

# MINING WASTE MANAGEMENT IN CHILE: EXPERIENCE, CHALLENGES AND OPPORTUNITIES

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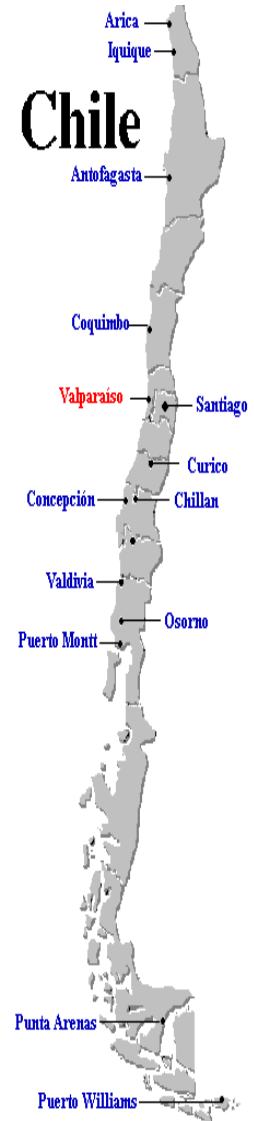
**WORKSHOP ON BEST PRACTICES ON MINING POLICIES AND TECHNOLOGIES**

Thematic session 2 - Mining waste management and mine rehabilitation

BREY Building, European Commission  
15-16 / 10 / 2015, Brussels, Belgium

# AGENDA

- 1. Mining production in Chile**
- 2. Environmental regulations**
- 3. Waste generation from copper processing**
- 4. Waste management and metals recovery**
- 5. Final Remarks**



# 1. Mining production <sup>(1/3)</sup>

Today, Chile is the largest producer of copper in the world and a globally significant supplier of Mo, Re, Ag, Au, and industrial minerals, like nitrate, lithium and iodine, among others.

## 2014 Production (\*)

Main Metals & minerals	Volume	Global ranking	Global share
Copper (Mton)	5.8	1 <sup>o</sup>	31%
Molybdenum (kton)	48.8	3 <sup>o</sup>	16%
Gold (ton)	46	18 <sup>o</sup>	1.6%
Silver (ton)	1,572	5 <sup>o</sup>	6.0%
Iron ore (Mton)	18.9	14 <sup>o</sup>	0.6%
Nitrates (Mton)	0.7	1 <sup>o</sup>	100%
Iodine (kton)	19	1 <sup>o</sup>	60%

(\*) 50% of rhenium world production, obtained as a by-product from roasted Mo concentrates

Note: by 2018, first TiO<sub>2</sub> production in Chile: 200 kt/y as concentrate (95% TiO<sub>2</sub>)

## 2025

Potencial Volume (**)
6.8
96
81
3,067
33
3.0
31

(\*\*) According to Cochilco's forecast (2015): US\$ 77 billion with 42 projects

# 1. Mining production <sup>(2/3)</sup>

## a. Growth in copper production from 1990 to 2014

Final product	Production (metric ton)		World share (%) 2014 (ranking)
	1990	2014	
Mine (total)	1,588,400	5,750,000	31.1 (1)
Concentrate	259,9	2,549,800	18.9 (1)
Cathode SX-EW	122,1	1,844,000	48.0 (1)
Cathode E-R	955,6	885,4	9.0 (3)
Blister and other (*)	250,8	470,8	N.A.

(\*) blister and fire refined; N.A.: not available

## b. Main copper producers, 2014

Operation	Main Owners	Production	
		(kton)	% total
7 operations (*)	Codelco (100%)	1,841	32.0%
Escondida	BHP-Billiton (57.5%), Rio Tinto (30%)	1,165	20.3%
Collahuasi	Anglo American (44%), Glencore (44%)	470	8.1%
Los Bronces	Anglo American (50.1%), Codelco (24.5%)	437	7.6%
Los Pelambres	Antofagasta Minerals (60%), Japanese investors (40%)	405	7.0%
Centinela (**)	Antofagasta Minerals (70%), Japanese co.	278	4.5%
Pampa Norte (***)	BHP-Billiton (100%)	256	4.5%
El Abra	Freeport McMoRan (51%), Codelco (49%)	166	2.9%
Candelaria	Lundin Mining (100%)	135	1.7%
Zaldívar	Barrick (50%), Antofagasta Minerals (50%)	100	2.2%
Others	Over 20 medium size mines and small operations	492	9.7%
<b>Total</b>		<b>5,745</b>	<b>100%</b>

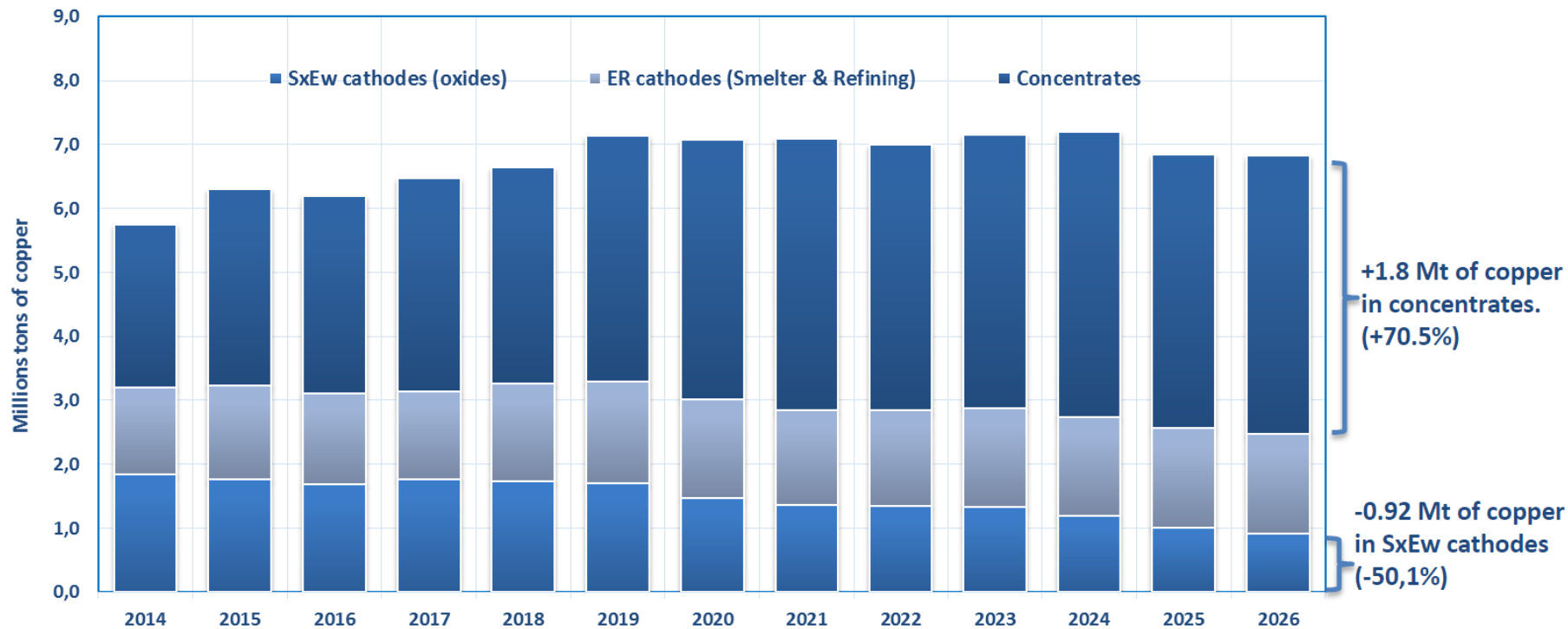
(\*) Chuquibambilla, Radomiro Tomic, Ministro Hales, Gabriela Mistral, Salvador, Andina and El Teniente

(\*\*) El Tesoro and Esperanza mines

(\*\*\*) Cerro Colorado and Spence mines

# 1. Mining production (3/3)

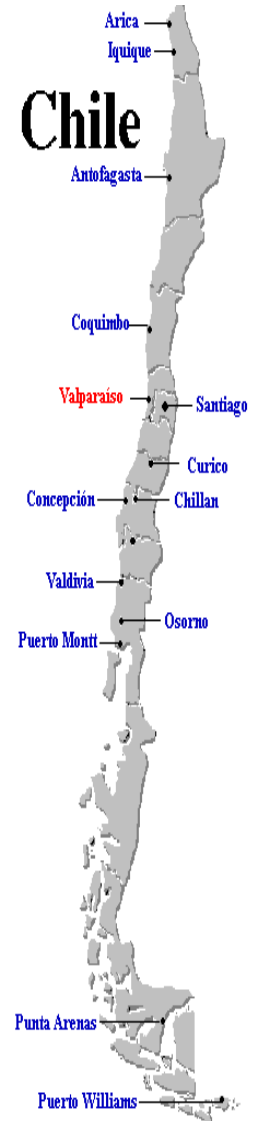
## c. Copper Production Forecast, 2014 - 2026



- By 2026: >90% of new Cu production will be in the form of concentrate
- Concentrate exports:
  - 2014: 2.55 Mton (65.3% of the total production)
  - 2026: 4.4 Mton (73.6% of the total production)

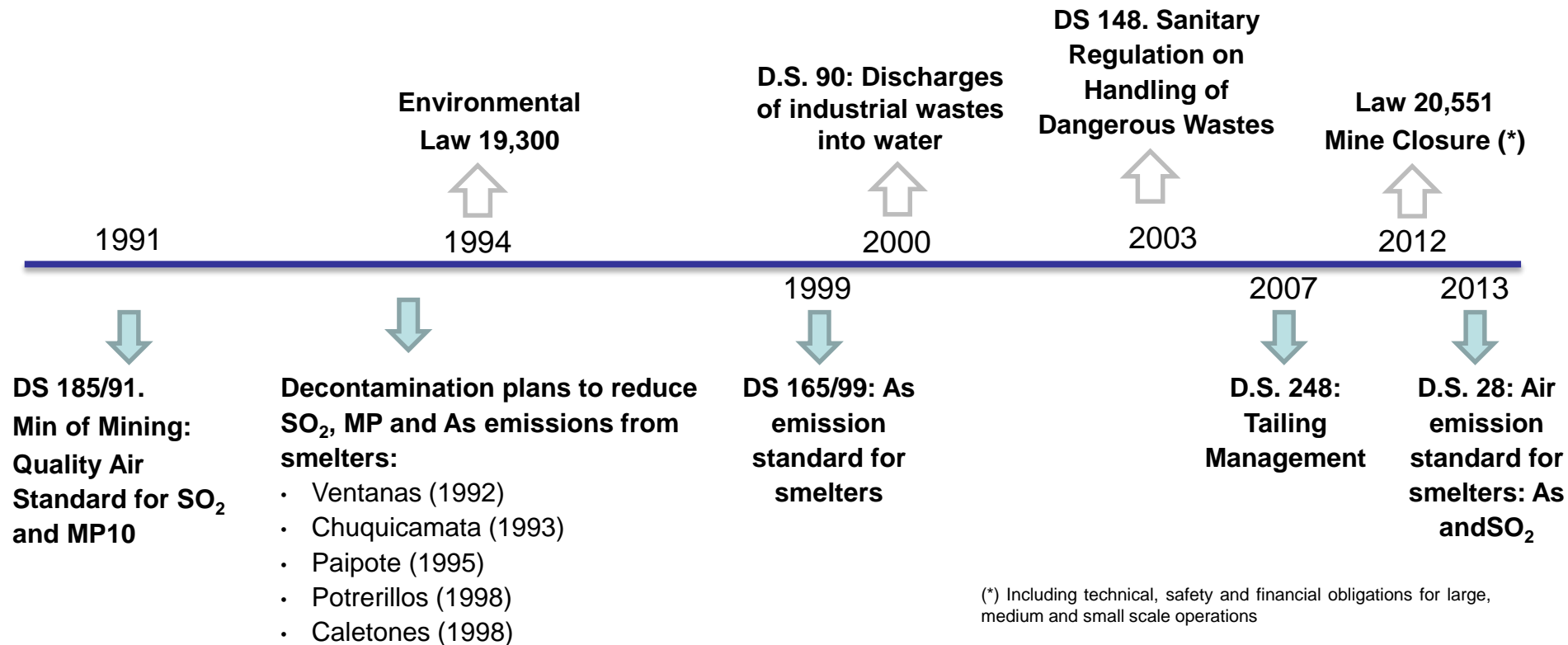
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## 2. Environmental regulations (1/3)

### a) Regulations affecting mining operations and copper smelters



**Next environmental regulations?**

## 2. Environmental regulations <sup>(2/3)</sup>

### b) SO<sub>2</sub> and As emissions from Cu smelters, the present standard, and future standard to be reached between 2016 and 2018

Smelter	Sulphur dioxide emissions (t/y)			Arsenic emissions (t/y)		
	Present standard	Average 2007- 2011	New standard by 2018	Present standard	Data 2011	New standard by 2018
Chuquicamata	56,600	92,104	49,700	800	520	476
Caletones	230,000	118,642	47,680	360	250	130
Potrerillos	100,000	82,258	24,400	800	600	157
Altonorte	24,000	44,251	24,000	126	97	126
Ventanas	90,000	18,820	14,650	120	90	48
Chagres	14,400	13,437	13,950	90	3	35
Hernán Videla Lira	40,000	23,021	12,880	34	12	17
Ministro Hales (*)	-	-	548	-	-	1

Note (\*): roasting plant starting operation by 2014.

- Investment to reach new standard (95% S capture): US\$ 2 billion, mainly from State's smelters: Codelco and ENAMI facilities
- In process: review quality standard for SO<sub>2</sub> – by 2020

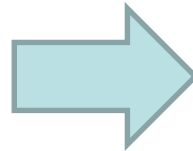


## 2. Environmental regulations <sup>(3/3)</sup>

### c) Law 20,551: mine closure for mining and metallurgical operations

#### Main objectives:

- To protect life, health and safety of people and the environment.
- To mitigate the negative effects of the mining industry.
- To avoid “new” abandoned mining operations and plants.
- To ensure the physical and chemical stability of mining facilities (i.e. tailings dam)
- To establish a financial guarantees covering mine closure costs.
- To create a post-closure fund for monitoring closed mining operations



#### Main characteristics:

- To submit a mine closure plan to the National Geological Service
- Different requirements, according exploitation or processing rate (10 kt/month)
- working plan and related activities based on risk assesment + economic evaluation
- Proposal of financial guarantees + payment schedule related to mine life

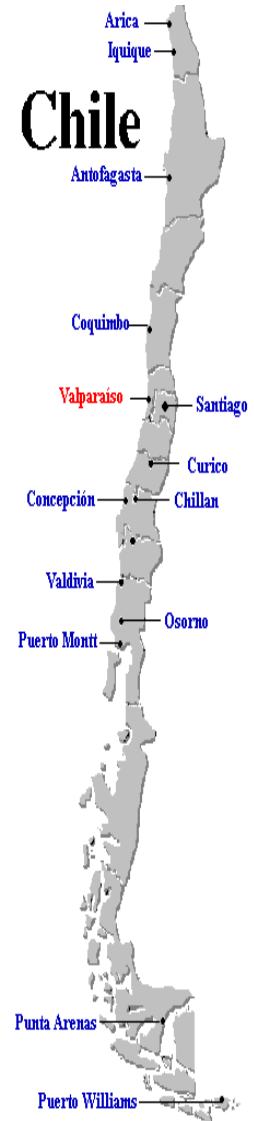


#### Result (to Dec 2014):

- 134 plans were submitted with a total value of US\$ 12 billion

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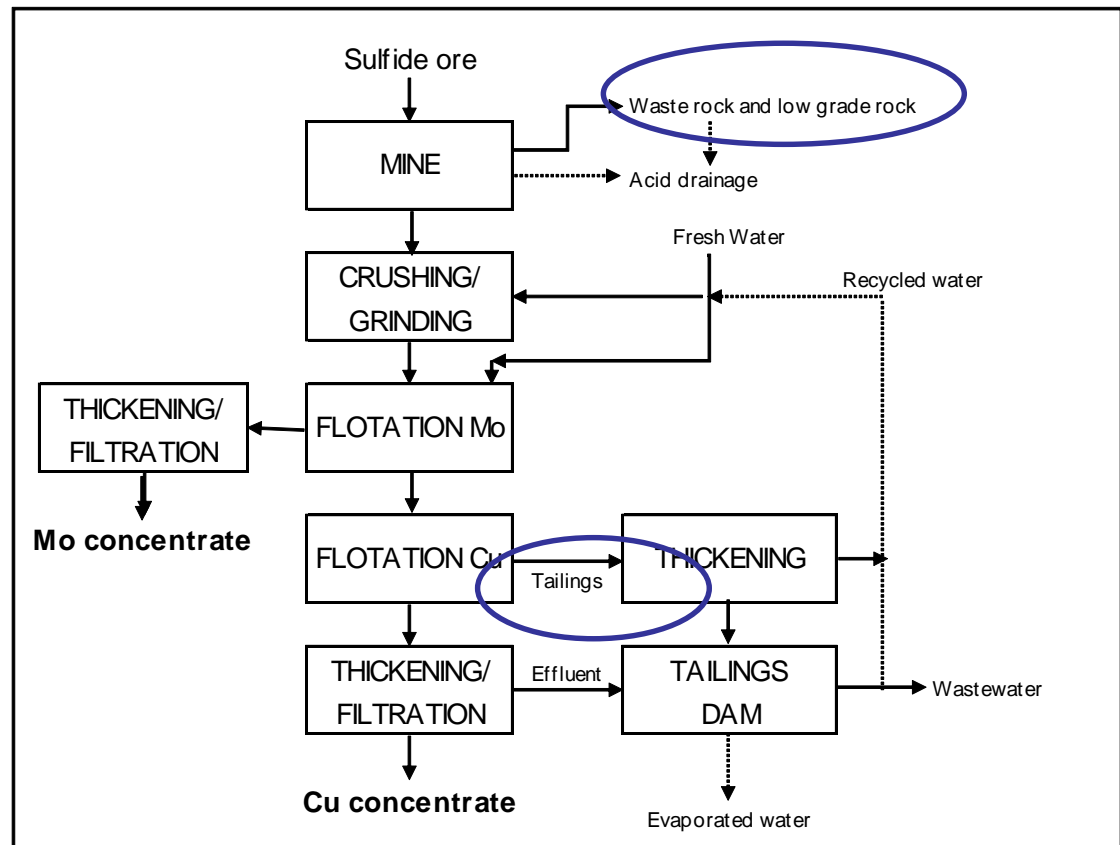
# 3. Waste generation (1/4)


## a) Concentrator plants

- 15 large-size operations (> 50 kton/y Cu production)
- +10 operations of medium-size

### **Tailings generation (Mton/y):**

- 2014: 511 (1.4 Mt/d)
- 2026: 1,078



 = main waste

# 3. Waste generation (2/4)

## a) Concentrator plants: tailings dams

Type	Total		Main regions - location
	N°	%	
Active	161	24.5%	Copiapó, Coquimbo, Valparaíso
No active	364	55.3%	Coquimbo, Copiapó, Valparaíso
Abandoned	94	14.3%	Coquimbo, Antofagasta, Copiapó
Without information	39	5.9%	Copiapó, Coquimbo
<b>Total</b>	<b>658</b>	<b>100%</b>	

### Source of tailings dam – metal processed:

- Copper: 50%
- Gold: 30%
- Without info: 18%
- other: (\*) 02%



**Additionally, over 400 abandoned processing plants**

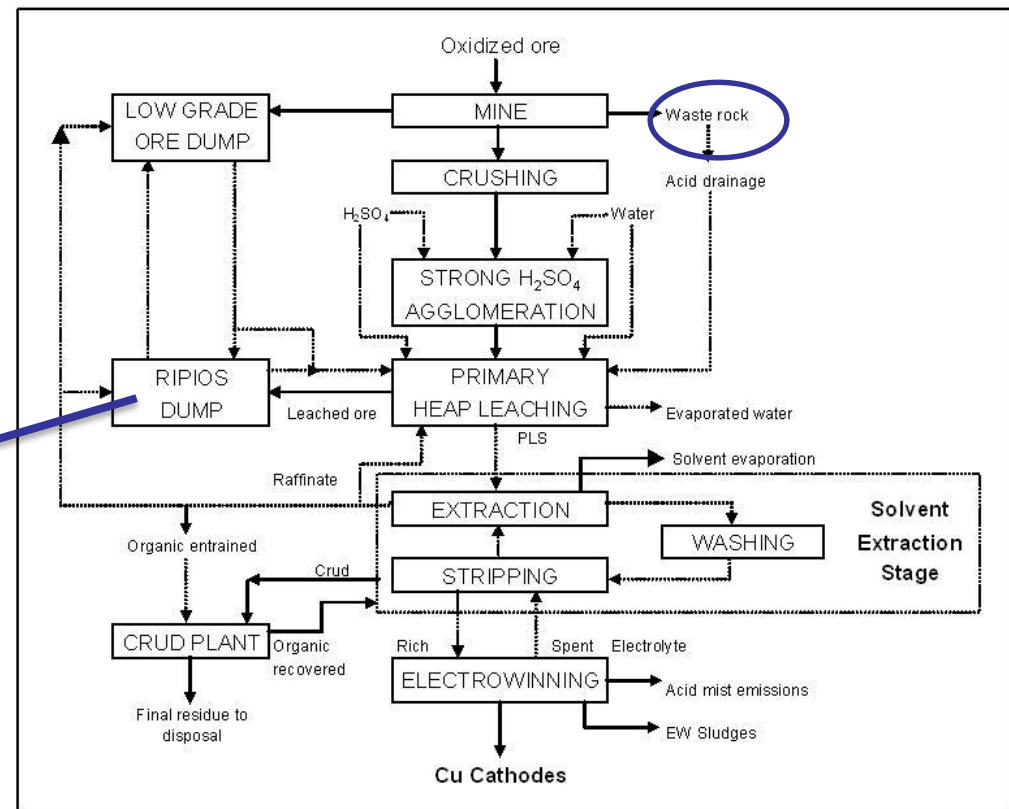
(\*) iron ore, molybdenum, zinc, silver, industrial minerals.

# 3. Waste generation (3/4)

## b) Hydrometallurgical plants

- 13 large-size operations (> 50 kton/y Cu)
- Several operations of medium-size

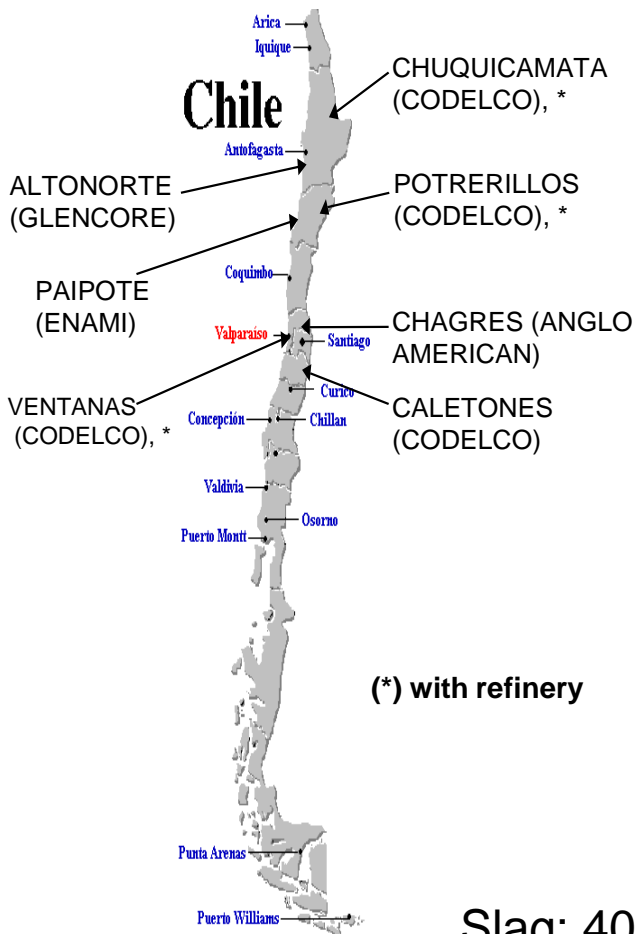
~ 270 Mton/year



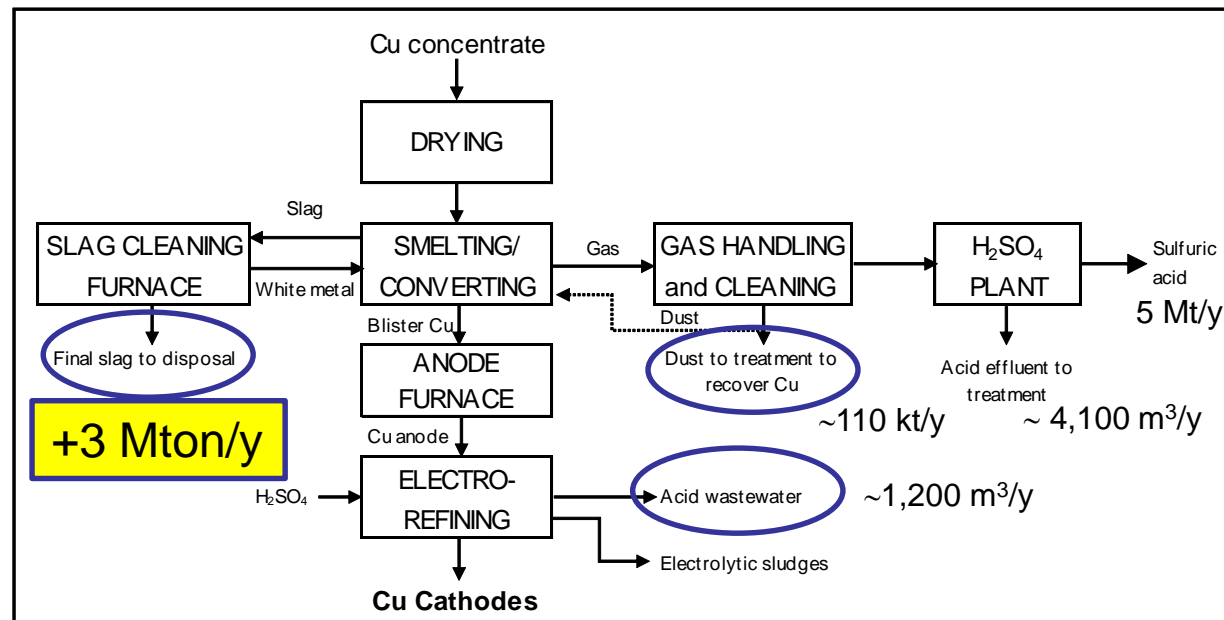
○ = main waste

# 3. Waste generation (4/4)

## c) Smelters



- Smelters using Flash, Teniente or Noranda technology
- Blister production: 100 to 580 kton/y copper



Slag: 40-50 Mt already disposed

○ = main waste

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# 4. Waste management and metals recovery

## Operations

### Smelter flue dusts (2007):

- EcoMetales Limited (Codelco)
- Cu in solution sent to SX-EW facilities

### Cu flotation tailings (2008):

- CMP magnetite plant (CAP)
- Iron ore concentrate

### Acid drainage (1984):

- Underground mine El Teniente (Codelco)
- 3-4 kton/y Cu cathodes

### Smelter flue dust (1982):

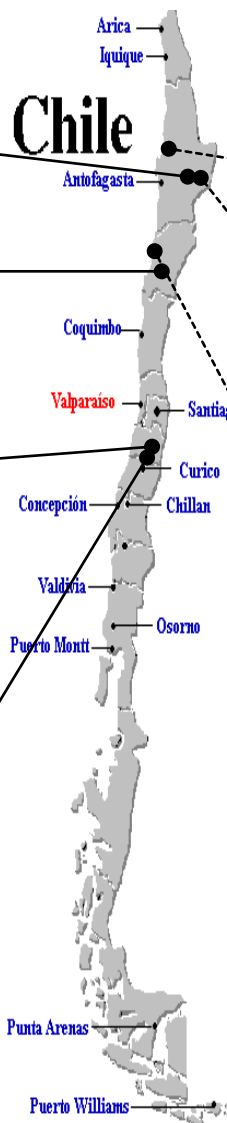
- Caletones smelter (Codelco)
- Cu in solution sent to SX-EW facilities

### Cu flotation tailings (1992):

- Minera Valle Central (Amerigo Res.)
- Cu-Mo concentrate from fresh and old tailings

### Mining waste (year startup):

- Plant's name – owner
- Metal recovery or waste generation



## Projects & R+D

### Anodic slimes (under construction):

- SpA Metals Recovery Plant (LS-Nikko Copper, 66% - Codelco, 34%)
- 4k/y processing plant to recover Cu, Au and Ag and PGM's (Pt, Pd, Rh), Te, Se, etc.

### Roasting plant flue dusts (under study):

- Ministro Hales plant (Codelco) – EcoMetales
- Waste generation: > 20 kt/y containing Cu, Ag, Bi and As

### Old flotation tailings – Chañaral beach (feasibility study):

- Playa verde Project (Copper Bay) to process 5 Mt/y during 10 years
- Concentrate (Cu, Au) and Cu cathodes

### Cu slags:

- Several smelters testing in road construction
- Some R+D to recover metals

### Flotation tailings:

- Several owners
- Lab testing to recover some rare earths, Ge, Ga, Te, Se, etc.



## 4. Waste management and metals recovery

### a) Cu and Mo concentrate from tailings

(2/6)



## 4. Waste management and metals recovery

### b) Iron ore from copper flotation tailings

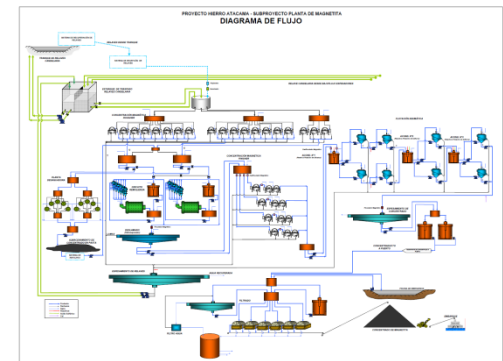
Typical chemical analysis for a tailings generated from a copper flotation process.

% Solid	Fe Total (%)	Fe Mag (%)	P (%)	S (%)	SiO <sub>2</sub> (%)	CaO (%)	MgO (%)	Al <sub>2</sub> O <sub>3</sub> (%)
30	18 -22	10 - 13	0.2 – 0.4	1 - 4	40	3.5 – 4.0	3.5	8 - 9

#### CMP magnetite plant (iron ore operator)

- Since 2008, this plant treats tailings (10% mag Fe and 1% S) from a flotation plant (a copper operation) located in Atacama region.
- About US\$ 70 in investment to produce about 3.5 Mton/y of iron ore concentrate (> 68% Fe)
- Process includes: magnetic concentration (Rougher), Milling, magnetic concentration (Cleaner), Flotation (Inverse pneumatic).

- Challenges: access to port (iron ore exports), high S level in copper tailings



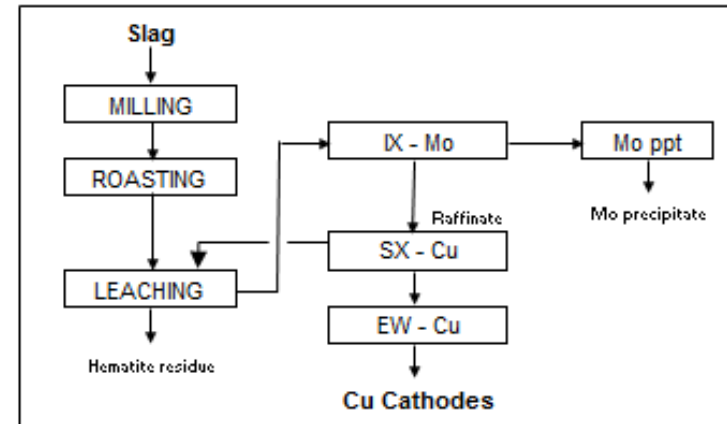
### c) Copper slag: research to recover value metals

- **Chemical analysis: 30-40% Fe, 35-40% Silica, 10% calcium oxide, 1% Cu, 0.3% Mo, as well as Zn and precious metals, among others)**

#### Research and flowsheet proposals:

- Target: recovery of Cu, Mo, Fe.
- Hydro and pyrometallurgical routes have been proposed, including a roasting-leaching, IX (Mo) and SX-EW flowsheet.
- However, no pilot plant yet, and more research is required to solve remaining challenges, such as proper separation of Mo-Fe, and high acid consumption

- Now, testing slag as material for road construction.

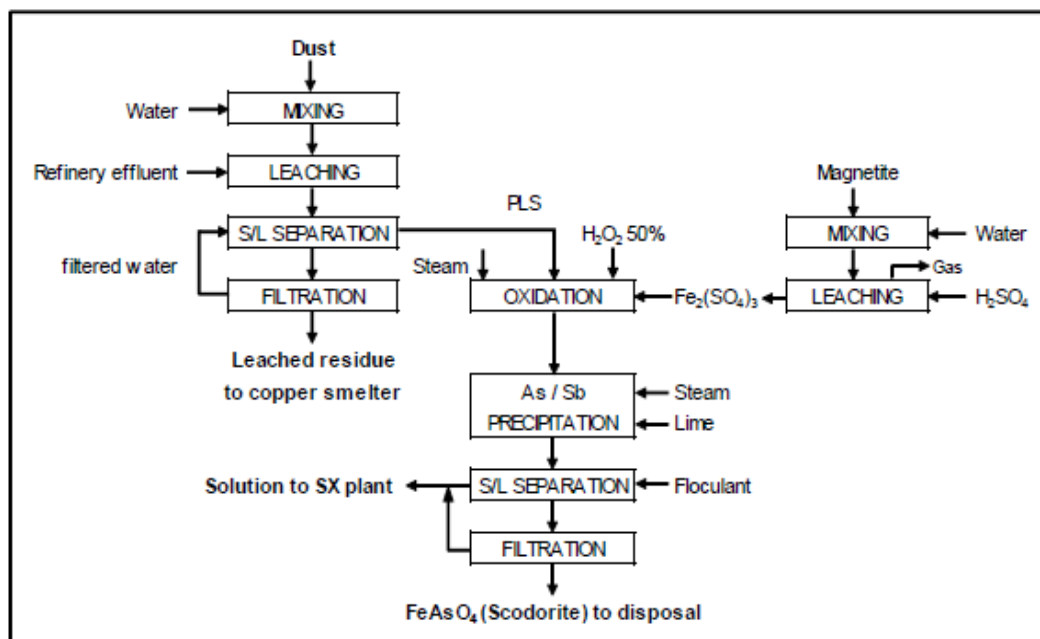


Source: Propuesta recuperación Mo desde escorias, Proyecto FONDEF D02 I 1159, Univ. De Concepción, Chile, 2006

## d) Treatment of smelter flue dusts

- Since 2007, EcoMetales treats smelter flue dusts, mainly generated from Codelco smelters:

Cu	As	S%	Bi	Cd	Pb	Sb	Others
3-30%	1-17%	0.8-13%	0.1-0.9%	0.2-20%	0.5-12%	0.1-1.5%	Ge, Mo, Ag, etc.



EcoMetales plant at Codelco Norte's facilities, Chile

### • Main achievements:

- ✓ >350 kton of dusts and >500,000 m<sup>3</sup> of refinery effluent
- ✓ >67 kton of Cu recovery, contained in a PLS solution
- ✓ Up to 10 kt/y of As is precipitated and disposed of as Scodorite (crystalline ferric arsenate).
- ✓ Precipitation also includes Sb and Cd, meeting D.S. 148 requirements.

**New focus: Recovery of Mo, Re, Ge, Pb, Ag, and other metals from PLS and leached residue.**

## 4. Waste management and metals recovery

### e) Chemical characterization of old tailings (\*)

Chemical element	Minimum [gr/ton]	Maximum [gr/ton]
Mg	800	18,880
Ti	107	4,000
V	27.5	206
Mn	113	37,660
Fe	10.100	183,450
Co	6.0	199
Cu	0.2	19,300
Mo	8.5	200
Zn	0.3	16,290
Ga	2.1	35
Ge	1.0	9.5
Se	0.6	2,202
Sr	72.4	1,138
Sb	2.1	581
Ba	1.0	70,576
W	5.0	52
Te	6.4	8.6



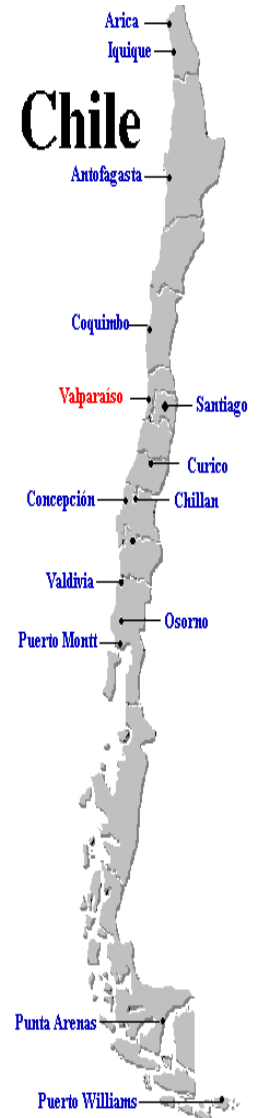
- Lab testing to recover some rare earths, Ge, Ga, Te, Se, Sr, V, etc.

(\*) from medium copper mining companies sites



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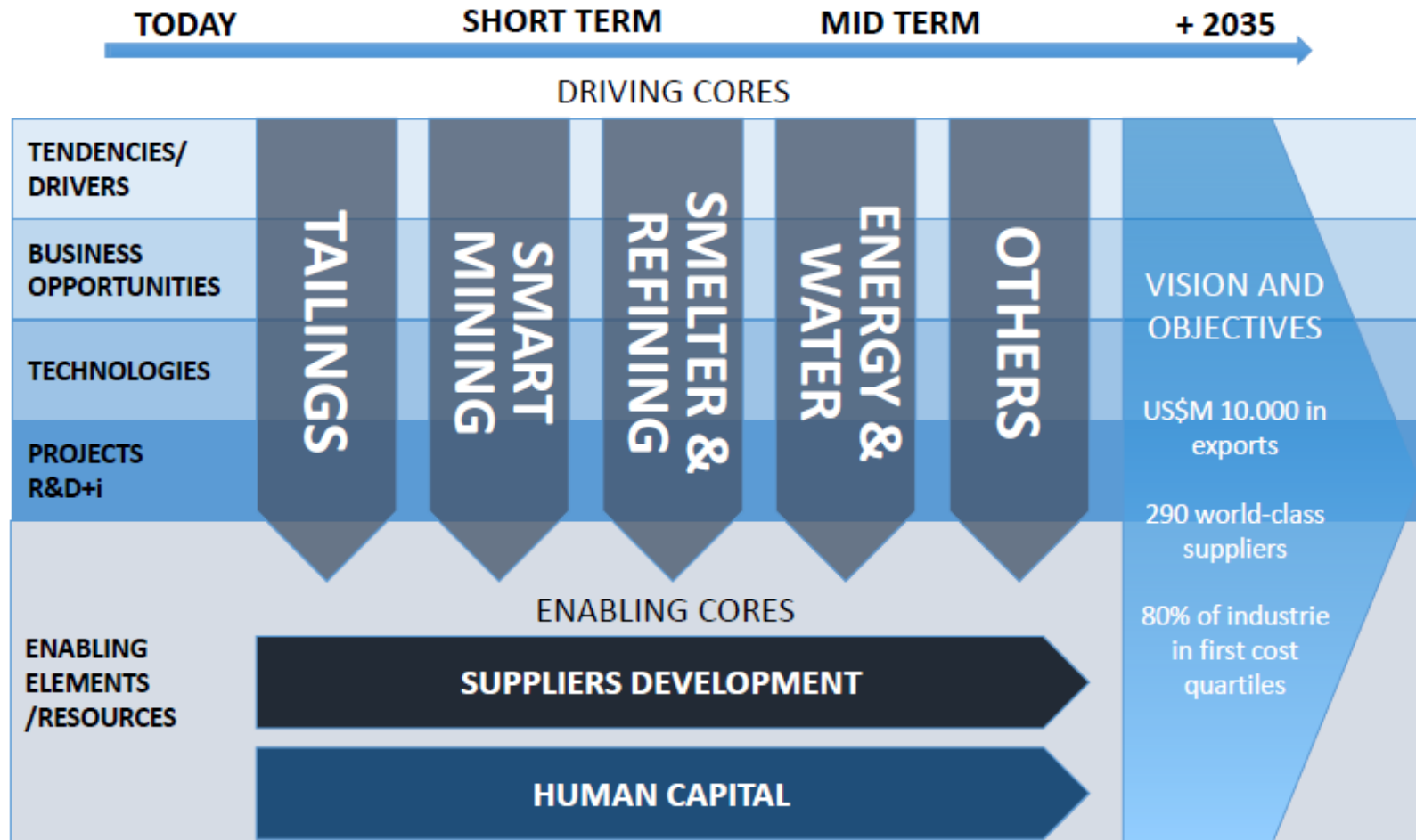
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# 5. Final remarks

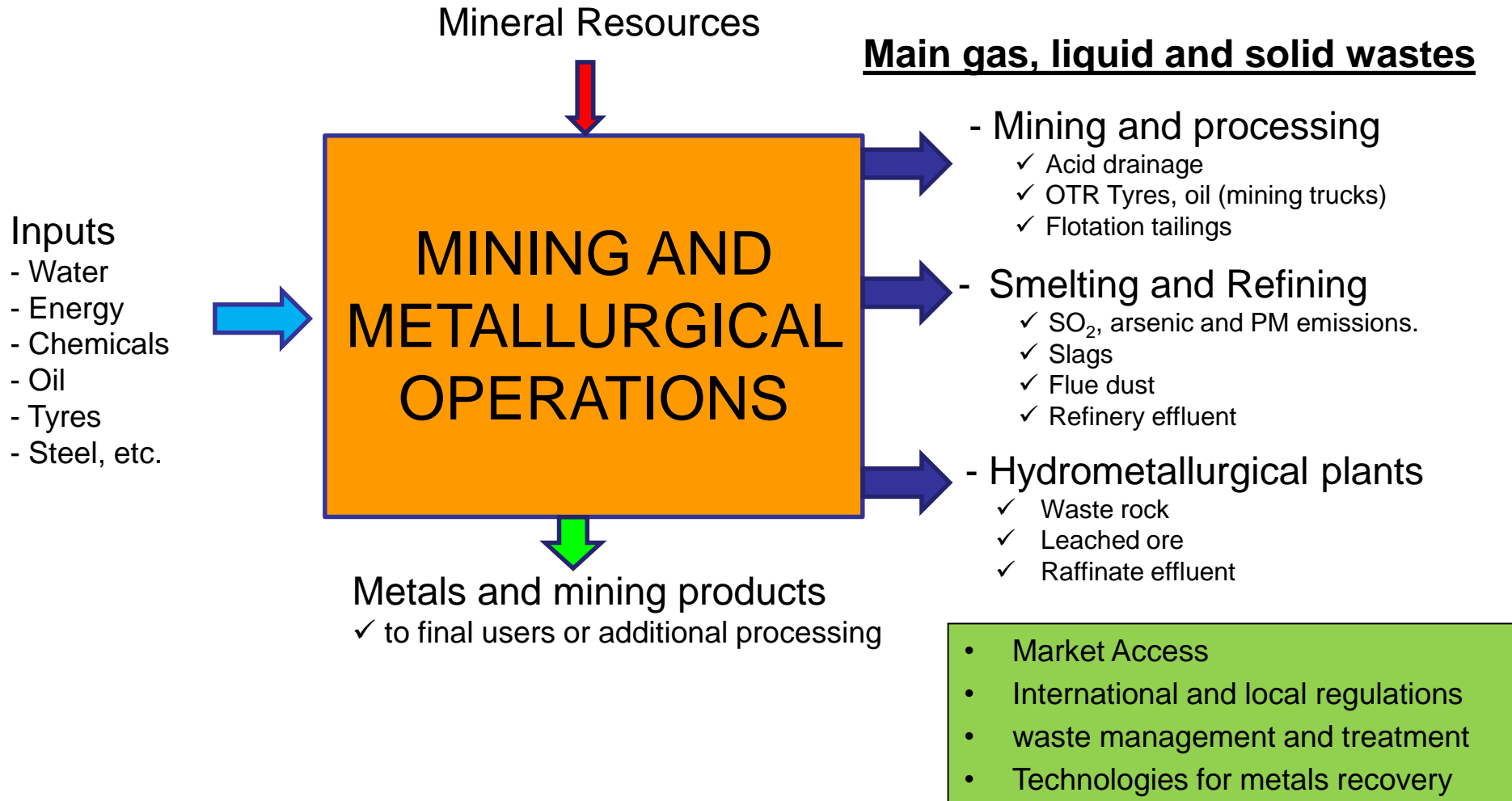
## a) What is Chile doing to stay competitive?

### Roadmap



**AL** Prospecta  
consultores

## **b) Mining Waste: New source of metals and materials**





# CONGRESS EXPOMIN 2016

April 2016, Santiago – Chile, [www.congreso.expomin.cl](http://www.congreso.expomin.cl)



Monday 25	Tuesday 26	Wednesday 27	Thursday 28	Friday 29
<b>Opening Ceremoy EXPOMIN Congress:</b>  <b>“CEO Summit” Round Table</b>	<b>2nd Seminar: “Mining Procurement ”</b>	<b>4th Workshop “Technological Development in Mining” - Codelco</b>	<b>2nd Seminar: “Smelting - Refining”</b>	<b>2nd Round Table: “Labor and Human Resources Challenges in Mining”</b>
	<b>3rd Seminar: “Sustainable Trends”</b>	<b>4th Workshop: “Metal Recovery from Mining Waste” (full-day)</b>	<b>Seminar: “Challenges in Mining Exploration”</b>	
<b>VII Seminar: Mining Competitiveness in the Americas</b>  <b>(hosted by National Society of Mining)</b>	<b>2nd Seminar: “Sea Water for Mining”</b>	<b>Seminar: “Productivity in Mining”</b>	<b>2nd Seminar: “Energy Challenges in Mining”</b>	
	<b>Seminar: “Public Policy in the Mining Sector”</b>  <b>(hosted by Ministry of Mining)</b>		<b>1° seminar: Environmental issues in mining</b>	

Organiza y Produce:



- AL PROSPECTA Consultores: Technical coordination

# 5. Final remarks

## 4th INTERNATIONAL WORKSHOP “METAL RECOVERY FROM MINING WASTE”

### Preliminary program:

- Regulatory and market trends for waste management:
  - ✓ European Commission, China, Australia and Chile
- Impurities: Waste or resources?:
  - ✓ Market trends
  - ✓ Management, neutralization, disposal or production
- Industrial Practices (projects and operations):
  - ✓ Chile, South Korea, Australia, Canada

**Looking forward for proposals!!!!**



**Chairman**

**PEDRO REYES**

General Manager  
Chagres Division  
Anglo American, Chile

### Technical Committee

- Anglo American
- BASF
- EcoMetales Limited
- ENAMI
- 5NPlus
- UNAB
- EXPOMIN



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