



FILIAL CODELCO

TRENDS AND TREATMENT OF IMPURITIES IN COPPER MINING

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October 16, 17, 2018 - Japan



INTERNATIONAL SEMINAR ON IMPURITIES IN COPPER RAW MATERIAL

Topics

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Arsenic

An unresolved problem



Structural problem: Most new copper deposits have a high arsenic content.



Closed circuit: The process of scorodite, or similar, stable residue is not applied extensively.



Stricter environmental norms for transporting and processing complex concentrates are expected

Arsenic content concentrate output is growing fast:

0.13% in 2000 ...>0.20% in 2016...0.30% in 2020, according to ICSG

Arsenic content in copper concentrates in Chile and Perú

▶ Chile is the world's leading producer of copper in concentrates with 24% of total



▶ Chile should increase its share to 26% by 2030.

Perú



- **El Brocal** (Buenaventura): 5 - 8% As
- **Cobriza** (Doe Run): 0.4 - 0.6% As
- **Chinalco**: 0.5 - 1% As
- **Magistral** (Nexa Resources) (*): 1% As
- **Cañariaco** (Candente Resources): 1% As
- **Other projects**: La Granja, Galeno

Chile



- **DMH** (Codelco): 1 - 3% As
- **Chuqui** (Codelco): 0.5 - 2% As
- **El Teniente** (Codelco): 0.15 - 0.20% As
- **Collahuasi**: paying penalties on higher As

(* Projects;

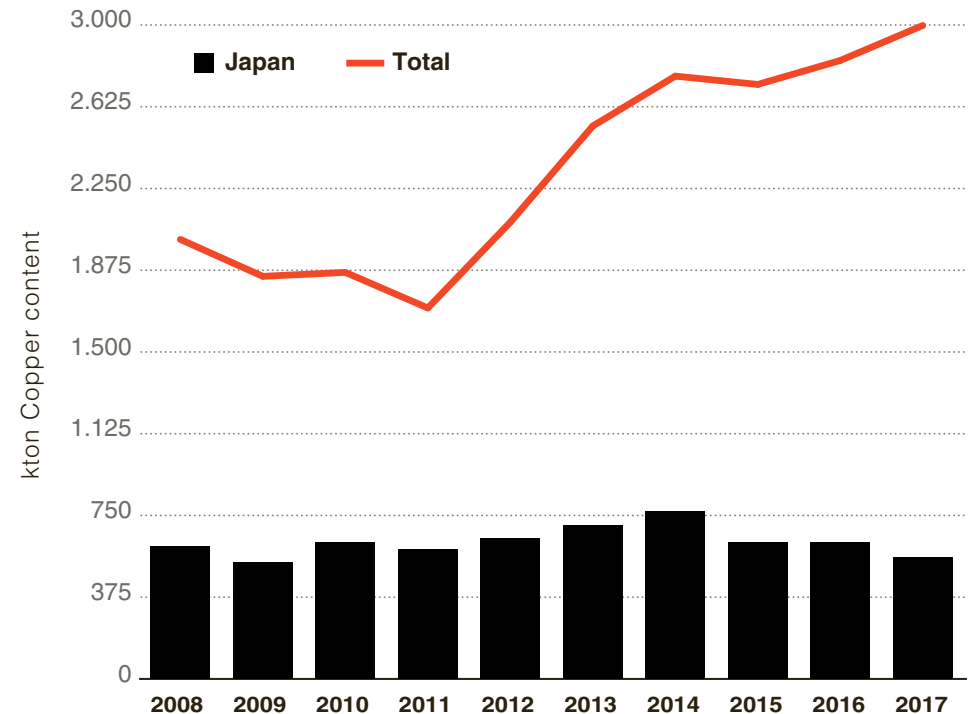
SOURCES: Codelco, Cochilco, Anglo American, EcoMetales, ICSG

Chilean exports of copper concentrate

20% of Chile's copper is exported to Japan today, compared to 30% in 2008

Japan is Chile's second most important destination for copper concentrates after China which represents 41% of the total

- ▶ The volume of Cu concentrates with high As will increase in the international market
- ▶ Blending practice is an option but not a suitable solution
- ▶ Chemical or biological treatment is needed, either using a hydrometallurgical or pyrometallurgical route



SOURCE: Chilean Copper Commission, 2018.

Stricter regulations for concentrates with arsenic in storage and transport

Some copper concentrates can be harmful to the marine environment and a risk to crews.



International Maritime Dangerous Goods Code (IMDG): packaged copper ores and concentrates.

MHB: Materials Hazardous Only in Bulk



International Maritime Solid Bulk Cargoes Code (IMSBC)



China set a benchmark maximum of 0.5% As in concentrates; other countries have reduced the limits further.

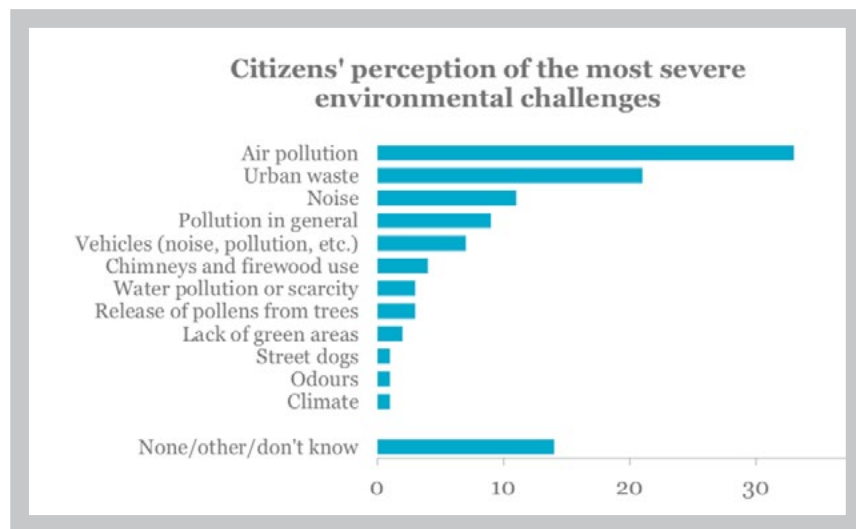
On the first day of 2018, **China ban scraps imports**

The **EU-28** established best available techniques (BAT) in 2016 for waste reduction of copper and other metal industries, including the reduction of quantities of waste sent for disposal from copper production

SOURCES: ICSG, Cochilco.

Environmental issues & community concerns:

a Chilean case



Pese a que primer día de alerta sanitaria redujo en 20% el nivel de SO₂:

Restricción en 8 industrias no logra frenar las intoxicaciones: el Hospital de Quintero tuvo que atender a 86 personas

Autoridad sanitaria señaló que plan "permite ir confirmando o descartando posibles fuentes emisoras" y no desechó extender prohibiciones a otras empresas de la zona.



MUNICIPIO SILEA Y ANDEMA CONFIRMA

Ayer fue el primer día de la alerta sanitaria en Quintero y Puchuncaví, con una histórica paralización de fuentes industriales para reducir las emisiones de dióxido de azufre (SO₂) y suspender las de compuestos orgánicos volátiles (COV). En las primeras horas de vigencia, la medida no logró frenar la demanda de atención médica por personas que sufrían síntomas de intoxicación por gases.

Hasta las 15:00 horas de ayer, 86 personas habían concurrido por esta causa al Hospital Adriana Costello, de las cuales 42 fueron menores de 14 años. 11 días anterior, durante todo el miércoles...

En el Colegio Don Orione, 20 estudiantes fueron enviados al hospital, como había ocurrido los días previos, e incluso a una auxiliar, que sufrió mareos y vómitos. El Colegio Santa Filomena, que no registraba una intoxicación masiva desde el 21 de agosto, debió mantener a sus alumnos dentro de las salas que cuentan con filtro de aire, pese a lo cual llegaron al hospital 14 alumnos, dos de ellos de prebética.

Mientras se ocurren, 24 fiscalizadores sanitarios recorrieron las ocho empresas con restricción a sus...

Alvarez fue consultado por qué, pese a ello, hubo nuevos intoxicados. "La parte de la investigación. Hay más de 17 empresas y aplicamos la prohibición a ocho. Esto nos permite ir confirmando o descartando posibles fuentes emisoras asociadas a estos casos", dijo y agregó que las restricciones se extenderán hasta que las ocho industrias entreguen sus planes operativos. Además, no descartó ampliar las medidas restrictivas a otras empresas.

El intendente Jorge Martínez apuntó que la Oga...

NUEVO EQUIPO
Durante la jornada llegó un cronógrafo, que evalúa la calidad del aire aún en alta concentración.

ENAP REFINERÍA ESTIMA EN US\$ 200 MILLONES SU INVERSIÓN PARA CUMPLIR CON EL FUTURO PLAN DE DESCONTAMINACIÓN:

El fantasma de las paralizaciones en Quintero obliga a calcular costos y tomar resguardos extras a las empresas de la zona

En la industria asumen que la autoridad será cada vez más exigente, y aunque en el Ministerio del Medio Ambiente aseguran que no habrá paralizaciones constantes, los privados ya hacen cálculos de eventuales detenciones. Un buque petrolero parado en el mar cuesta entre US\$ 25 mil y US\$ 35 mil diarios y la menor producción de energía puede significar pérdidas de más US\$ 100 mil cada día. • CLAUDIA RAMÍREZ

SOURCES: El Mercurio newspaper, OECD, Ministry of Environment - Chile

Chile's air quality and emission standards for copper smelters

- **Environmental regulation in Chile** (since 1990) has a shorter history than Japan and US (early 1970s)

- **Chilean smelters are now working to reach a new SO₂ and As emission standard by 2018, which will:**

A

Reduce emission limits by 225% for As and by 186% for SO₂

B

Increase SO₂ and arsenic capture to 95% for current operations and to over 98% for new smelters. Average capture today is about 85%

Details on standards in Annex I

- **A new stricter air quality standard** for SO₂ is being analyzed for a 2020 startup

- Chile is working hard to reduce emissions but needs to close the gap with international **standards** such as those in Japan, EU or China

Chilean regulations for waste treatment and disposal of impurities

D.S. N° 148/2003: Management of Hazardous Waste:

- **Scope:** Generation, storage, transport, treatment, reuse & recycling, disposal
- **Focus on** characterization and toxicity (TCLP test), but not on Best Available Techniques

Extended producer responsibility (EPR) (mining waste not included)



Some figures in copper smelters (7 operations)

- +110 kt/y of flue dusts (1-15% As) and 4,000 m³/y of acid effluents (acid plants)
- 85% of total flue dust with As is treated at EcoMetales plant and As disposed as scorodite together with Sb and other impurities
- Almost all the As from acid effluent is treated with lime, while one operation uses NaSH

In summary, regulatory trends will place greater requirements/obligations on the treatment and disposal of unstable waste containing impurities in Chile

Details per operation in **Annex II**

Copper smelters and other metallurgical plants in Chile face the following challenges:



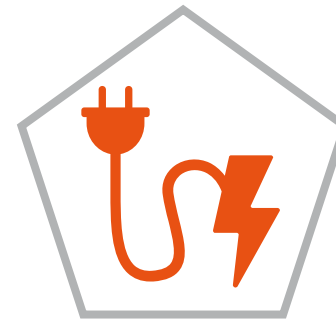
Improve
environmental
performance



Reduce costs
and to increase
productivity



Introduce **more**
automation and
technological
improvements



Energy
recovery



Recovery
of strategic
metals (Bi, Ge,
Sb, etc.) and
alternative uses
for waste like
slag or sulfur.

Topics

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**GLOBAL
TRENDS**

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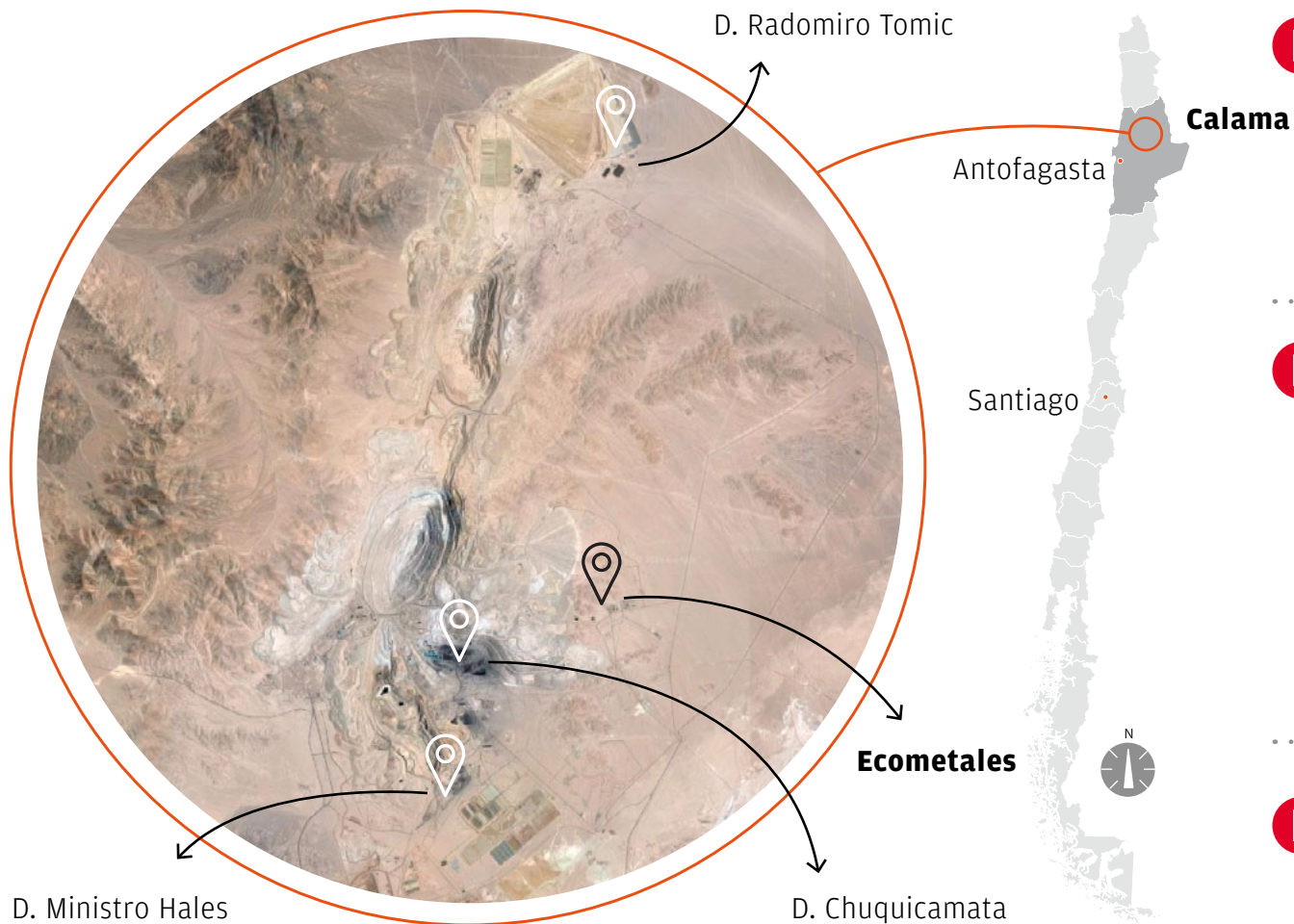
ECOMETALES

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**FINAL
REMARKS**

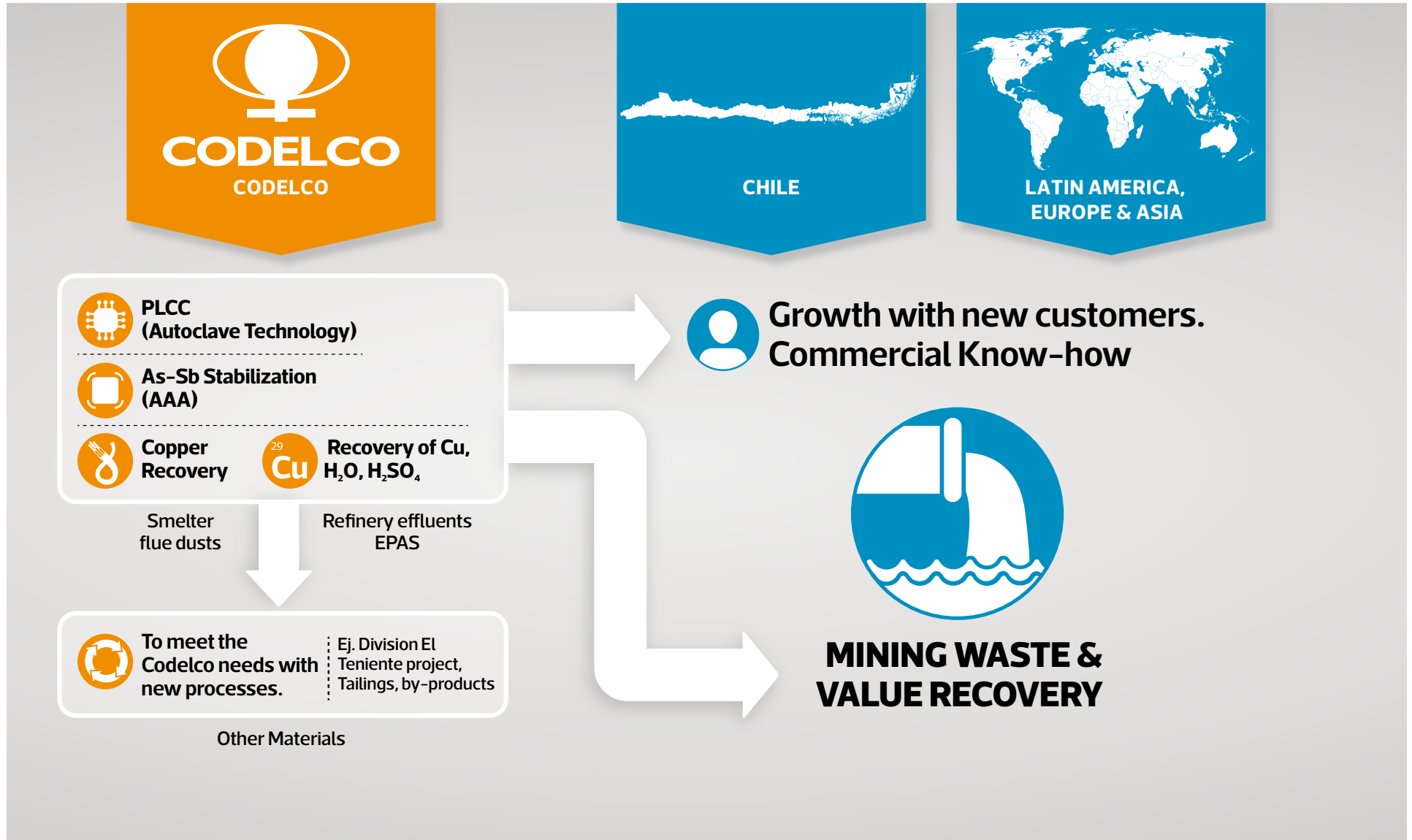
About EcoMetales Limited

(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 kms northeast of Calama. ECL has a total workforce of about 300 and more than 250 environmental permits for the transportation, treatment and disposal of hazardous waste
- ▶ ECL currently processes waste from CODELCO and is looking for opportunities to work with other mining companies

EcoMetales's development plan



Projects & business

CURRENT PLANT Flue dust leaching & As disposal as Scorodite



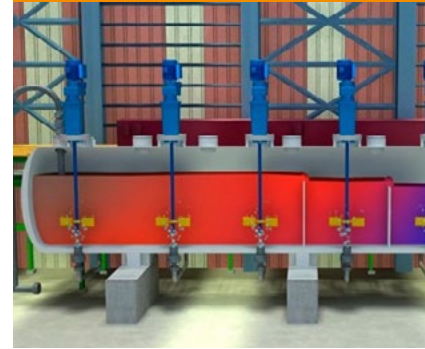
- **Productivity Improvement 2018/2017:** + 47% Production and - 22% cost
- **Declassification Scorodite 2018:** It will allow its disposal under less demanding conditions

WASTE VALORIZATION



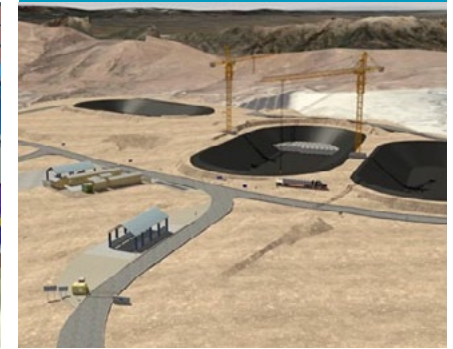
- **Leached residue:** Recovery of Ag, Cu and Ge. A new hydro process in evaluation
- **Tailings:** Recovery of minor elements. Tailings characterization and lab testing.

PLCC PLANT Pressure Leaching of Complex Concentrates



- **Feasibility engineering completed in 2017**
- **Environmental permit approved in 2017**
- **Independent Review Approval and decision to go forward in 2018**

DET PLANT Improvement of arsenical waste generation, transport and disposal at El Teniente Division, Codelco



- **Environmental permit approved in 2018**
- **Definition of El Teniente Division for project continuity in 2018**

2018

2019/
2020

- **Scorodite 2.0:** Volume reduction and encapsulation (2019)
- **AAA process commercialization:** B.O.T. contract - Technical license (2019)
- **Replacement of calcium arsenite by scorodite**
- **Geo-polymer study for existing calcium arsenite deposits**
- **End of the transfer area**

- **Leached residue:**
First Milestone Cu recovery (2019)
Second Milestone recovery of other elements (2020).
- **Tailings:** Technical-economic process evaluation (2019).

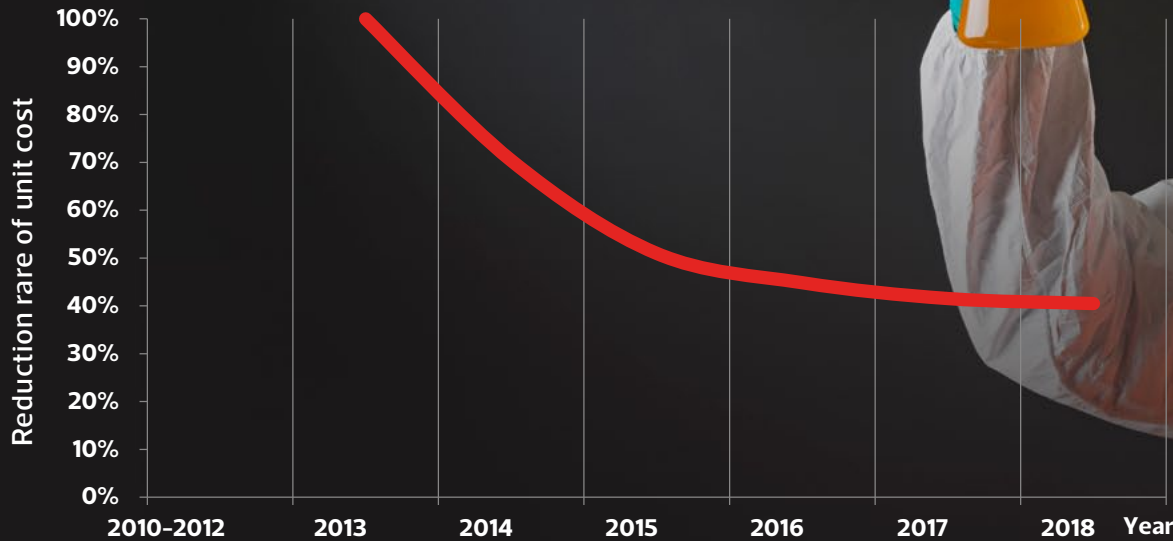
- **Begin detailed engineering by 2019**
- **Start-up in Northern District by December 2020**

Arsenic stabilization process (Chilean Patent Grant 50423)

ECOMETALES LANDMARKS:

We had a problem...

Continuous learning during the plant operation

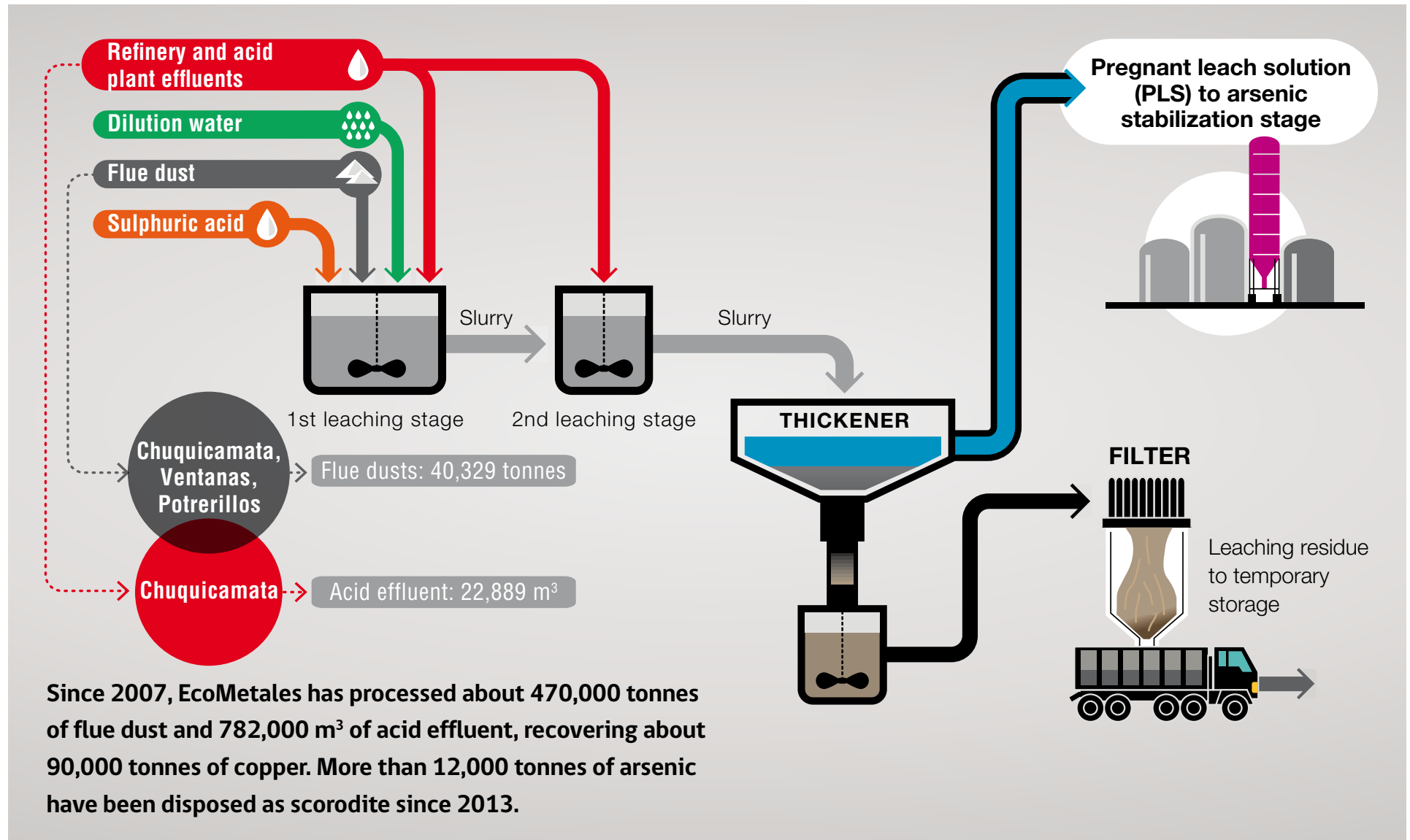


2006	2010-2012	2013	2014	2015	2016	2017	2018
Precipitation of scorodite at laboratory scale.	PAA Project. Pilot Plant Trials. PAA Construction. PAA Start-up.	Start of operation of PAA.	Improvement of boiler use and limestone preparation stage.	Optimization of ferric solution preparation stage.	Improvement of oxidation stage.	Optimization of precipitation stage.	Improvement of automatic control.



EcoMetales plant

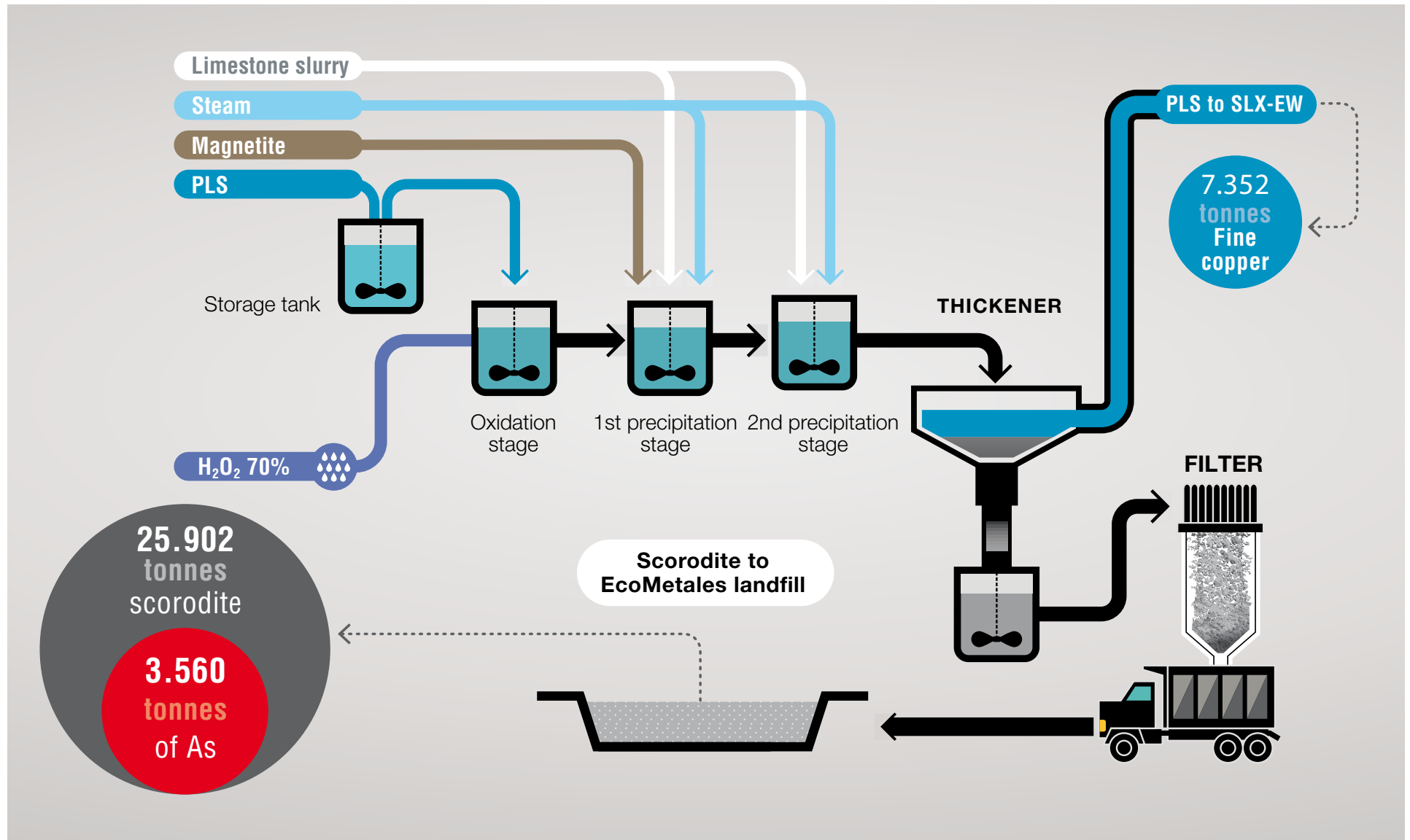
Flue dust leaching process



Since 2007, EcoMetales has processed about 470,000 tonnes of flue dust and 782,000 m³ of acid effluent, recovering about 90,000 tonnes of copper. More than 12,000 tonnes of arsenic have been disposed as scorodite since 2013.

EcoMetales plant:

Arsenic stabilization process



Complex concentrate leaching project

(PLCC)

The process involves the leaching of complex copper concentrates through a high-pressure vessel. The arsenic stabilization is also performed inside the vessel.

The project capacity is 200,000 t/y, the go-ahead decision should be taken during 2018.

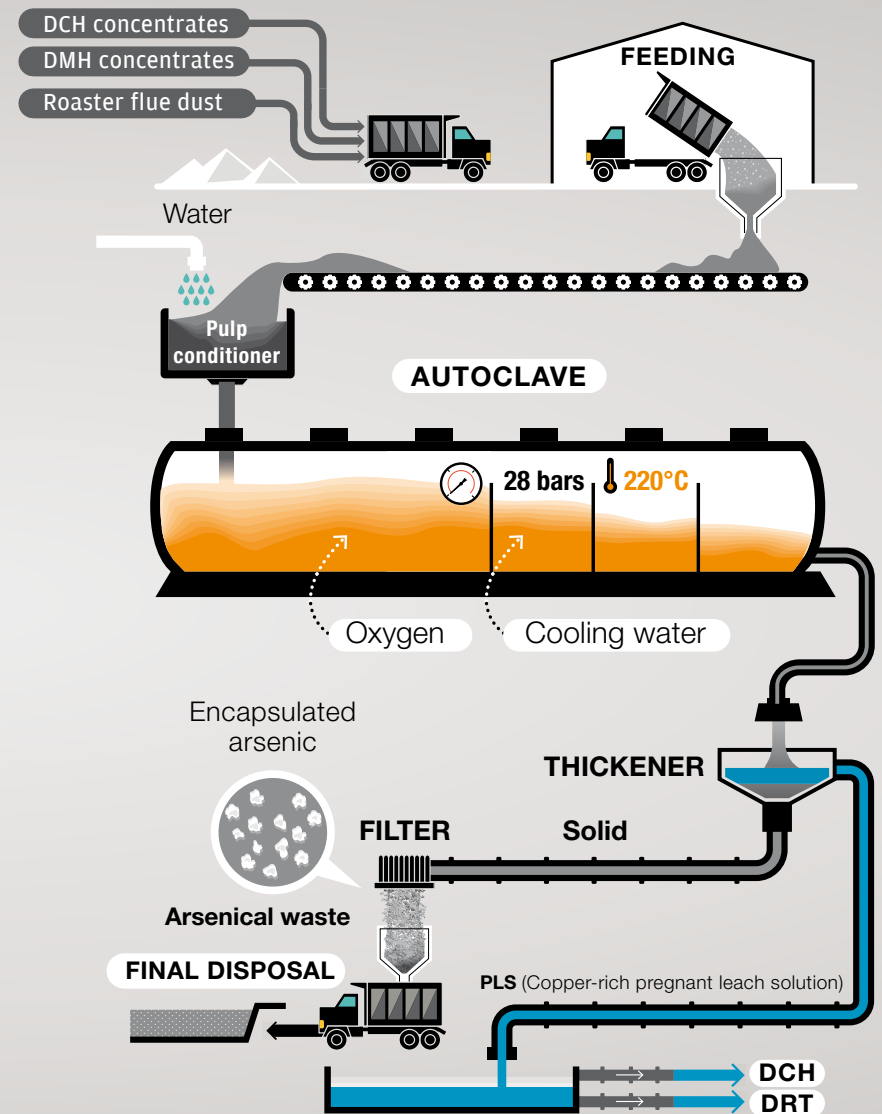
Advantages:

- ▶ Almost zero emission
- ▶ Stable waste as scorodite
- ▶ Utilization of existing SX-EW facilities
- ▶ Low water consumption
- ▶ Competitive costs

Environmental permit approved in 2017

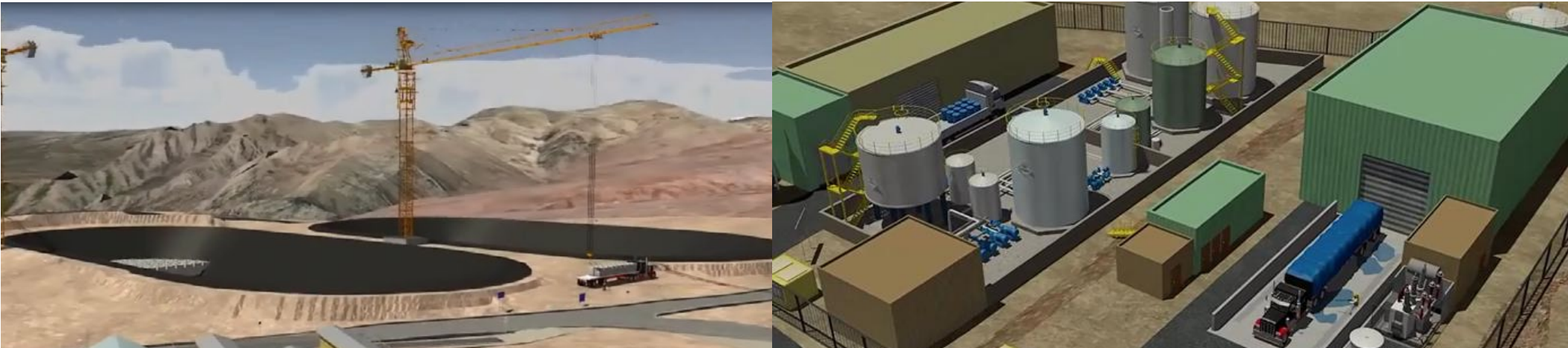
The schedule defines the start-up for the new facilities in 2020-21

Capex USD \$ 324 million



El Teniente Project

Arsenic removal from sulfuric acid plant effluents (weak acid)



The project will produce arsenic trisulfide instead of the current process based on treating arsenic with lime.

Advantages:

- ▶ 5 times less waste volume
- ▶ less than 1 ppm of [As] in treated effluent
- ▶ 500,000 m³ landfill facility inside El Teniente facilities, avoiding current transportation through populated areas outside Codelco's division

Environmental permit was approved in 2018

Capex
USD \$ 70
million

Other developments & cooperation

opportunities



- ▶ Recovery of trace elements (Ag, Bi, Sb and Ge) from smelter flue dusts (in cooperation with K-UTEC Salt Technologies and RMC with CORFO - Eureka support)
- ▶ Tailings processing & recovery of value metals (in cooperation with JRI Ingeniería Chile, CORFO project)
- ▶ Oxidation of As (III) and Fe (II) using new biotechnological methods (in cooperation with CeBiB – University of Chile)
- ▶ Increase of current copper recovery of flue dust treatment plant (ECL)
- ▶ Treatment of Acid Mine Drainage (AMD)

Topics

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Final remarks



The treatment of arsenic remains an unsolved problem worldwide with several pending challenges in the mining sector:

- Transportation of higher As content and more complex concentrates
- Stricter regulations for air emissions and waste disposal
- Communities deeply concerned about environmental pollution issues

Metallurgical facilities' management of flue dust and acid effluent still needs to improve treatment and disposal of arsenic and other impurities. More research is needed for the removal of As from water sources, as well as for more efficient disposal alternatives.

EcoMetales supports JOGMEC's initiative related to the separation of impurities from copper raw materials at the mineral processing stage.

From a more integral perspective, it is also necessary to find the best solution for the residual fraction of high arsenic concentrate.

EcoMetales is looking for synergies and collaboration to solve the challenge posed by arsenic treatment and disposal.



Thanks
you!!!!



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