



## Environmental solutions for Mining

### Stabilization of deleterious elements and circular economy

Carlos Rebolledo, Business & Developments Manager

April 2022

## Content

- **Copper. Growth & Demand**
- **Copper and Arsenic. Unique Challenges/Problems**
- **Copper and Arsenic. EcoMetales Unique Opportunities/Solutions**
- **Circular Economy and Applied Innovation to concrete problems**
  - **Our technology**
  - **Arsenic stabilization. Tailor-made developments**
  - **Tailings**
  - **Slag as raw material**
- **IP & Open Collaboration**

## Content

- **Copper. Growth & Demand**
- Copper and Arsenic. Unique Challenges/Problems
- Copper and Arsenic. EcoMetales Unique Opportunities/Solutions
- Circular Economy and Applied Innovation to concrete problems
  - Our technology
  - Arsenic stabilization. Tailor-made developments
  - Tailings
  - Slag as raw material
- IP & Open Collaboration

## Copper concentrate market

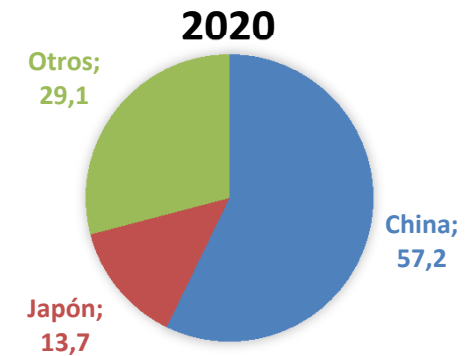
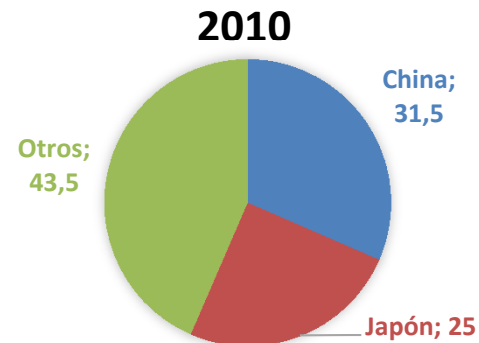
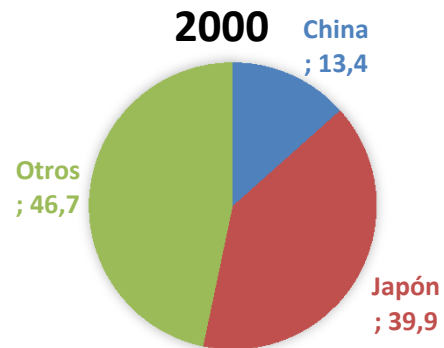
International trade of copper concentrates in

2000: 12 Mt fine Cu

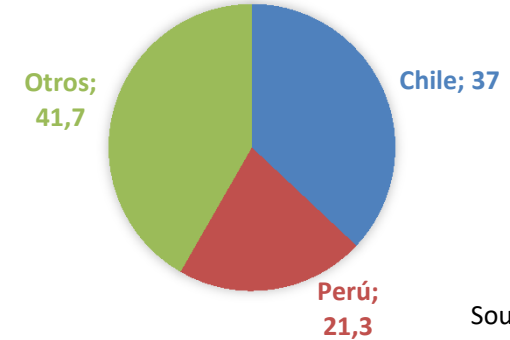
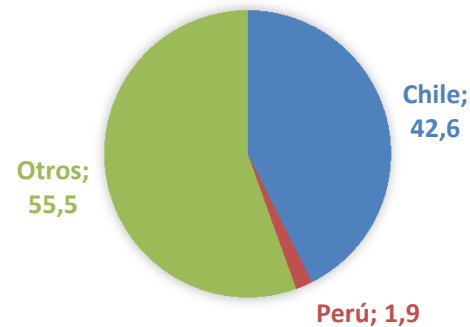
2010: 15 Mt fine Cu

2020: 18 Mt fine Cu

### IMPORTS



### PRODUCERS



Source: Cochilco, ICSG



# More copper will be needed in the future

## RUSSIA'S WAR ON UKRAINE

### The weapons and military aid the world is giving Ukraine

More than 25 countries have joined in delivering support to Ukraine's war effort. Here's what we know.



In this image provided by the U.S. Air Force, pallets of ammunition, weapons and other equipment bound for Ukraine are loaded on a plane at Dover Air Force Base, Del., on Jan. 30, 2022. | Senior Airman Stephani Barge/U.S. Air Force via AP

By JOSEPH GEDEON  
03/22/2022 02:54 PM EDT  
Updated: 03/28/2022 11:17 AM EDT

<https://www.politico.com/news/2022/03/22/ukraine-weapons-military-aid-00019104>



World Business Legal Markets Breakingviews Technology Investigations Sport

November 5, 2021  
7:03 AM GMT-3  
Last Updated 4 months ago

COP27

### Forget COP26. The world needs COPPER 26

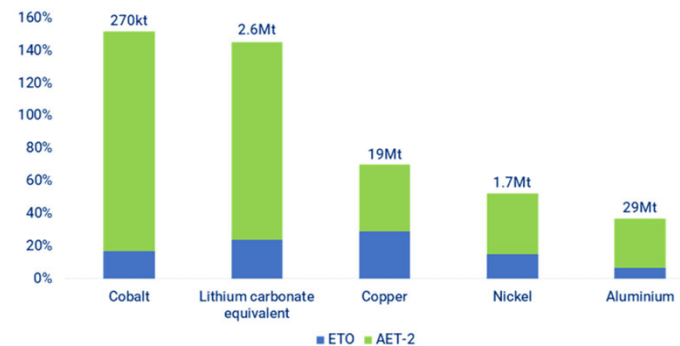
By George Hay

3 minute read



Consultant Wood Mackenzie has run the numbers. Limiting global warming to 2 degrees Celsius above preindustrial levels implies 19 million tonnes of additional annual copper production by 2030, a 60% increase. Aluminium supply needs to jump 30%, nickel 50%, and lithium and cobalt 140% and 150% respectively. Limiting warming to 1.5 degrees Celsius implies an even greater supply hike.

#### Required 2030 energy-transition metal supply under Wood Mac ETO and AET-2 scenarios

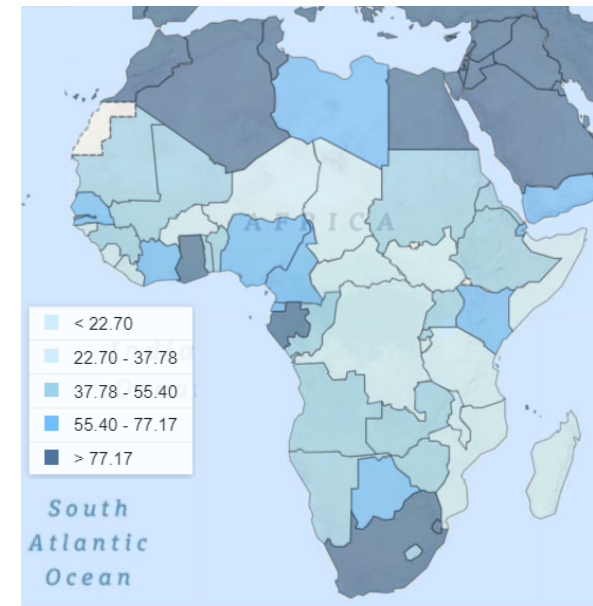


Source: Wood Mackenzie

CONFIDENTIAL

<https://www.reuters.com/business/cop/forget-cop26-world-needs-copper-26-2021-11-05/>

### Most subsaharan countries have below 50% electricity coverage

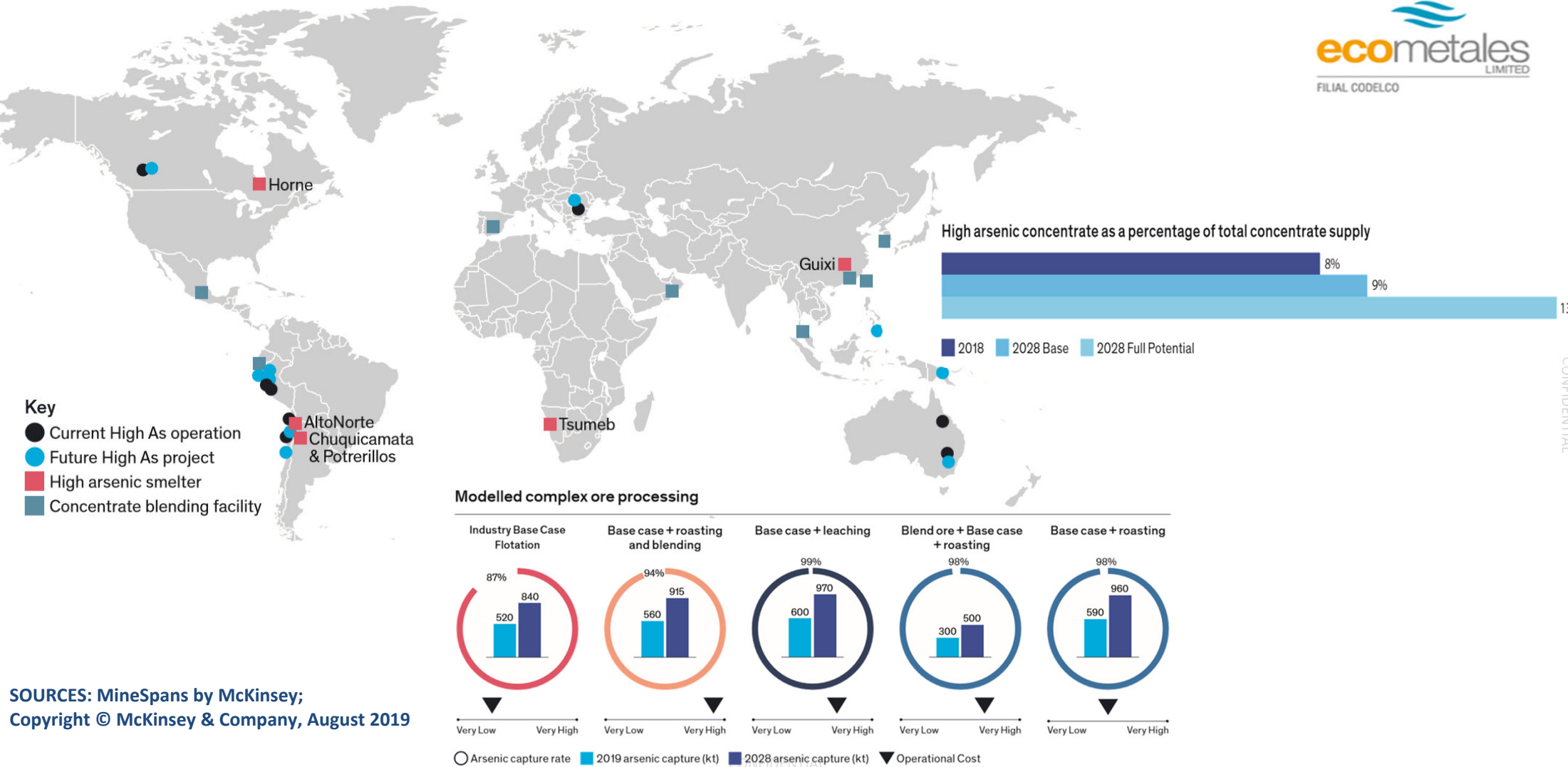


[https://data.worldbank.org/indicator/EG.ELC.AC.SS.ZS?end=2019&most\\_recent\\_value\\_desc=false&start=2019&type=shaded&view=map](https://data.worldbank.org/indicator/EG.ELC.AC.SS.ZS?end=2019&most_recent_value_desc=false&start=2019&type=shaded&view=map)

## Content

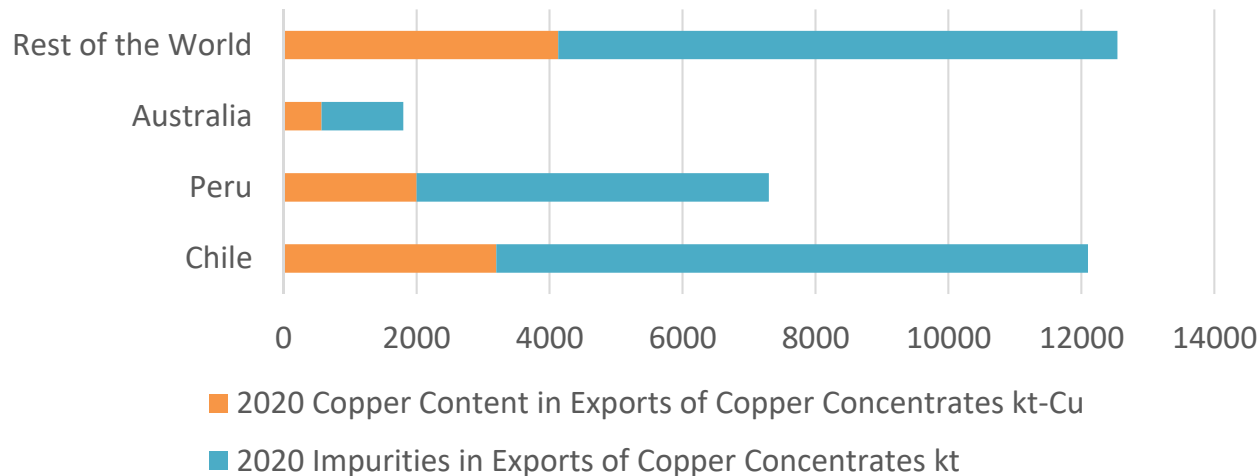
- Copper. Growth & Demand
- **Copper and Arsenic. Unique Challenges/Problems**
- Copper and Arsenic. EcoMetales Unique Opportunities/Solutions
- Circular Economy and Applied Innovation to concrete problems
  - Our technology
  - Arsenic stabilization . tailor-made developments
  - Tailings
  - Slag as raw material
- IP & Open Collaboration

# Arsenic mines, projects and complex concentrate treatment facilities



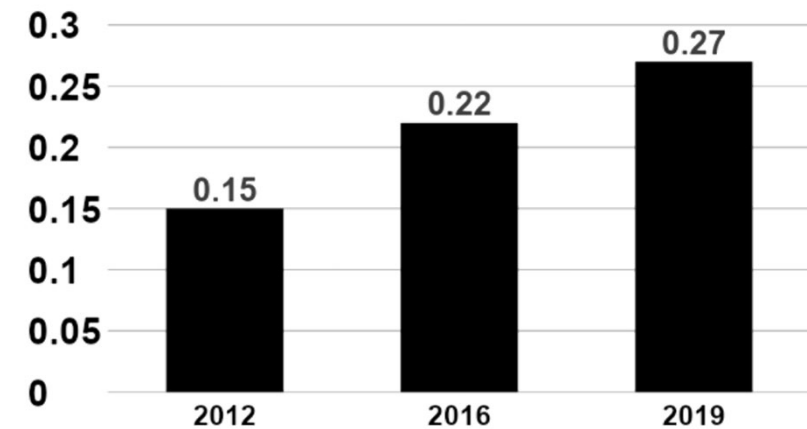
## COPPER CONCENTRATES EXPORTERS

Copper and No Copper Content in Main Exporters of Copper Concentrates: 2020 Estimate in Thousand Tonnes Gross Weight (kt)



Source: Arsenic in the Global Copper Value Chain: Trends in 2022 and Beyond. Risopatron, 2022

Increasing arsenic content in global output of copper concentrates:  
 source of environmental regulations and more careful industry monitoring, processing, extraction, stabilization and disposal.

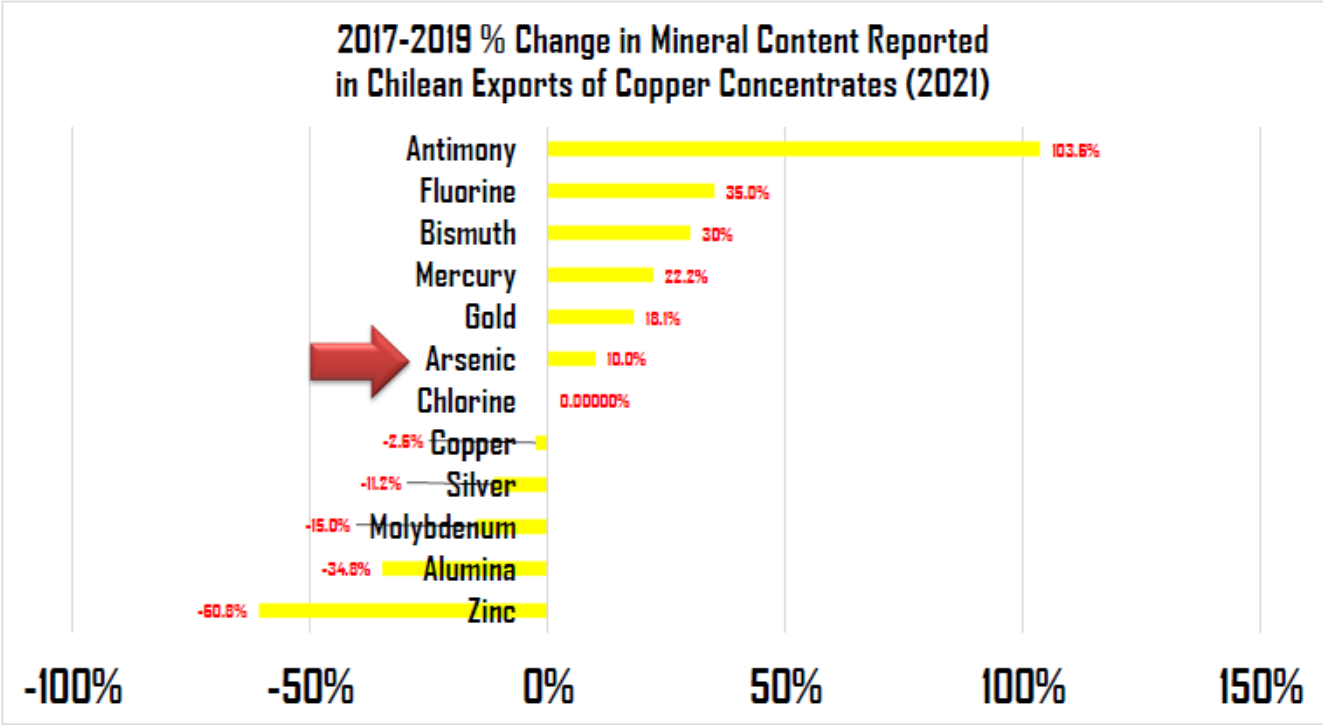


# As content is increasing in Cu concentrates

CONFIDENTIAL



The mineral composition of Chile exports of copper concentrates changed fast in 2017 – 2019 and will keep changing in the future.

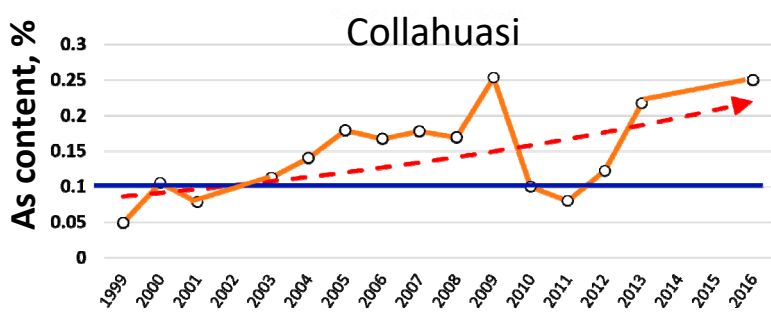
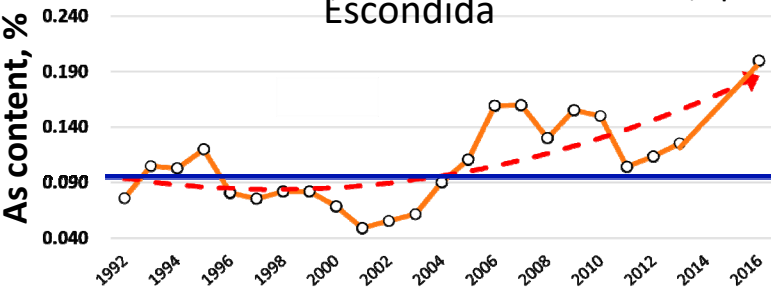


Source: ICSG based on COCHILCO analysis of Chile Customs Bureau Statistics (2021).

Source: Arsenic in the Global Copper Value Chain:Trends in 2022 and Beyond. Risopatron, 2022

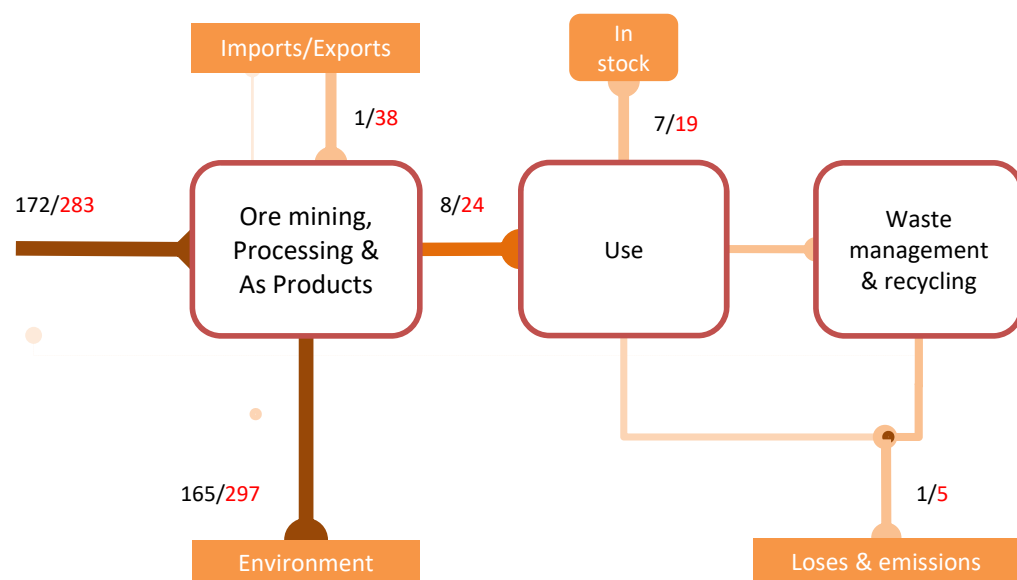
2<sup>nd</sup> International Seminar on Impurities in Copper Raw Materials. 2018. JOGMEC.

Nobuo YAMAZAKI, Metal Economics Research Institute, Japan



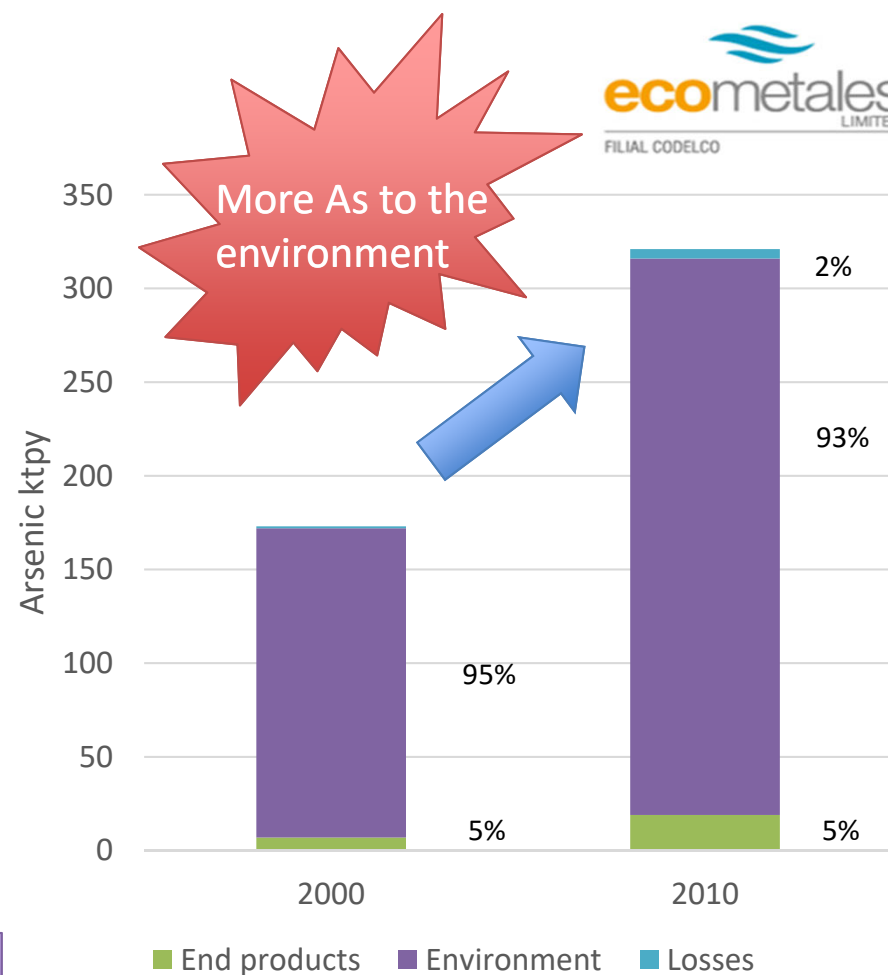
Source: MERI/J

## As antropoghenic flows in China



Figures in ktpy 2000/2010

More than 60% increase in the handling of As within Chinese Non-ferrous metallurgical facilities between 2000-2010



Adapted from:  
*Environ. Sci. Technol.* 2017, 51, 1670-1678  
 DOI: 10.1021/acs.est.6b01669

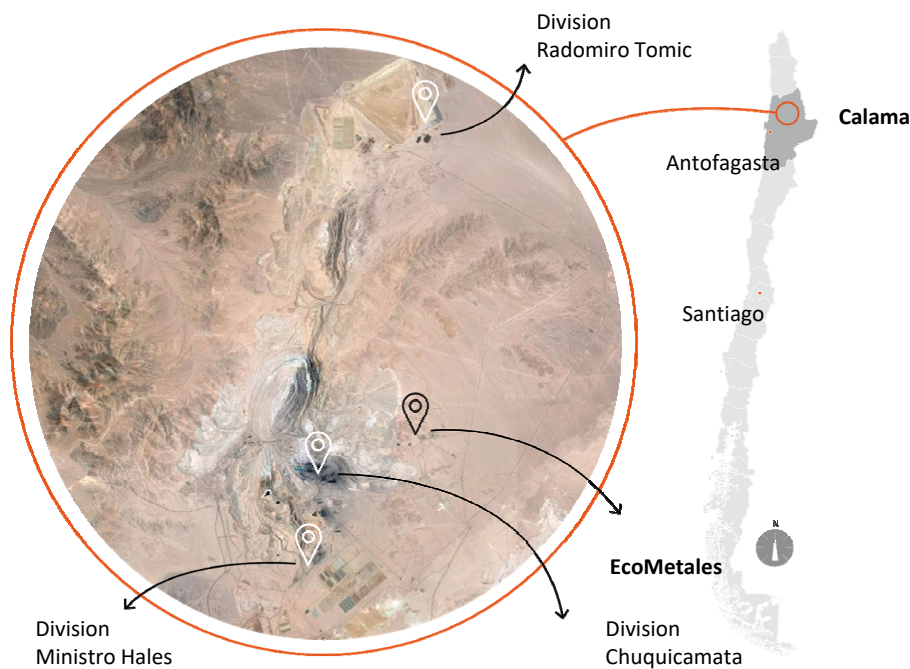
## Content

- Copper. Growth & Demand
- Copper and Arsenic. Unique Challenges/Problems
- **Copper and Arsenic. EcoMetales Unique Opportunities/Solutions**
- Circular Economy and Applied Innovation to concrete problems
  - Our technology
  - Arsenic stabilization. Tailor-made developments
  - Tailings
  - Slag as raw material
- IP & Open Collaboration



## Copper and Arsenic. Oportunities/Solutions Uniques

### About EcoMetales Limited (ECL)

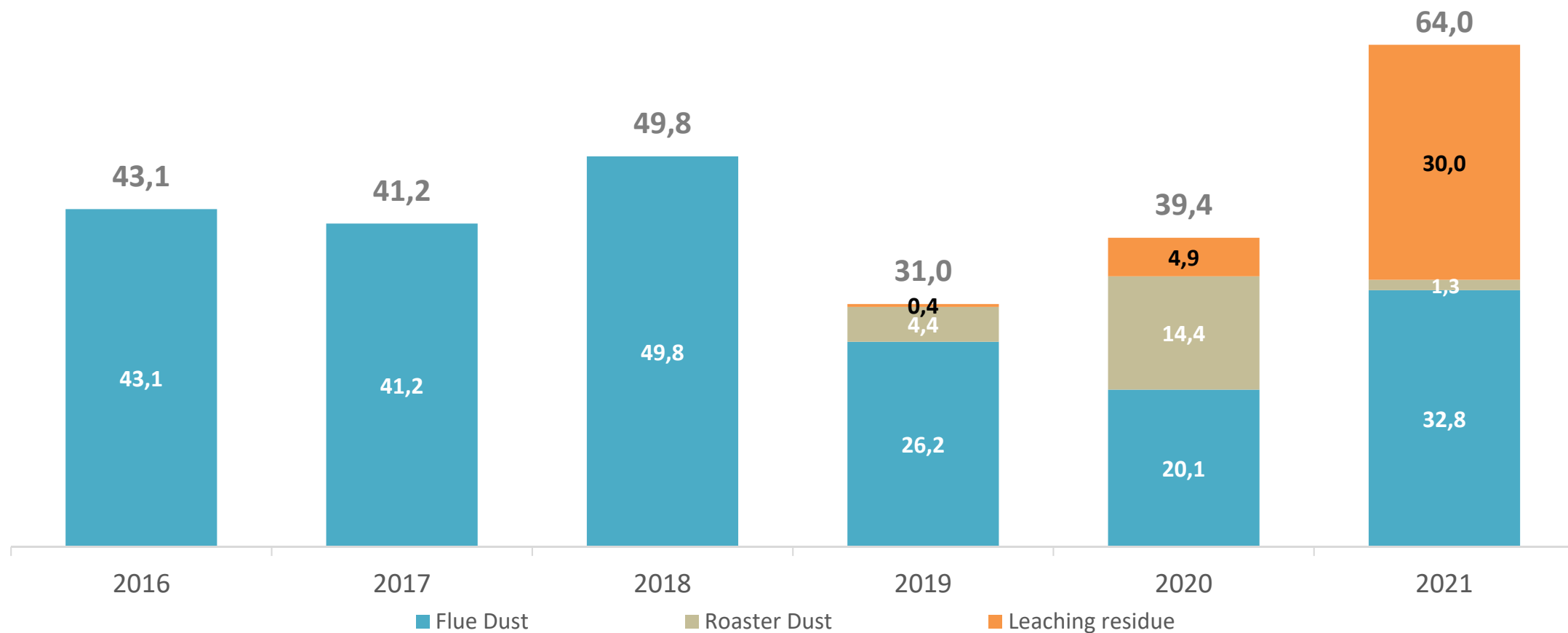


- ▶ ECL is a 100% subsidiary of CODELCO, established to implement environmental solutions and metal recovery processes in the mining industry
- ▶ Our facilities are strategically located 35 km Northeast Calama. ECL has a total workforce of about 303 people, 16% are women, and more than 250 environmental permits for the transportation, treatment and disposal of hazardous waste
- ▶ Since 2007, EcoMetales has processed about 650.000 tonnes of flue dust and 1.193.522 m<sup>3</sup> of acid effluent, recovering about 119.384 tonnes of copper.
- ▶ More than 21.833 tonnes of arsenic have been disposed as scorodite since 2013.



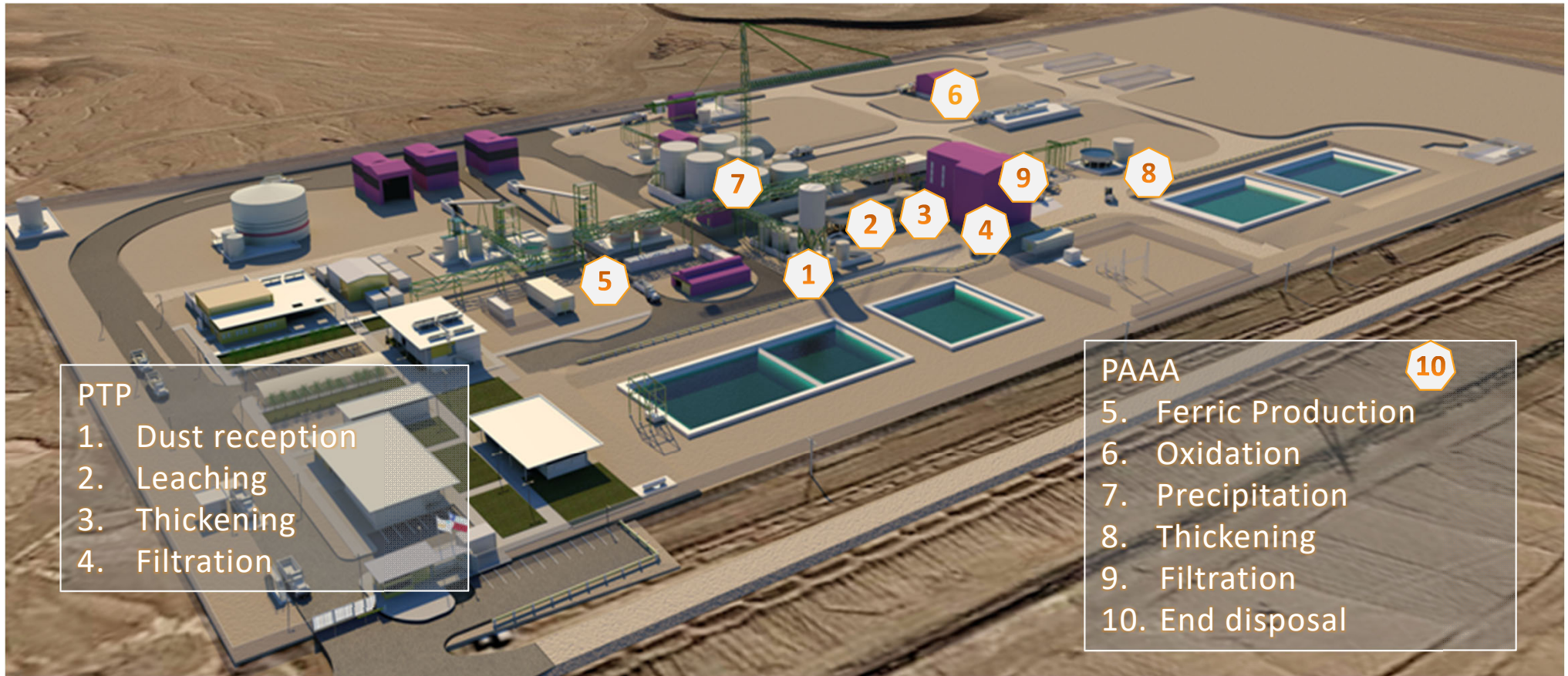
CONFIDENTIAL

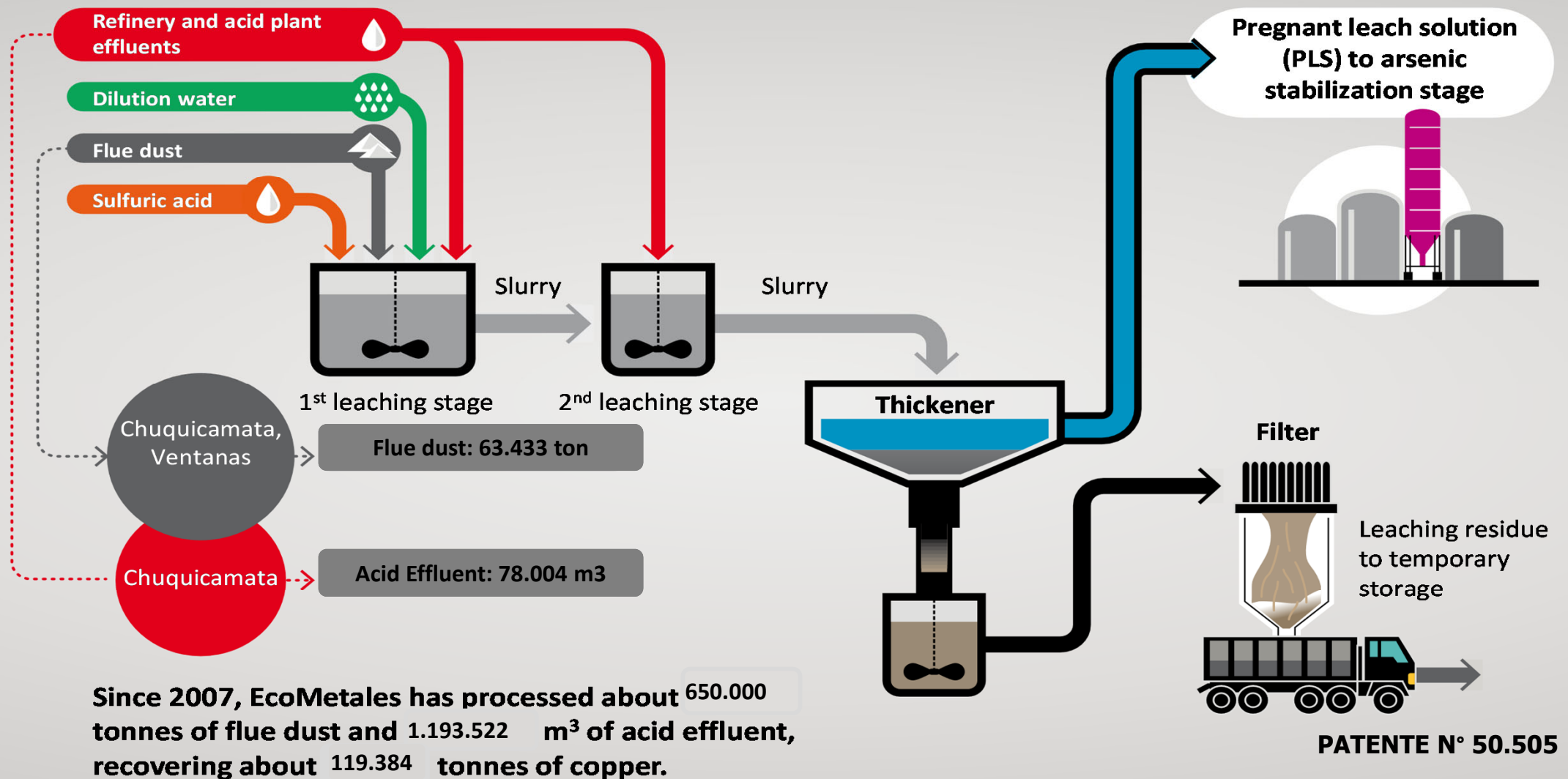
## ¿Wastes? (KTpa)



CONFIDENTIAL

## Proceso PTP y AAA









## 1. Dust Silo

Presurized trucks unload flue dust at the ECL plant.

The hermetic transport system prevents environmental pollution. ECL currently processes flue dust from Codelco's smelter Chuquicamata and Ventanas .

CONFIDENTIAL

## 2. Leaching & 3 Thickening



The flue dust is leached with water and sulfuric acid or as an alternative refinery effluent and/or Acid plant effluent to produce a solution rich in copper and arsenic, called PLS.

- Reactors from 50 to 200 m<sup>3</sup>
- Relevant parameters:
  - Granulometry
  - Solids content
  - Sulfuric acid concentration
  - Temperature

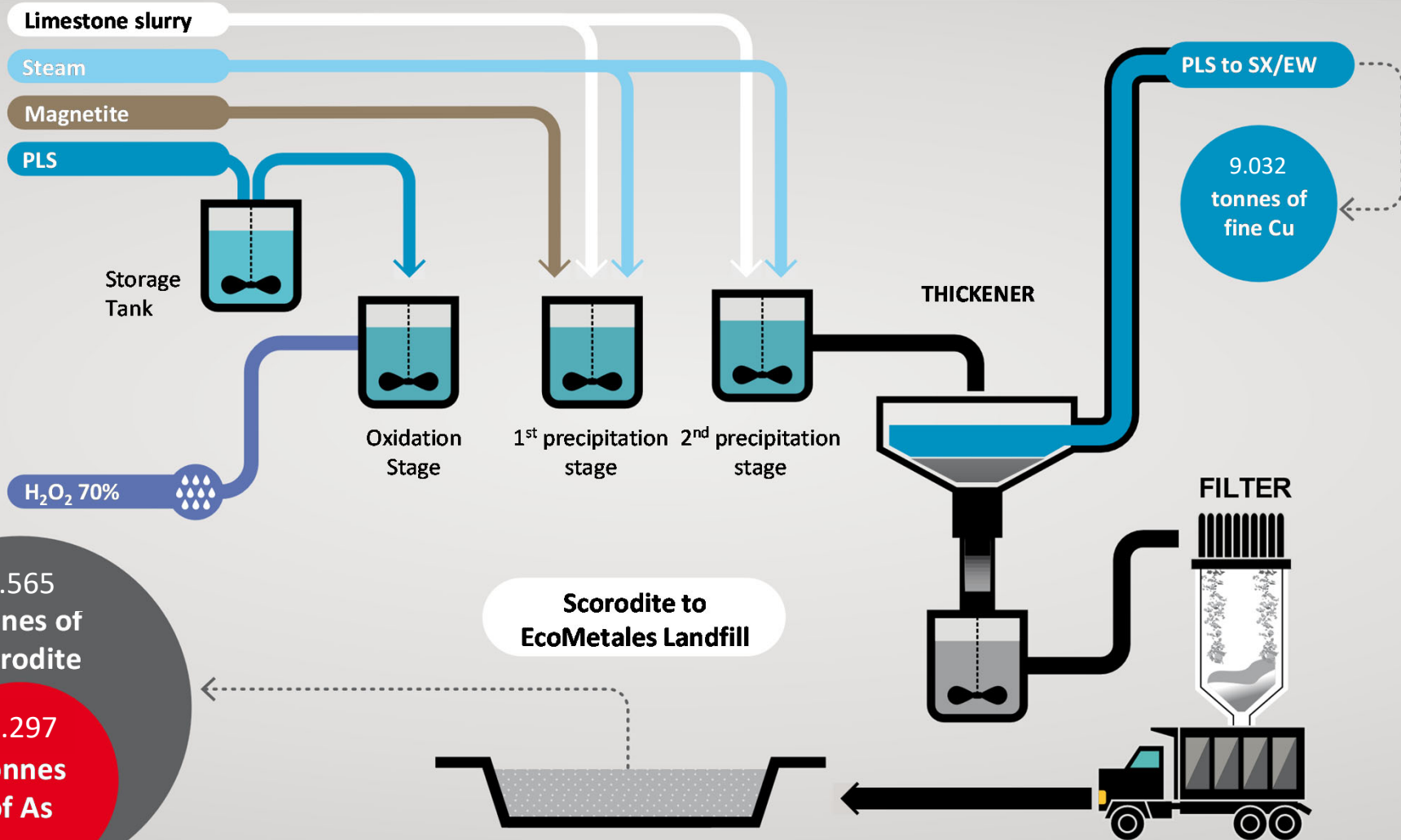
In this phase the pulp is conditioned to carry out the solid and liquid separation in the following products: PLS and leaching residue

CONFIDENTIAL

## 4. Filtration



The solid waste generated in the leaching process, with a copper content of the order of 7%, is filtered and returned as **leaching residue** to the ECL deposit.



More than 21.833 tonnes of arsenic have been disposed as scorodite since 2013.

## 5. Magnetite leaching



In the ferric plant magnetite and sulfuric acid are used to produce a solution of ferrous and ferric sulfate.  
50 m3 reactors

## 6. Oxidation ( $\text{As}^{+3} \rightarrow \text{As}^{+5}$ )



The AAA process begins with the oxidation stage of the arsenite ion contained in the PLS, to which hydrogen peroxide is added to convert it into an arsenate ion.

## 7. Precipitation



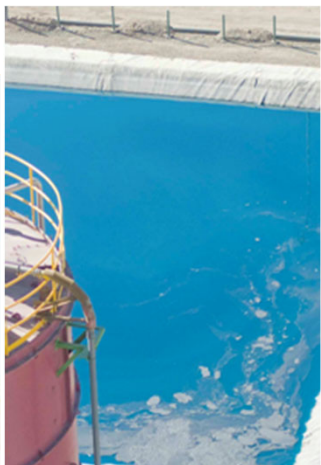
In 1,200 m3 capacity reactors, the precipitation of scorodite occurs. To the oxidized mixture limestone, ferric sulfate and steam are added, essential to bring down the As and Sb.

Relevant parameters:

- Temperature
- Sulfuric acid concentration
- Dosage Fe(III)/As(V)



## 8. Thickening



CONFIDENTIAL

In the clarifier the density of the pulp is increased for the final stage. The solid decants and liquid is separated and stored in pools and then sent as copper-rich PLS and low in arsenic concentrations to Chuquicamata.

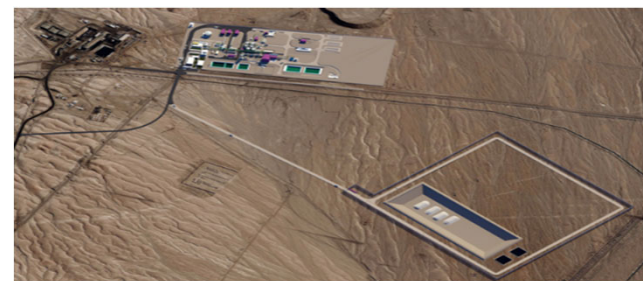
## 9. Filtration

CONFIDENTIAL

The filter press processes the solid waste, removing the excess liquid. The stabilized Ace and Sb, that is, the scorodite, is sent to the warehouse located 1 km from the Industrial Plant



## 10. End disposal



The deposit has a surface area of 25 hectares and capacity to store 1,100,000 tons. Its life cycle is estimated to be more more than 15 years.

# Scorodite: A non-hazardous residue



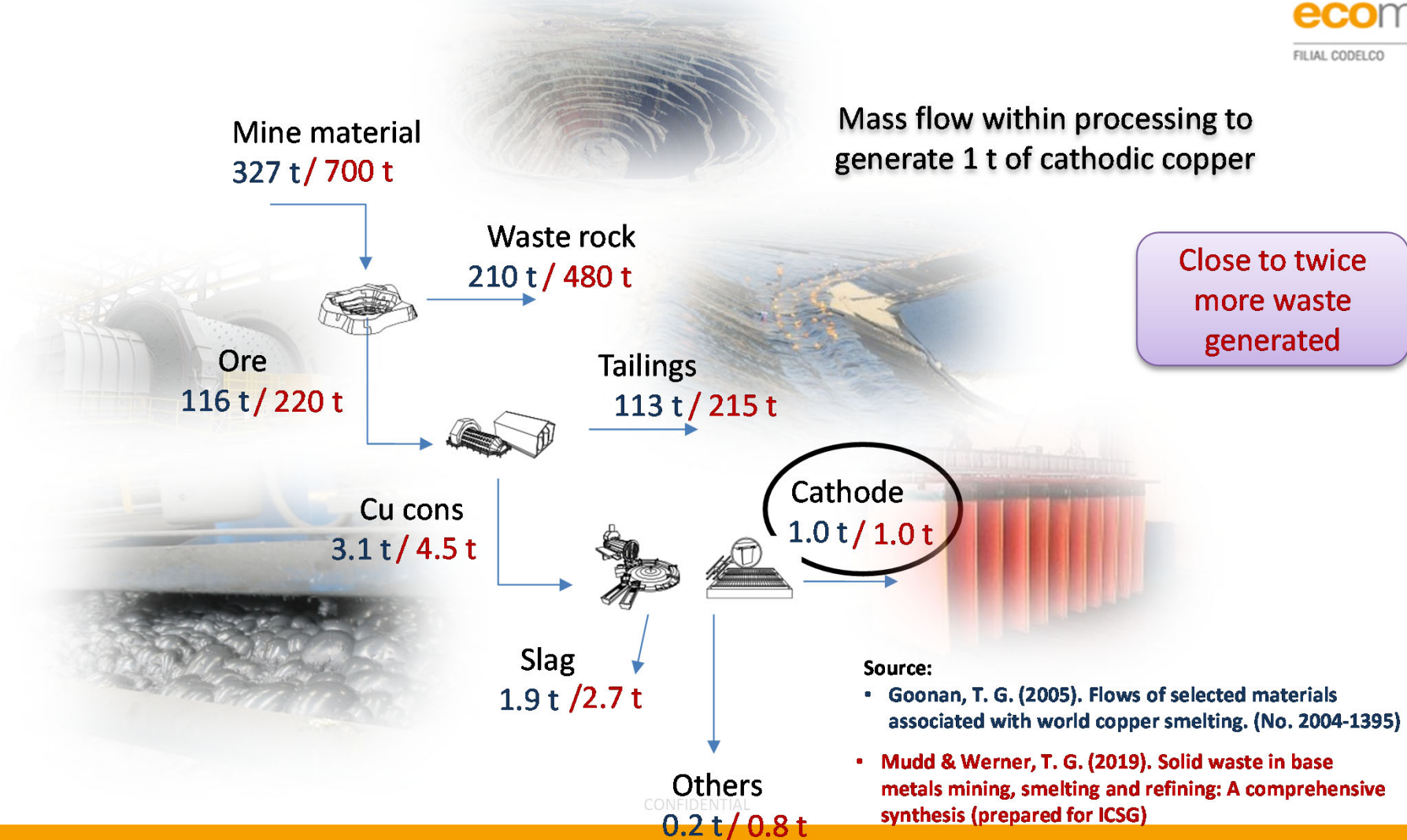
- In 2018 the Secretary for Healthy Affairs of the Región de Antofagasta of the Chilean Government reclassified Scorodite as a Non-hazardous residue after a study that considered conducting stability tests to the residue disposed in EcoMetales landfill during the course of one year.
- This decision allowed the disposal of scorodite under less demanding conditions and represents an important milestone for EcoMetales to differentiate scorodite from other types of arsenical residues with do not meet safety regulations.



## Content

- Copper. Growth & Demand
- Copper and Arsenic. Unique Challenges/Problems
- Copper and Arsenic. EcoMetales Unique Opportunities/Solutions
- **Circular Economy and Applied Innovation to concrete problems**
  - **Our Present technology**
    - Arsenic stabilization. Tailor-made developments
    - Tailings
    - Slag as raw material
- IP & Open Collaboration

# Mining (Copper) is increasing the generation of ¿wastes?



# Our technology

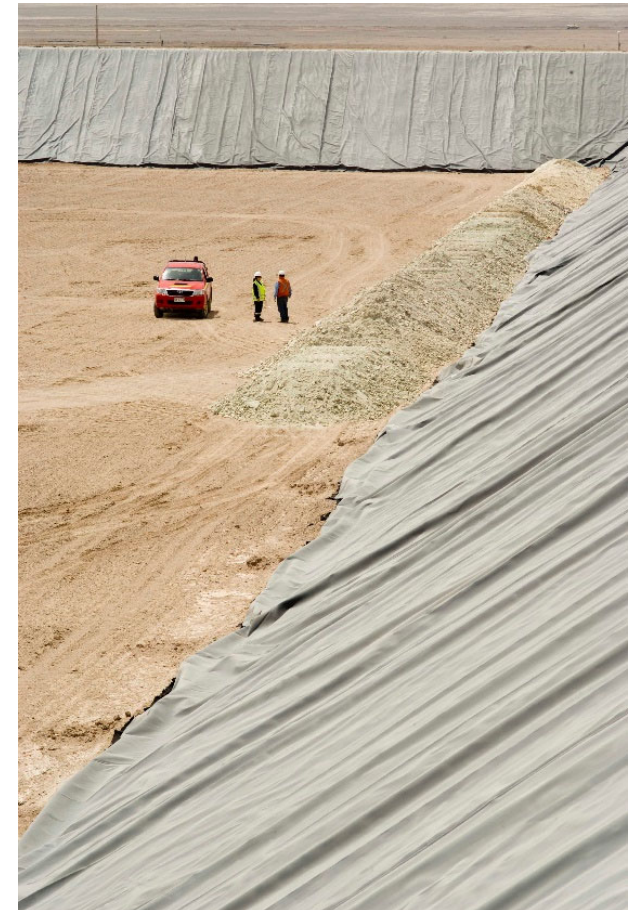
- Arsenic and antimony abatement technology
  - Process for the precipitation of scorodite
  - First scorodite production plant operating worldwide
  - Safe residue for the environment
- Value recovery from mining residues
  - Increased copper production
  - Lead transformed into a salable product
  - Recovery of valuable metals
- Scorodite 2.0
  - Improvement at the oxidation stage
  - Increase of the As content in the final residue
  - Decrease of the final residue volume
- Pressure Leaching of Complex Concentrates (PLCC)
  - Leaching of high As copper concentrate
  - As is fixed as a stabilized residue
  - Synergies with SX/EW available capacity

# Our technology

## Scorodite 2.0

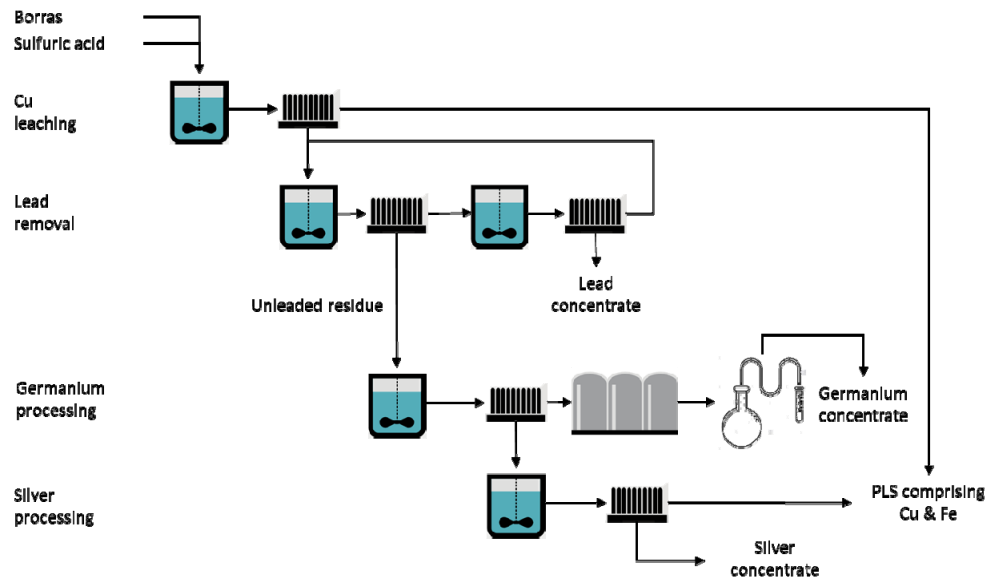
Improvement of the current industrial process focused on its key stages:

- Optimization of the oxidation stage using different oxidants for increasing the concentration of arsenate which results in lower costs and a cleaner output solution
- Increase up to **25% of the arsenic content on the final residue** which results in a landfill lifetime extension

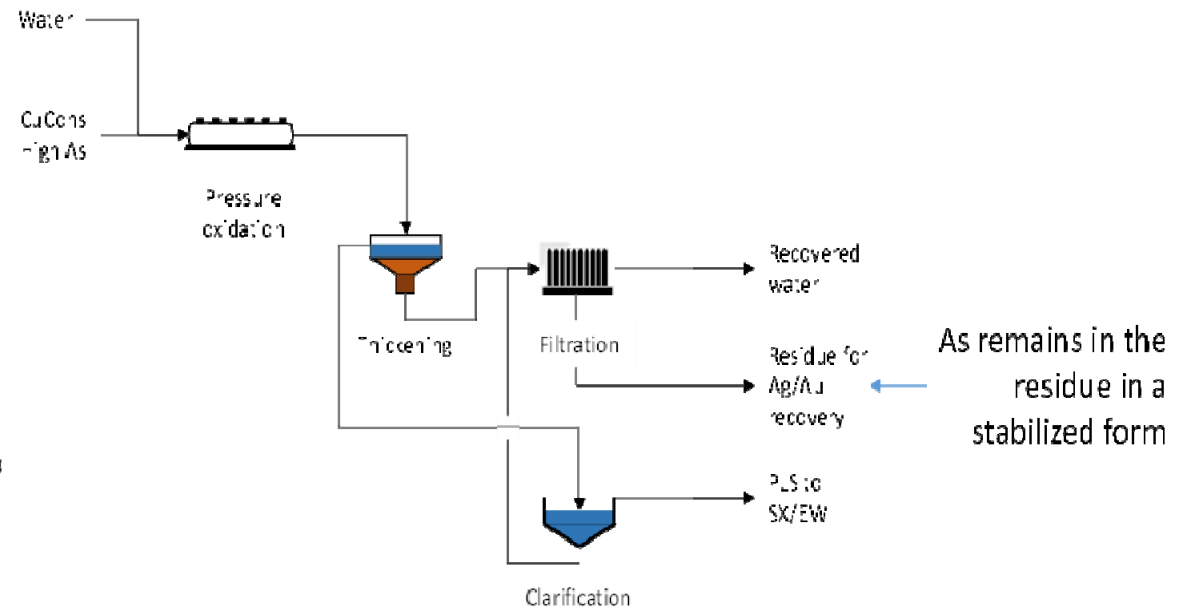


# Our technology

## Value recovery from mining residues



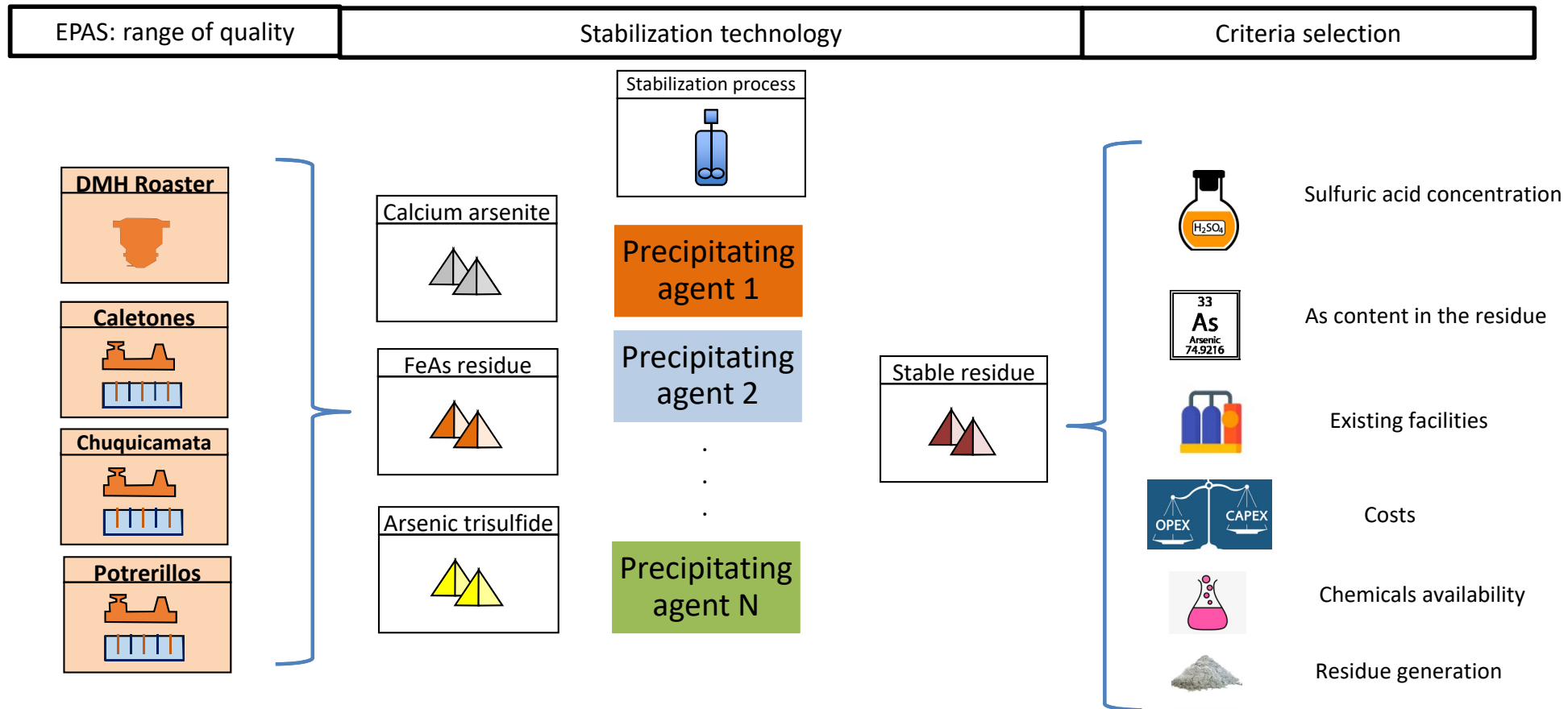
## Pressure leaching of complex concentrates (PLCC)



## Content

- Copper. Growth & Demand
- Copper and Arsenic. Unique Challenges/Problems
- Copper and Arsenic. EcoMetales Unique Opportunities/Solutions
- **Circular Economy and Applied Innovation to concrete problems**
  - Our Present technology
  - **Arsenic stabilization. Tailor-made developments**
  - Tailings
  - Slag as raw material
- IP & Open Collaboration

## Stabilization of Arsenic –tailor-made proposals





CONFIDENTIAL

# Lab



CONFIDENTIAL



CONFIDENTIAL

# Pilot plant



CONFIDENTIAL

## Stabilization processes

Residue	Abatement			Stabilization			
	Technology	TCLP	Cost	Technology	Ley As	TCLP	Cost
Scorodite	Neutrization and iron precipitation	<1 mg/L	\$\$\$\$\$	No required	8-15%	<1 mg/L	
Arsenate residue	Neutralization and precipitating agent	<5 mg/L	\$\$\$\$	No required	15-20%	<5 mg/L	
Arsenate residue	Neutralization and precipitating agent	10-20 mg/L	\$\$\$	Stabilization process I	10-15%	<1 mg/L	\$
Arsenite residue	Neutralization and precipitating agent	10-20 mg/L	\$\$	Stabilization process II	10-25%	1-3 mg/L	\$
	Neutralization and precipitating agent	<3 mg/L	\$\$\$	No required	4-8%	-	-
Arsenic sulfide	Sulfidization	60-80 mg/L	\$\$\$\$	Stabilization process III	35-45%	4,6 mg/L	\$\$\$
Arsenic sulfide	Sulfidization	60-80 mg/L	\$\$\$\$	Stabilization process IV	8-11%	3 mg/L	\$\$
Arsenic sulfide	Sulfidization	60-80 mg/L	\$\$\$\$	Stabilization process V	35-45%	<3 mg/L	\$\$

## Content

- Copper. Growth & Demand
- Copper and Arsenic. Unique Challenges/Problems
- Copper and Arsenic. EcoMetales Unique Opportunities/Solutions
- **Circular Economy and Applied Innovation to concrete problems**
  - Our technology
  - Arsenic stabilization. Tailor-made developments
  - **Tailings**
  - Slag as raw material
- IP & Open Collaboration



# Who are we?

CONFIDENTIAL



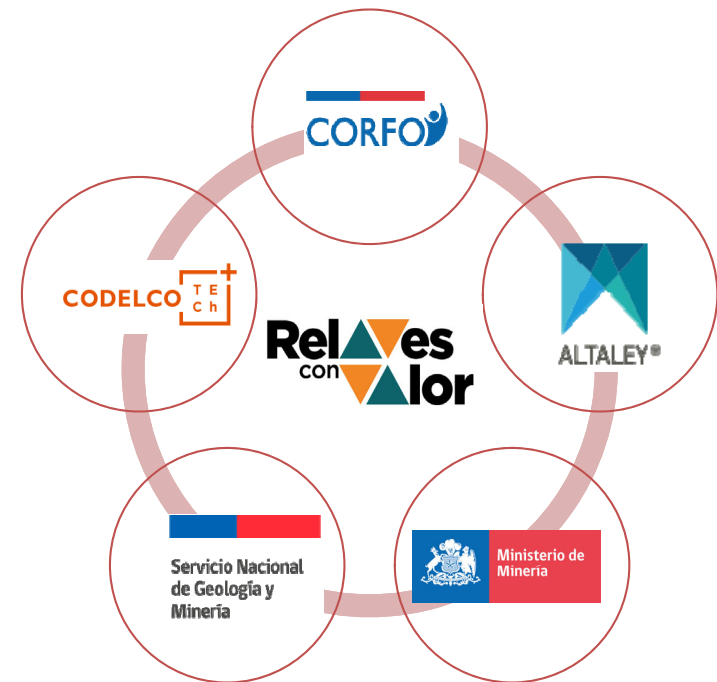
## General Data

- **Name:** I+D for the recovery of valuable elements from mining tailings.
- **Common name:** Tailings with value.
- **Organization**



CONFIDENTIAL

## ECOSYSTEM



CONFIDENTIAL

# Achievements



## Identify y Quantify minor metals (MM)

REE, Co, Cr, Rb, Sr, among others, in 3 tailing deposits (El Salado de Enami, El Gato de Atacama Kozan y Perez Caldera de AASur)



## Recovery of MM from tailings

Configuration of a polymetallic metallurgical process for the recovery of Fe, Cu and REE from tailings. Broadening of know how to elements other than Cu



## Manuals for public use

- 1) *Drilling, sampling and characterization techniques*
- 2) *Tailings reprocessing and MM recovery.*



## Correlations MM-major oxides

Using Sernageomin public BBDD, se have indentified and analized correlations, by región, between traces of MM and major oxides, with a geometalurgic view.



## Legal framework analisis

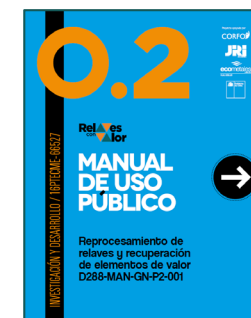
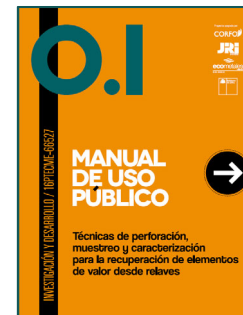
Proposal of technical considerations to complement the current regulations before future tailings reprocessing projects. Agreement with Min. Minería and Sernageomin: Guide for developing projects of tailings and gravel reprocessing.



## Commercial Branding

Logo, website, triptych and infographics are created. The name of Tailings with Value is positioned, and it is registered by mixed trademark in 2 classes in INAPI.

CONFIDENTIAL



Free Download

[www.relavesconvalor.cl](http://www.relavesconvalor.cl)



**From tailings to REE concentrates**

CONFIDENTIAL

## Content

- Copper. Growth & Demand
- Copper and Arsenic. Unique Challenges/Problems
- Copper and Arsenic. EcoMetales Unique Opportunities/Solutions
- **Circular Economy and Applied Innovation to concrete problems**
  - Our technology
  - Arsenic stabilization. Tailor-made developmets
  - Tailings
  - **Slag as raw material**
- IP & Open Collaboration

## PROJECT FUNDAMENTALS



DS594 and DS28 regulations have increased the demand for exhaust gas capture and forced copper smelters to incorporate operational improvements to boost the business.



The smelters have incorporated slag flotation processes, avoiding emissions and aiming to increase copper recovery.



Iron is a critical input in the abatement of As in the form of Scorodite. A smelter that produces slag flotation tailings is sent final disposal (50% iron). Iron has other relevant uses.



EcoMetales presents this project, in its role of delivering environmental solutions for mining and that are linked to Codelco's circular economy challenges.



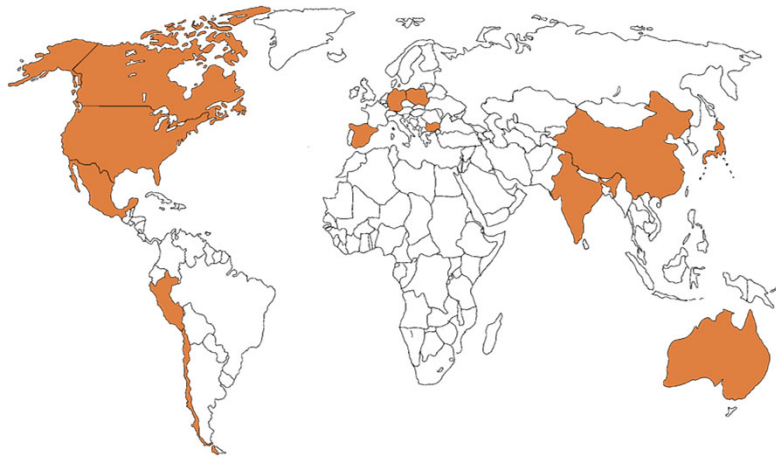
Stock: 20 Mt  
Generation: 4,5 Mt/y



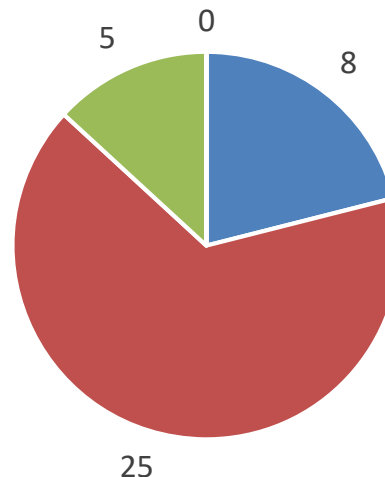
## Content

- Copper. Growth & Demand
- Copper and Arsenic. Unique Challenges/Problems
- Copper and Arsenic. EcoMetales Unique Opportunities/Solutions
- Circular Economy and Applied Innovation to concrete problems
  - Our technology
  - Slag as raw material
  - Tailings
  - Arsenic stabilization. Tailor-made developmets
- **IP & Open Collaboration**

# Intellectual Property



We have 38 documents distributed into patent applications under examination and granted, corresponding to seven (7) technologies



- Granted
- Processing
- Closed
- Rejected



US11220437B2

## (12) United States Patent Acuna Goycolea et al.

(10) Patent No.: **US 11,220,437 B2**  
(45) Date of Patent: **Jan. 11, 2022**

(54) **PROCEDURE FOR OBTAINING SCORODITE WITH A HIGH ARSENIC CONTENT FROM ACIDIC SOLUTIONS WITH HIGH CONTENT OF SULFURIC ACID**

2101/103 (2013.01); C02F 2103/10 (2013.01); C02F 2103/34 (2013.01)

(71) Applicant: **EcoMetales Limited**, Providencia (CL)

(58) **Field of Classification Search**  
CPC ..... C01G 49/0018; C02F 1/5236  
See application file for complete search history.

(72) Inventors: **Marcelo Gustavo Acuna Goycolea**, Las Conde (CL); **Enrique Anselmo Roman Espinoza**, La Florida (CL); **Ricardo Miguel Pezoa Conte**, Paine (CL)

### (56) References Cited

#### U.S. PATENT DOCUMENTS

5,820,966 A 10/1998 Krause et al.  
7,695,698 B2 4/2010 Fujita et al.  
2017/0145540 A1 5/2017 Bartsch et al.

(73) Assignee: **EcoMetales Limited**, Providencia (CL)

#### FOREIGN PATENT DOCUMENTS

CA 2927033 A1 10/2017  
CN 103553197 B 12/2014  
FI 118802 B 8/1998

(\*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 118 days.

#### OTHER PUBLICATIONS

D. Filippou, et al; Arsenic immobilization by controlled scorodite precipitation; JOM; Dec. 1997; 1:49(12); pp. 52-55.

(21) Appl. No.: **16/721,436**

(22) Filed: **Dec. 19, 2019**

#### (65) Prior Publication Data

US 2020/0198985 A1 Jun. 25, 2020

#### Related U.S. Application Data

(60) Provisional application No. 62/784,628, filed on Dec. 24, 2018.

(51) **Int. Cl.**  
C02F 1/52 (2006.01)  
C01G 49/00 (2006.01)  
C02F 1/70 (2006.01)  
C02F 1/72 (2006.01)  
C02F 101/10 (2006.01)  
C02F 103/10 (2006.01)  
C02F 103/34 (2006.01)

Primary Examiner — Peter Keyworth

(74) Attorney, Agent, or Firm — Lucas & Mercanti, LLP

#### (57) ABSTRACT

The present invention provides a process that allows the oxidation of trivalent arsenic and ferrous ion, simultaneous with neutralization of the acid solution to be treated, the precipitation of arsenic and oxidized ferric iron added in a molar ratio Fe:As determined at a defined pH, all of the above with a high efficiency of precipitation of arsenic as ferric arsenate or scorodite, obtaining a final residue stable in the long term, characterized by their higher content of arsenic in a lower volume compared with the procedures described in the state of the prior art.

**12 Claims, 7 Drawing Sheets**

# EcoMetales colaboration network



## Industrial Partners



## Concept Partners



## Academic Partners



## Topics for collaboration

- Setting a global view of the industry in terms of the tremendous environmental challenges we are facing
- Increasing the data available about the flux of hazardous materials
- Standardizing best practices for residues disposal
- Applied Research and piloting on leaching of complex sulphides
- New developments for the concentration and selective separation of impurities

**© ECOMETALES® SANTIAGO DE CHILE, 2021**  
***“PROPERTY OF ECOMETALES® LIMITED ALL RIGHTS RESERVED.***  
***TOTAL OR PARTIAL REPRODUCTION WITHOUT THE OWNER***  
***CONSENT IS FORBIDDEN”***



Nueva de Lyon 72 • Piso 17 • Providencia • Santiago • Chile  
Camino a Radomiro Tomic, Km 16 ½ • Calama • Chile  
**[www.ecometales.cl](http://www.ecometales.cl)**