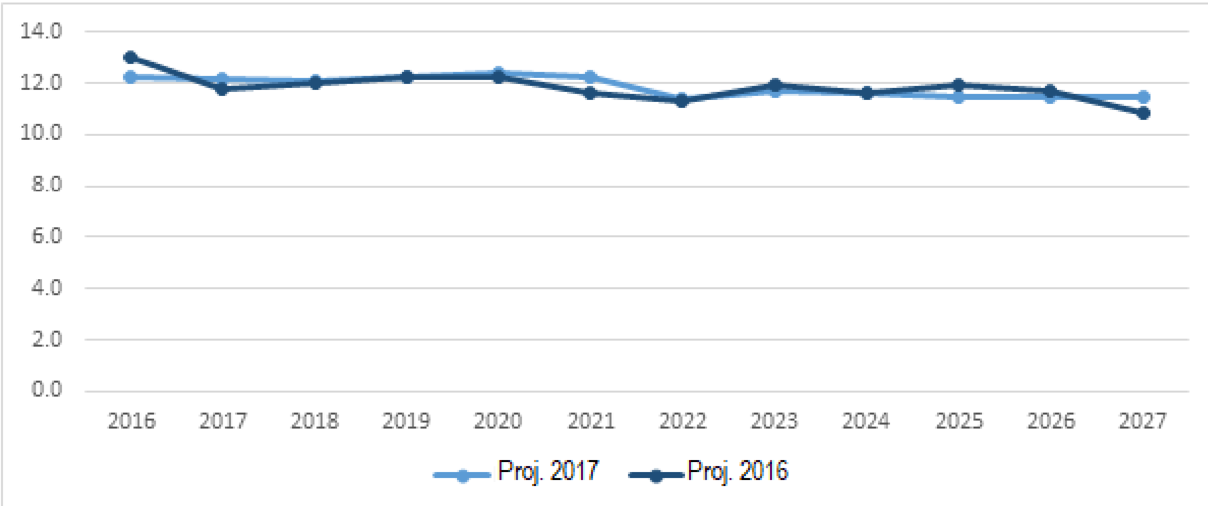
Differences	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Concent.	-10.5%	-4.5%	-6.1%	-6.7%	-7.7%	-3.6%	0.5%	2.0%	0.1%	3.9%	4.3%	6.2%
SxEw Cath.	8.6%	7.8%	9.3%	9.8%	10.5%	0.0%	5.6%	-11.6%	-2.6%	14.6%	19.4%	24.6%

Source: Cochilco, 2017

Then, the unit coefficients of each operation regarding fresh and seawater consumption for the different process also vary in relation to the projection of 2016 because the efficiency changes every year. For example, from 2015 to 2016 decreased by 4.6% in concentration and an increase by 30.9% in hydrometallurgy (COCHILCO 2017).

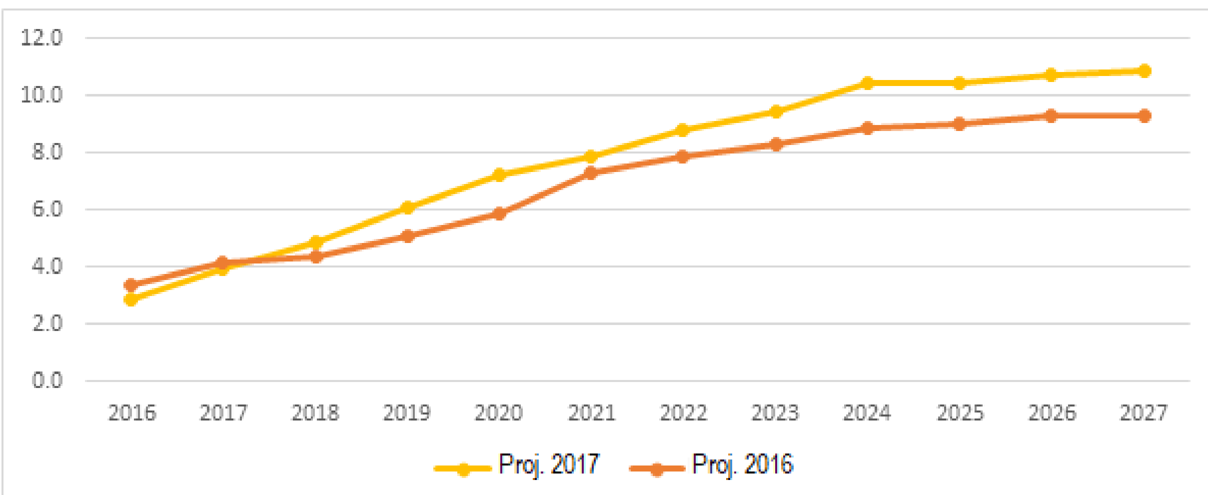
In regards to the projection of water consumption, there are also differences regarding the estimation performed in 2016. In comparison to the projection of last year, differences are observed in the consumption of both fresh and seawater. These are due to both the variations in the projection of copper production explained above, and new desalting plants that will be built and that were not considered in last year's projection, and also a difference in unit consumption of water that is used in this year's projection. In general, the error of the projection of fresh water tends to be lower than that projected in 2016, while the error in seawater consumption tends to be greater (2.58% vs. 14.57% of error). See Figure 4-2 and Figure 4-3 below.

Figure 4-2: Fresh water 2016 and 2017 projection differences



Source: Cochilco, 2017

Figure 4-3: Seawater water 2016 and 2017 projection differences



Source: Cochilco, 2017

5 Final Comments

One of the main results of the projection is the strong increase in use of seawater in mining industry processes, especially for concentration processes. In 2028, the use of seawater will increase 289.9% while in case of fresh water decreases by 6.3%. It can be observed that most of the water from this source will be consumed in the Antofagasta region, which will drastically reduce its fresh water consumption (by 55% percent). Considering that in the year 2016, Antofagasta was the region that consumed the freshest water (in absolute terms, not weighted), this reduction will certainly mark a difference in the region, which would stop consuming 2.56 m^3/sec.

In general terms, the concentration process is the one that would increase the most its total water consumption (fresh and seawater), and does so by 74.7% in the 2016 to 2028 period. In the same period, the hydrometallurgical process will reduce its total water consumption by 51.7%.

The latter is, definitely, of great help for the availability of water for other uses (amount of water). However, the use of seawater does not resolve the problem of the quality of water for mining, which, after being used becomes loaded with metal, reagents of the concentration, acids, and other chemicals. We reaffirm that the level of recirculation in Chilean mining is high, and to avoid a surge in problems because of water quality, this recirculation rate must be maintained or risen.

Although the use of seawater appears to be a strategic solution to water scarcity in the country, the potential impacts on the marine environment must also be considered. Thus it is essential to have an integral outlook which considers other sources of water recycling, such as the use of grey water or discarded water from waste water treatment plants, in addition to new techniques that reduce such potential impact.

Annexes

Annex 1: Probability matrix

Minimum Scenario		1	2	3	4	5	6	7	8	9	10	11	12	13	14
	#	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14
Potential	1	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Possible	2	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61
Probable	3	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Base	4	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84

More Probable		1	2	3	4	5	6	7	8	9	10	11	12	13	14
	#	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14
Potential	1	0.16	0.28	0.38	0.5	0.61	0.68	0.72	0.8	0.82	0.84	0.85	0.86	0.9	0.9
Possible	2	0.61	0.68	0.72	0.8	0.82	0.84	0.85	0.86	0.88	0.9	0.9	0.91	0.91	0.92
Probable	3	0.8	0.82	0.84	0.85	0.86	0.88	0.9	0.9	0.91	0.91	0.92	0.92	0.92	0.92
Base	4	0.84	0.85	0.86	0.88	0.9	0.9	0.91	0.91	0.92	0.92	0.92	0.92	0.92	0.92

Maximum Scenario		1	2	3	4	5	6	7	8	9	10	11	12	13	14
	#	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14
Potential	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Possible	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Probable	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Base	4	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Annex 2: Materialization conditions of a project

Condition	Type of project	Progress status	SEA proceeding	Implementation
BASE	Any	Execution	RCA approved or N/A due to having started construction before Law 19300 entered into force	Within the period
PROBABLE	Any	Suspended execution	RCA approved or in judicial claim	Within the period
	Any	Feasibility	RCA approved	Within the period
	Replacement or Expansion	Feasibility	EIA or DIA in process	Within the period
POSSIBLE	Replacement or Expansion	Feasibility suspended	EIA or DIA in process	Within the period
	Replacement or Expansion	Feasibility	EIA or DIA not presented	Within the period
	Nuevo	Feasibility	EIA or DIA in process or not presented	Within the period
	Any	Feasibility	RCA approved	Out of the period
	Replacement or Expansion	Feasibility	EIA o DIA in process or not presented	Out of the period
POTENTIAL	Any	Suspended feasibility	Any	Out of the period
	Any	Pre-feasibility	Any	Any

Source: Cochilco, 2017

Annex 3: Development stages of a project

- Operation: Projects that are currently operating
- In execution: They have been approved by investment and have the corresponding permits for their development. They are already in one of the detailed engineering and construction phases up to the initiation of activities.
- In feasibility study: Those that have already initiated their feasibility studies and environmental evaluation (EIA or DIA) until they are finished, but without having made the final investment decision.
- In pre-feasibility study: Those that are in the initial phase of the pre-feasibility study until the decision to continue to the next step is made.

Source: Cochilco, 2017

Annex 4: Table with expected consumption by region (m3/sec)

Continental Water													
Region / Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Arica y Parinacota	0.00	0.02	0.03	0.03	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tarapacá	1.02	1.06	1.02	1.03	1.07	1.11	1.34	1.48	1.69	1.75	1.76	1.80	1.85
Antofagasta	4.65	3.89	3.75	3.76	3.86	3.79	2.77	2.81	2.62	2.46	2.31	2.23	2.10
Atacama	1.54	1.73	1.84	1.89	1.92	1.71	1.73	1.77	1.73	1.84	1.86	1.85	1.87
Coquimbo	0.82	0.91	0.90	0.94	0.96	1.01	1.16	1.22	1.28	1.27	1.24	1.24	1.25
Valparaíso	1.37	1.35	1.39	1.41	1.34	1.36	1.27	1.38	1.24	1.30	1.63	1.60	1.64
Metropolitana	0.90	1.11	1.11	1.13	1.13	1.14	1.13	1.13	1.16	1.17	1.18	1.23	1.07
O'Higgins	1.96	2.04	2.06	2.07	2.06	2.06	1.96	1.90	1.86	1.67	1.47	1.53	1.70
Seawater													
Region / Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Arica y Parinacota	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tarapacá	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.34	0.55	0.62	0.68	0.71	0.76
Antofagasta	2.38	3.46	4.32	5.47	6.26	6.81	7.27	7.32	7.96	7.83	8.09	8.14	8.28
Atacama	0.49	0.48	0.56	0.64	0.68	0.68	0.87	1.23	1.41	1.48	1.45	1.50	1.57
Coquimbo	0.00	0.00	0.00	0.00	0.27	0.40	0.49	0.52	0.53	0.54	0.54	0.55	0.56
Valparaíso	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Metropolitana	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
O'Higgins	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Source: Cochilco, 2017

Annex 5: Table with expected consumption Based on type of process (m3/sec)

Agua continental													
Continental Water													
Process	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**
Mine	0.54	0.54	0.54	0.54	0.56	0.56	0.55	0.54	0.56	0.54	0.53	0.52	0.52
Concentrates Process	8.84	8.67	8.65	8.88	9.01	8.89	8.24	8.63	8.77	8.92	9.10	9.15	9.47
Others	0.80	0.75	0.75	0.73	0.73	0.71	0.66	0.67	0.65	0.63	0.63	0.62	0.64
Refinery	0.03	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Smelting	0.40	0.44	0.48	0.50	0.52	0.56	0.58	0.63	0.62	0.62	0.61	0.62	0.62
LX-SX-EW	1.67	1.72	1.65	1.59	1.52	1.46	1.30	1.20	0.95	0.73	0.56	0.54	0.21
Seawater													
Process	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**
Mine	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Concentrates Processing	2.35	3.03	3.72	4.56	5.74	6.44	7.36	7.95	9.05	9.13	9.47	9.65	10.08
Others	0.00	0.07	0.17	0.22	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24
Refinery	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Smelting	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LX-SX-EW	0.51	0.84	1.00	1.32	1.23	1.21	1.23	1.23	1.15	1.10	1.05	1.00	0.84

Annex 6: Table with expected consumption Based on conditions (m3/sec)

Continental Water													
Condition	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**
BASE	12.26	12.12	11.99	12.06	11.98	11.66	10.30	10.35	9.92	9.52	9.45	9.46	9.35
POSSIBLE	0.00	0.00	0.00	0.00	0.00	0.04	0.12	0.19	0.20	0.20	0.20	0.20	0.20
POTENTIAL	0.00	0.00	0.00	0.00	0.02	0.08	0.37	0.54	0.78	1.08	1.17	1.18	1.29
PROBABLE	0.00	0.02	0.11	0.20	0.37	0.43	0.57	0.62	0.67	0.67	0.64	0.64	0.65
Seawater													
Condition	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**
BASE	2.86	3.73	4.23	5.44	5.53	5.75	5.84	5.80	6.35	6.13	6.12	5.93	5.85
POSSIBLE	0.00	0.00	0.00	0.00	0.72	1.11	1.51	1.57	1.59	1.61	1.61	1.65	1.67
POTENTIAL	0.00	0.00	0.00	0.00	0.00	0.05	0.37	0.61	0.99	1.20	1.65	1.93	2.30
PROBABLE	0.00	0.21	0.66	0.66	0.96	0.98	1.11	1.45	1.51	1.52	1.38	1.39	1.34
PROBABLE	0.00	0.21	0.66	0.66	0.96	0.98	1.11	1.45	1.51	1.52	1.38	1.39	1.34

Source: Cochilco, 2017

Annex 7: Table with expected consumption Based on stage of development (m3/sec)

Continental Water													
Phase	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Pre-feasibility	0.00	0.00	0.00	0.00	0.02	0.08	0.18	0.20	0.25	0.48	0.53	0.50	0.56
Feasibility	0.00	0.02	0.11	0.20	0.37	0.47	0.88	1.15	1.41	1.47	1.47	1.52	1.57
In Execution	0.00	0.05	0.05	0.03	0.14	0.33	0.65	0.86	1.15	1.38	1.58	1.60	1.69
Operation	12.26	12.07	11.94	12.03	11.84	11.33	9.65	9.49	8.78	8.14	7.87	7.86	7.66
Seawater													
Phase	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Pre-feasibility	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.17	0.26	0.31	0.42	0.46	0.54
Feasibility	0.00	0.21	0.66	0.66	1.68	2.14	2.90	3.46	3.83	4.02	4.22	4.50	4.78
In Execution	0.00	0.00	0.12	0.24	0.23	0.38	0.52	0.66	1.27	1.32	1.28	1.22	1.17
Operation	2.86	3.73	4.11	5.20	5.30	5.37	5.32	5.14	5.08	4.81	4.84	4.72	4.68

Source: Cochilco, 2017

Annex 8: Table with expected consumption Based on the status of environmental permits (m3/sec)

Continental Water													
amb permission	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
EIA Approved	0.60	0.53	0.62	0.65	0.76	0.96	1.40	1.66	1.99	2.30	2.51	2.52	2.62
EIA Submitted	0.56	0.61	0.62	0.66	0.79	0.86	1.09	1.24	1.45	1.51	1.34	1.38	1.43
Without EIA	0.00	0.00	0.00	0.00	0.02	0.12	0.30	0.39	0.44	0.68	0.73	0.70	0.76
N/A	11.10	10.99	10.86	10.94	10.79	10.27	8.57	8.40	7.69	6.97	6.88	6.87	6.67
Seawater													
amb permission	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
EIA Approved	1.09	1.67	2.16	2.76	3.00	3.16	3.39	3.57	4.22	4.27	4.20	4.14	4.04
EIA Submitted	0.00	0.00	0.07	0.10	0.89	1.30	1.87	2.34	2.65	2.81	2.80	2.89	2.96
Without EIA	0.00	0.00	0.00	0.00	0.00	0.05	0.23	0.36	0.47	0.54	0.86	1.08	1.38
N/A	1.77	2.27	2.66	3.24	3.32	3.38	3.32	3.16	3.10	2.84	2.91	2.79	2.77

Source: Cochilco, 2017

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