1º SEMINARIO INTERNACIONAL

INNOVACIÓN EN PLANTAS HIDRO-METALÚRGICAS

1º INTERNATIONAL SEMINAR:

INNOVATION IN HYDROMETALLURGICAL PLANTS

23
MIÉRCOLES / WEDNESDAY

A sustainable hydrometallurgical process to develop copper deposits challenged with high arsenic

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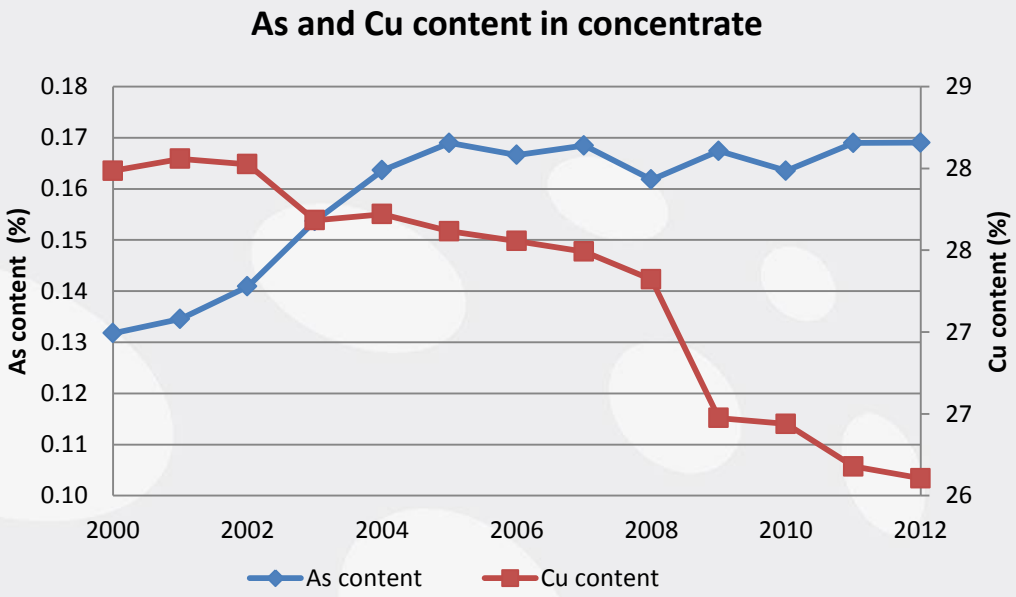
XIII CONGRESO INTERNACIONAL EXPOMIN 2014
13th INTERNATIONAL CONGRESS

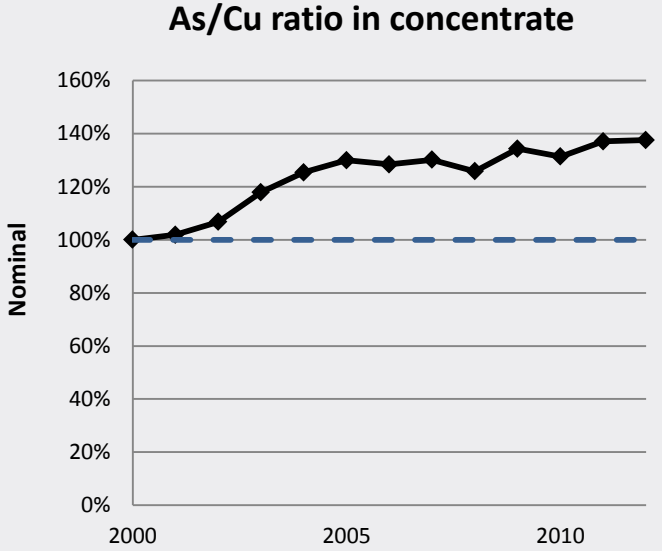
CONTENT

1. INTRODUCTION
2. PROCESS DEVELOPMENT AND RESULTS
3. ECONOMIC FEASIBILITY
4. FINAL REMARKS

ARSENIC IN COPPER CONCENTRATES

Concern for miners, smelters and refiners



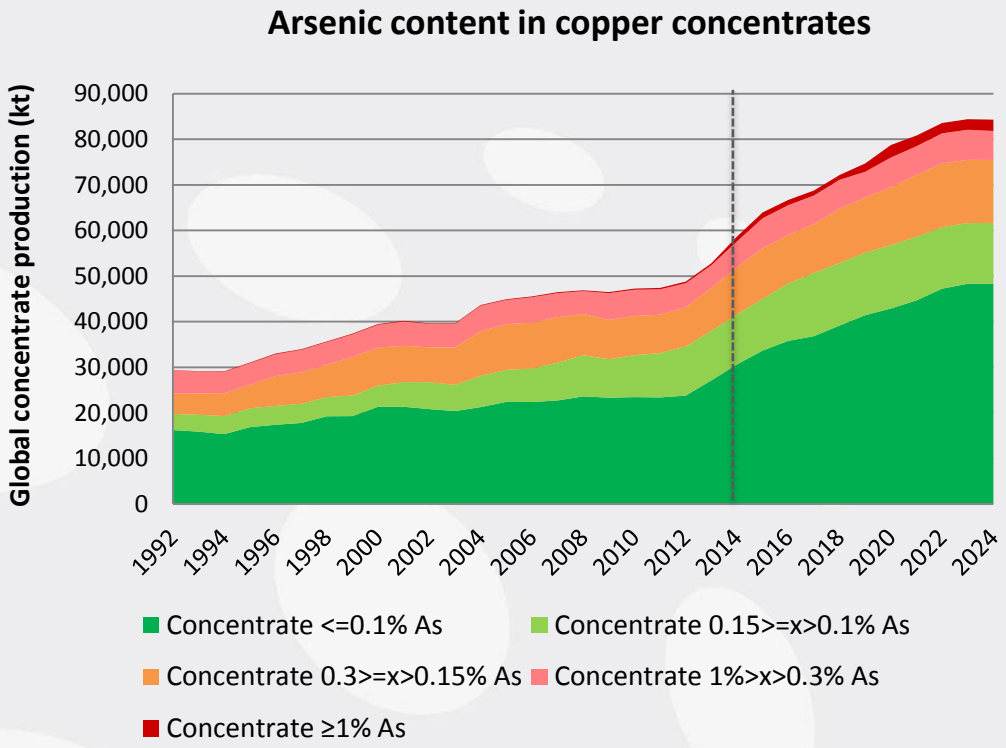


- Although arsenic content in copper concentrates has been stable since 2004, copper contained in concentrates has declined due to more complex mineralogy and lower grade copper ores
- The As/Cu ratio has ***increased by 40%*** in the last decade which causes higher processing and environmental costs
- More stringent environmental regulations, particularly related to arsenic, are making the operation of mines and smelters more difficult

Source: Wood Mackenzie 2013; Internal analysis

INCREASING COPPER DEMAND

The arsenic challenge – a sustainable solution is needed



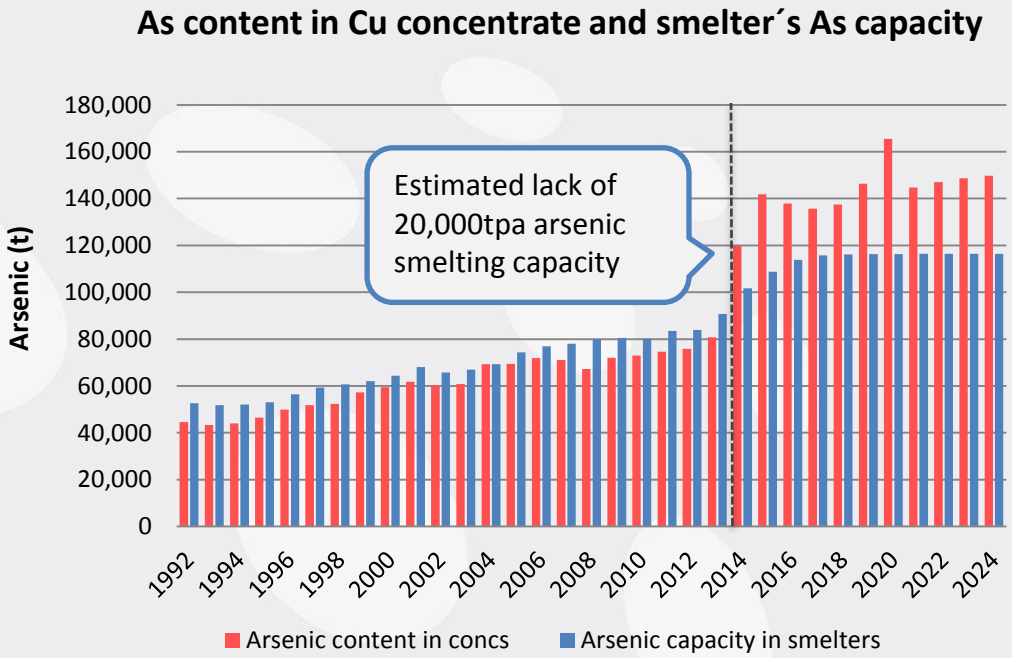
- Arsenic contained in copper concentrates is expected to ***double*** in next 6-years
  - 75,000 tpa (2014) arsenic contained increasing to 150,000 tpa (2020)
  - ~ 2/3 of the additional arsenic derives from high arsenic (>1%) copper concentrates

- A significant amount of high arsenic-bearing copper concentrate (> 1% As), which cannot be processed by standard smelting technology, could enter the market
- Increasingly stringent import bans further reduce the marketability of these types of concentrates

Source: Wood Mackenzie 2013; Internal analysis

LIMITED ARSENIC PROCESSING CAPACITY

A viable process solution is needed



If ***nothing*** changes:

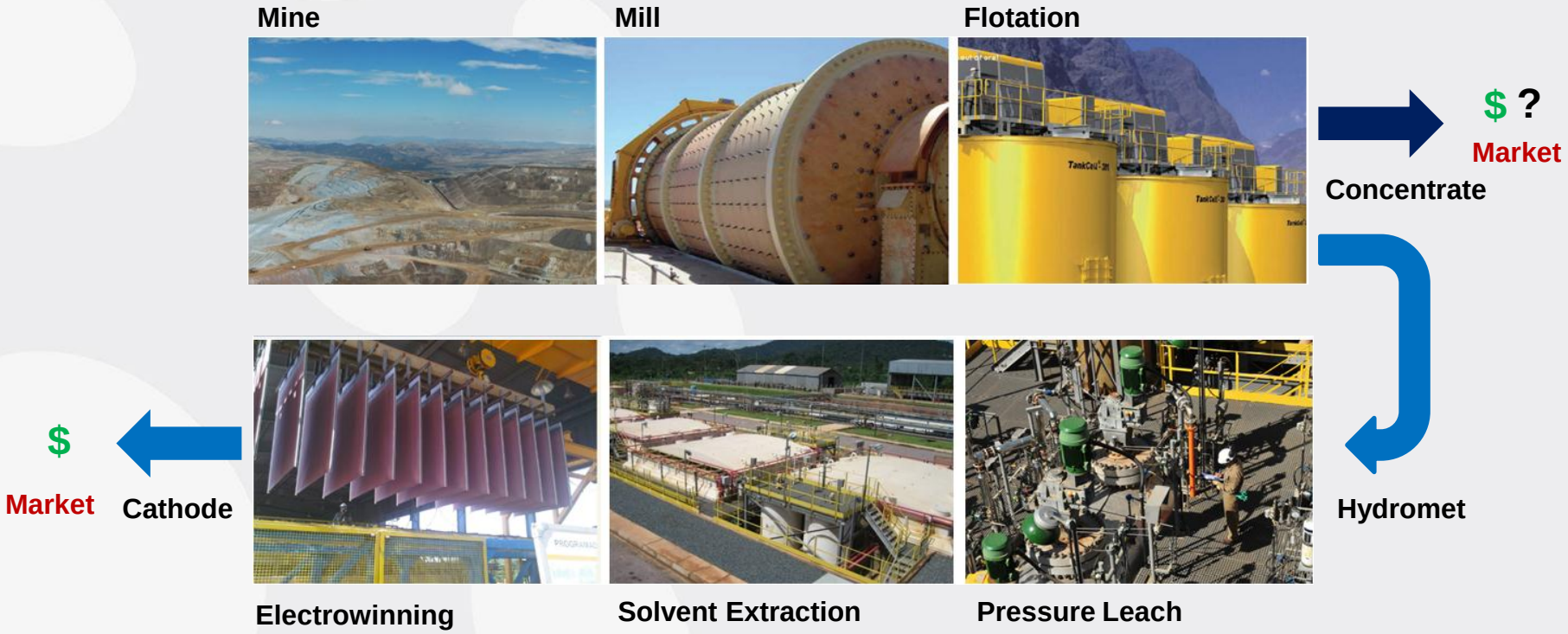
- ~2.8 Mt of copper contained in high arsenic concentrates by 2020 will be processed using technologies that do not meet best-in-class environmental requirements

- New technologies and processes are necessary, especially for high arsenic-bearing copper concentrates (> 1% As), to maintain sustainable copper production
  - Pyro metallurgical pretreatment processes have their own restrictions and additional costs

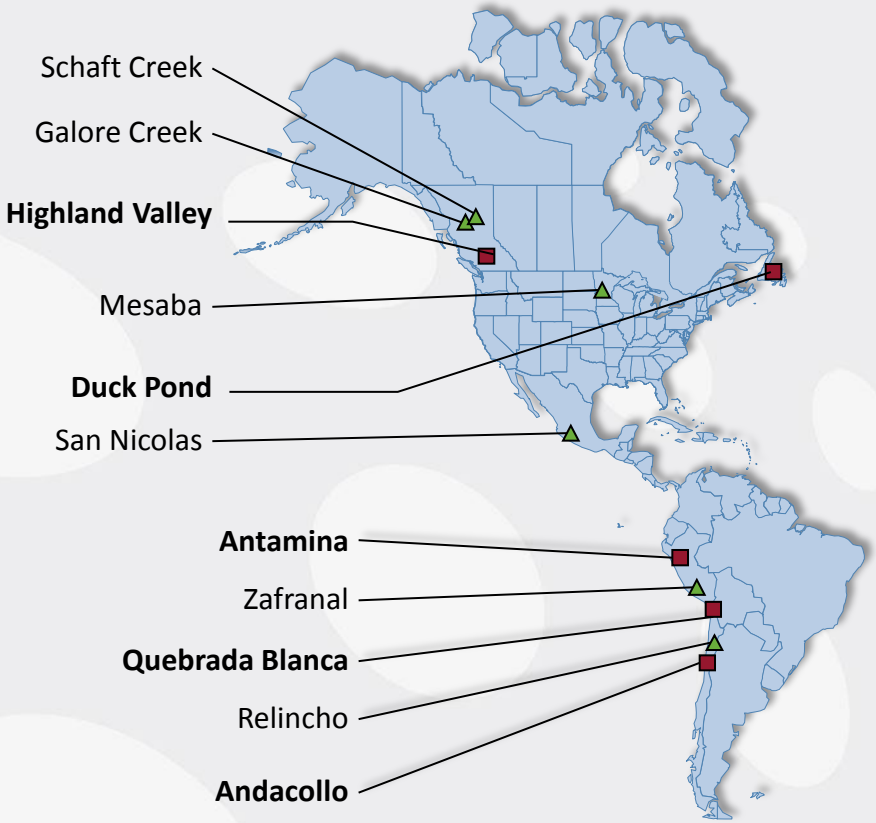
Source: Wood Mackenzie 2013; Aurubis analysis

TECK & AURUBIS – A Strategic Partnership

- Combination of strong technical capabilities (mining, mineral processing and refining) and high environmental, safety and product stewardship standards
- Objective is to unlock high arsenic bearing copper ore bodies for sustainable copper production using a ***mine-to-metal*** approach
- An environmentally sound and cost effective on-site process route can be provided as a technical basis for joint projects with third parties



TECK RESOURCES
A Significant Copper Producer



- **Mine**
- Advanced Project

Highland Valley (97.5%) Large, low-cost copper mine

Antamina (22.5%) Large, low-cost copper-zinc mine

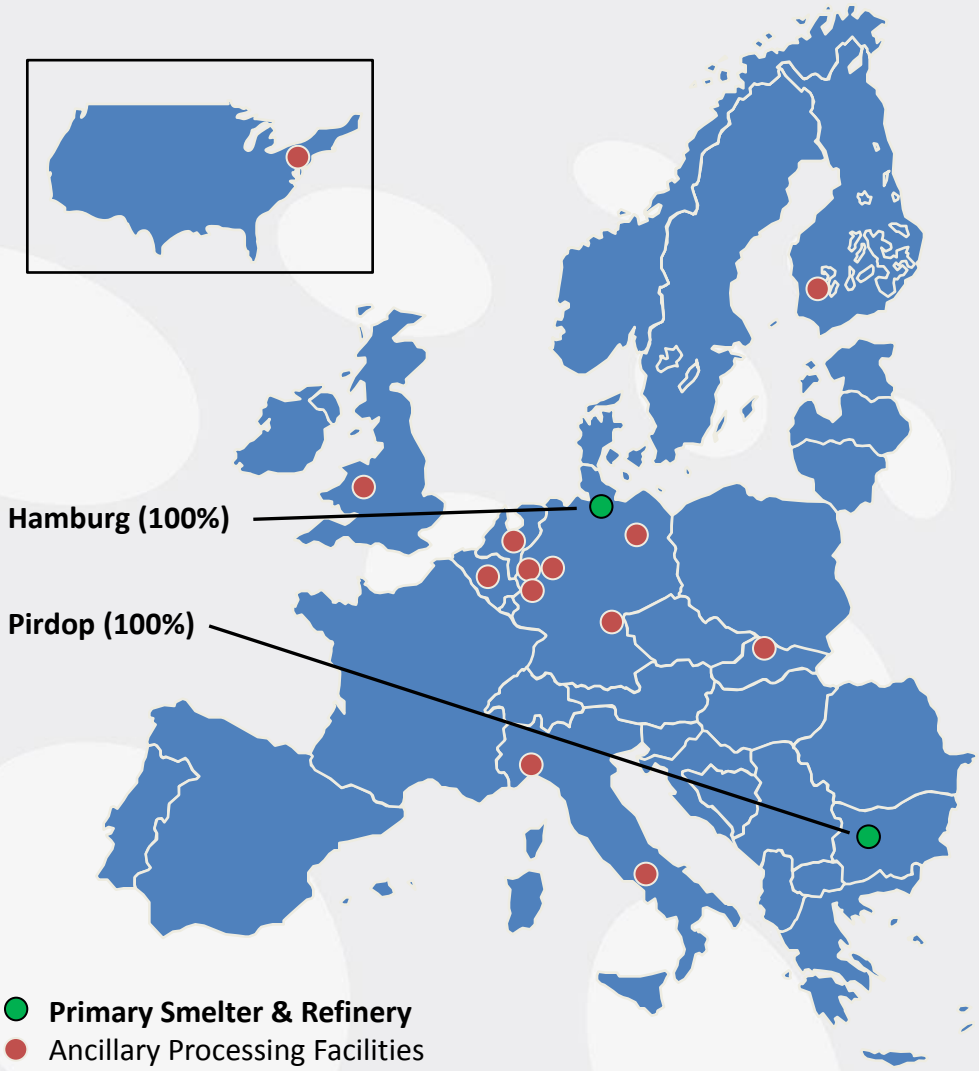
QB (76.5%) SX/EW operation, large sulphide resource

Andacollo (90%) Recently completed expansion

Note: Projects listed have Scoping, Prefeasibility or Feasibility studies completed.

AURUBIS – An Integrated Refined Copper Producer

Production sites



- Largest buyer of custom copper concentrates worldwide (approx. 50 % from South America)
- Second largest international cathode producer
- Leading position in the raw material supply markets
- Improved relative cost position and competitiveness in concentrate processing
- Key strength: environmental compliance
- Leading wire rod producer with expertise and customer proximity
- World market leader in copper recycling

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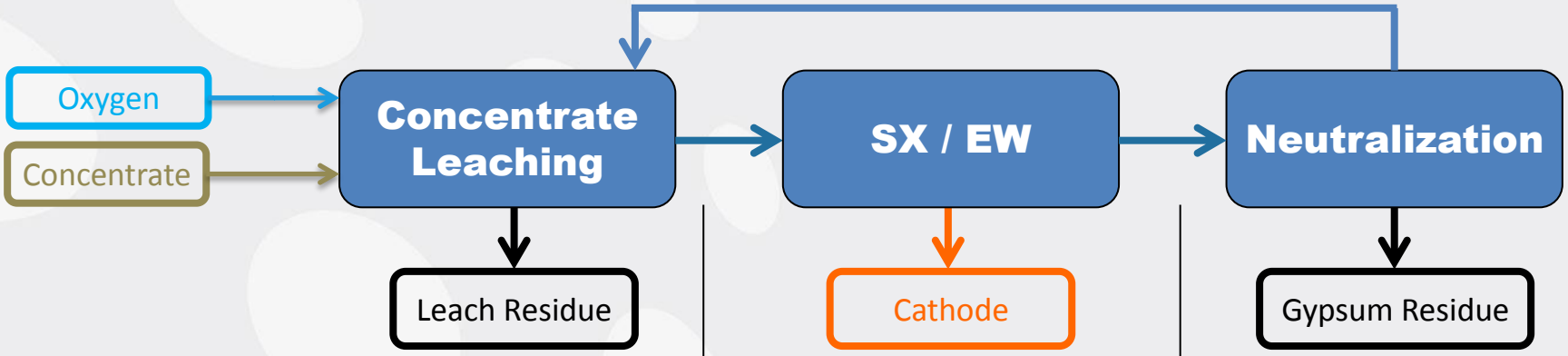
CESL Cu-As PROCESS

- Patented medium pressure-temperature leach process and flow sheet tested on >100 copper-, copper-gold and copper-arsenic concentrates
- Scalable and efficient with potential for integration into existing SX/EW circuits
- Single step fixation of arsenic into highly stable ***scorodite***[1]-bearing residue



- Pressure leach: 1380 kPa, 150°C, 60-90 min
- Leach medium: H_2SO_4 / HCl
- Copper extraction: 97% - 98%
- Arsenic fixation in leach residue (scorodite)

- Standard process
- Direct production of copper cathode
- LME grade A quality copper

- Neutralize excess acid with limestone

1 – Scorodite is a thermodynamically stable ferric arsenate ($FeAsO_4.2H_2O$) mineral favoured by industry for arsenic disposal (Riveros 2001)

FULLY INTEGRATED PILOT PLANT FACILITY
Process Development and Preliminary Engineering Studies

Pilot Autoclave

Stable Residue

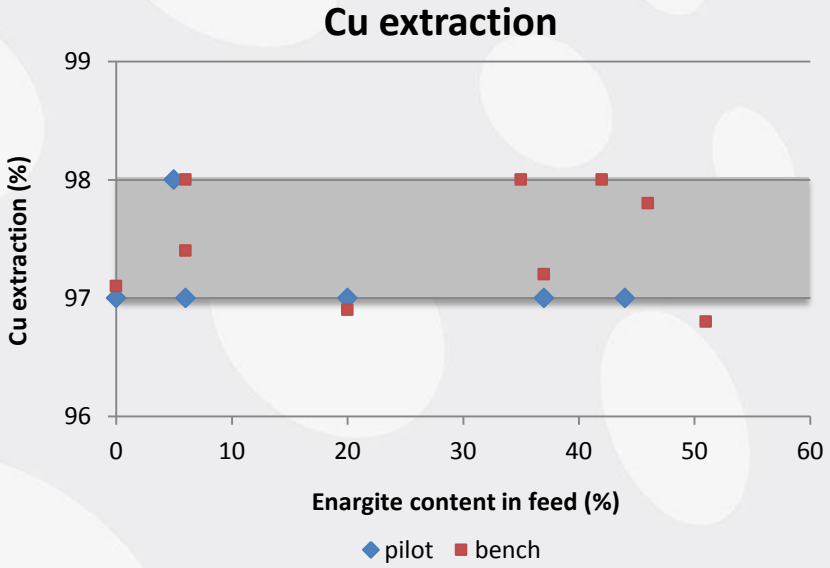
Solid/Liquid Separation

LME Grade A Cu Cathode

- Expert in continuously operated pilot plant campaigns and detailed bench test work
- Typical pilot campaign lasts 6 – 8 weeks and processes ~1 tonne of concentrate per week
  - 5kg/hr concentrate throughput
- Fully equipped laboratory provides analytical support
- Capital and operating cost estimation

CESL Cu-As PROCESS RESULTS

- 16 different ***enargite***[1]-bearing concentrate samples have been tested since 2010
- 10-months of pilot plant operations processing enargite-bearing concentrates
  - Achieved high copper (>97%) and precious metals (>90%) extraction
  - Proved the ability to process arsenic in an environmentally superior manner
  - Collected design criteria data for commercial design and economic evaluation



Arsenic input chemistry and mineralogy

- Arsenic: 1.4% - 10%
- Enargite: 5% - 50%

Process results and outputs

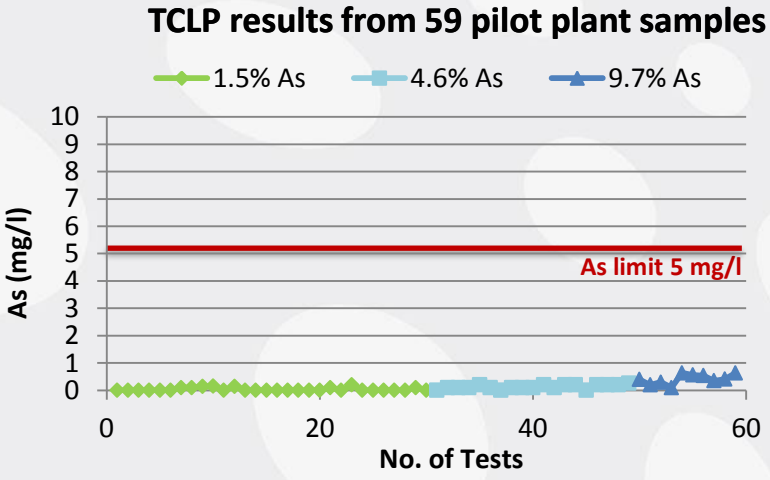
- Copper extraction: 97% - 98%
- LME grade A Cathode
- Stable residue

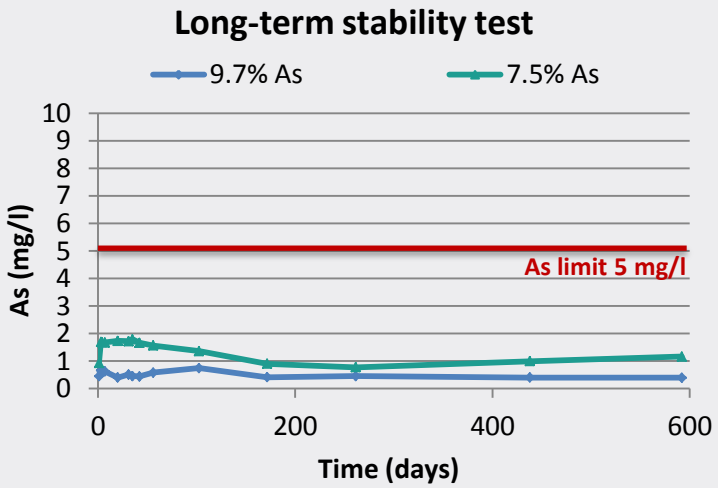
- CESL Cu-As process demonstrated high copper extraction from enargite-bearing concentrates

1 – Enargite is a copper-arsenic sulphide (Cu_3AsS_4) mineral, often refractory in nature, which is a common contributor of arsenic in concentrate from copper mines worldwide

ENVIRONMENT, HEALTH & SAFETY

- Up to 99% deportment of arsenic to stable leach residue
- Arsenic components in residue identified are basic ferric arsenate sulphate (BFAS) and scorodite[1], considered the most stable forms for arsenic fixation





- CESL Cu-As leach residue is characterized as non-hazardous waste (TCLP below 5mg/l arsenic limit) with excellent medium- to long-term stability characteristics
- Samples from pilot plant operations confirmed air quality well below government occupational exposure levels[2]

1 – XRD, MLA, XPS, RAMAN methods, cooperation with McGill University, Prof. Demopoulos
2 – British Columbia, Canada arsenic limit: 12 h shift < 0.005 mg/m^3

CESL Cu-As PROCESS

Best option for high arsenic copper concentrates

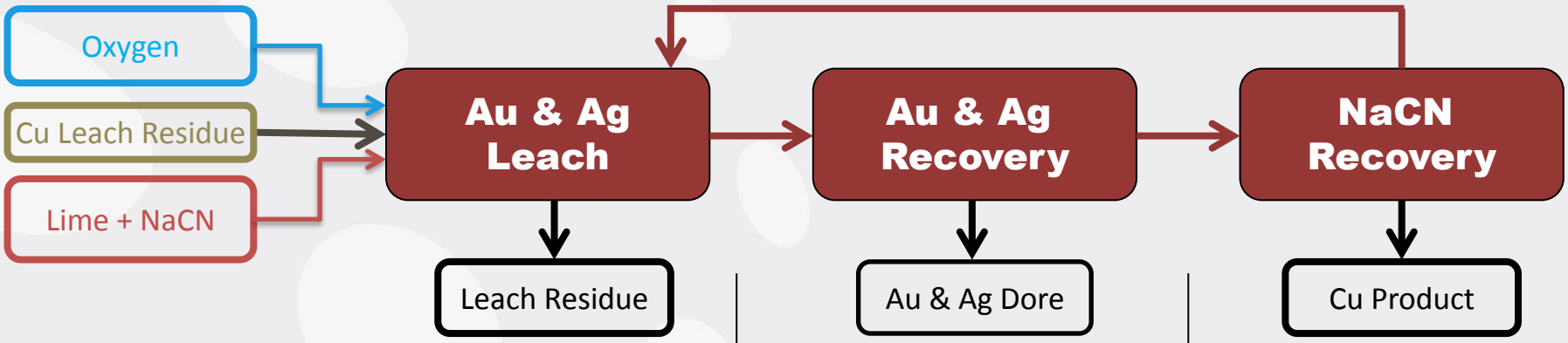
	CESL	TOL[1]
Technological factors		
• High copper extraction, including from enargite	✓✓	✓
• Single step copper extraction and arsenic fixation	✓	✓
• Low oxygen consumption due to partial sulphur oxidation	✓	✗
• Ability to use sea water within process	✓✓	✗
Economic factors		
• OPEX: lower acid neutralization requirements and oxygen use	✓	✗
• CAPEX: smaller autoclave sizing requirements	✓✓	✓
Environment, Health & Safety factors		
• Residue stability, TCLP	✓✓	✓
• Worker safety	✓	✓
• No off-gas emissions, lower water consumption	✓✓	✓
• Residue and waste volumes	✓	✗
Social factors		
• Value added copper cathode production on site	✓	✓

1 – Total Oxidative Leach (TOL)

CESL Au-Ag PROCESS

Optional process add-on to recover gold and silver

- Patented cyanide pressure leach process and flow sheet tested on numerous copper-gold and copper-arsenic concentrates
- Maintains fixation of arsenic in highly stable scorodite-bearing residue



- Pressure leach: 1720 kPa, ambient T and 60-90 min RT
- Gold extraction: up to 95 % (highly dependent on mineralogy)
- Silver extraction: up to 85 %
- Long term stable residue

- Adsorption on carbon
- Gold and Silver dore metal to market

- Recovers >95% NaCN
- Copper byproduct recycled to copper plant
- Bleed stream to cyanide destruction for treatment

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MARKET CONSIDERATIONS

- Long term positive demand for copper requires the development of 6Mt of new mine production by 2023[1], equivalent to 30x 200,000tpa Cu mines
- Declining head grades in existing deposits and new mines, combined with increasing capital and operating costs, require a closer assessment of higher grade arsenic-bearing deposits that remain undeveloped
- Smelter-Refiners have limited capacity to deal with arsenic in their copper concentrate feed in an environmentally sound manner
- Mine-to-metal approach has several advantages including:
  - Value added copper production on-site
  - Potential lower overall project complexity and cost, i.e. removal of concentrate pipeline and dedicated port facilities from project scope
  - Ability to process arsenic bearing ores (and concentrates) on-site
  - Significantly improved material stewardship and arsenic management
- 21st Century Resource Development Concept (mine-to-metal)
  - Allows Cu-As project owners to evaluate a multi-decade operation from the perspective of future operational, environmental & social requirements

1 – Wood Mackenzie (2014)

200 kt Cu MINE TO METAL BUSINESS CASE STUDY

- Teck & Aurubis have completed multiple financial evaluations to assess the commercial viability of a mine-to-metal operation for high arsenic resources using CESL technology
- Mine-mill[1], and refinery[2] cost estimates were gathered from external consulting and service groups and past CESL feasibility studies

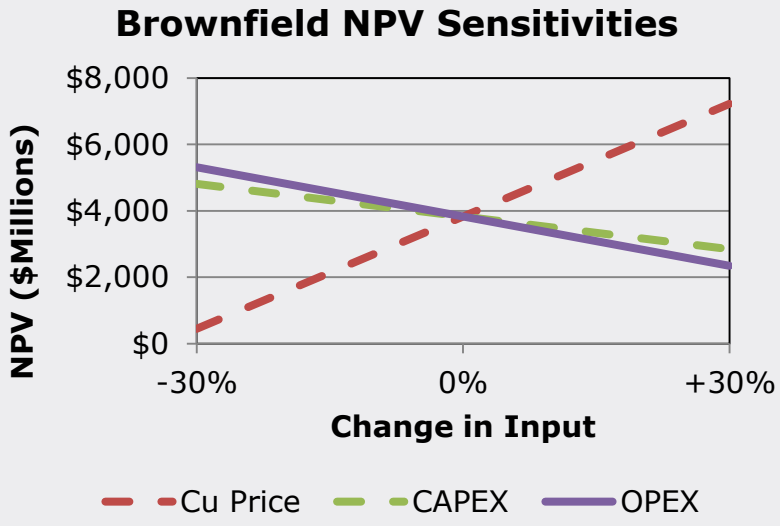
Project Inputs		
Concentrate production	745 ktpa (2,040 tpd)	
Payable Production	200,000 tpa Cu; 65koz/a Au; 1.3Moz/a Ag	
Concentrate Grade	27%	
Arsenic in concentrate	1.5%	
Life of Mine	20 years	
Cash Costs (mine/mill/refinery)	$1.35/lb Cu (net of byproduct credit)	
	Greenfield	Brownfield (existing SX/EW)
Mine Capital[1]	4,000 US$M	3,000 US$M[3]
Refinery Capital[2]	940 US$M	600 US$M

1 – Wood Mackenzie (2013): Greenfield Capital Development Cost - 20,000 US$/t Cu
2 – Internal estimate factored from third party engineering cost estimates for CESL Cu-Au refinery
3 – Assumes $1,000M benefit from existing mine-refinery capital & infrastructure, i.e. pre-strip, mine fleet, water & power, and SX/EW installations, and lower concentrate handling requirements, i.e. no concentrate pipeline and smaller port facility.

CASE STUDY SHOWS POSITIVE ECONOMICS

- Positive results of the case study are:
  - A project of this scale is positive at long-term copper price forecasts
  - Brownfield development, particularly where existing SX/EW capacity and infrastructure is in place, reduces CAPEX and improves project returns
- Project returns are most sensitive to changes in copper price
  - Break-even project returns on brownfield development is $2.28/lb copper

Valuation[1] – Pre Tax		
Financial Metric	Greenfield project	Brownfield project
NPV (8%)	2,600 US$M	3,800 US$M
IRR	15%	20%

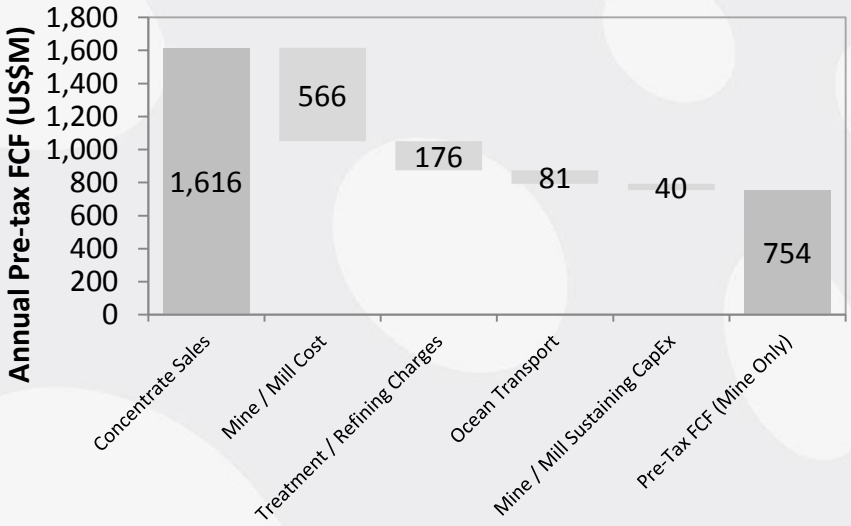


1 – Wood Mackenzie long-term metal prices assumption (2013): 3.50 US$/lb Cu, 1,214 US$/oz Au, 11 US$/oz Ag

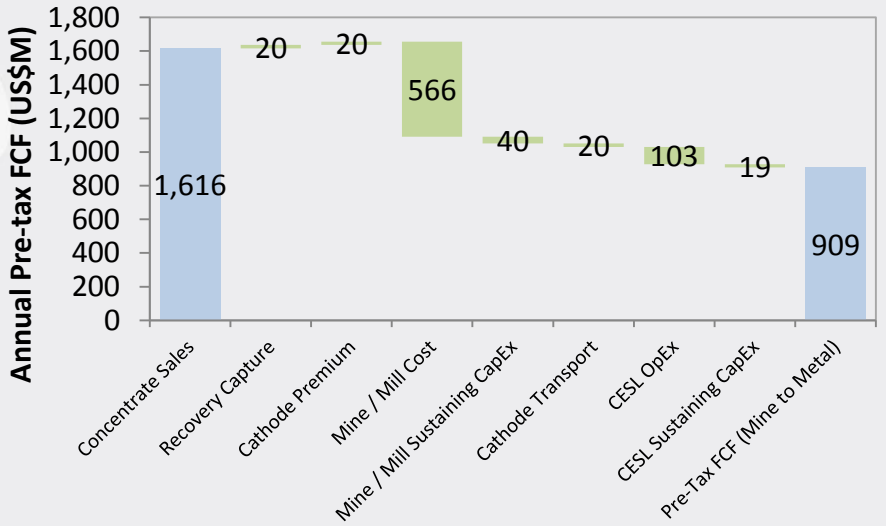
MINE-TO-METAL CREATES REVENUE CERTAINTY

- Revenue certainty in a mine-only approach for a 200,000 tpa copper project with >0.5% to 1.5% arsenic in concentrate is highly improbable in the future
  - Concentrate blending to 0.3% arsenic would require >3Mt of clean concentrate and limit process capabilities of smelter/refinery for other concentrate processing options
  - Regulations restrict marketability of copper concentrate with elevated arsenic

Mine-Only Pre-tax FCF [1]



Mine-to-Metal - Pre-tax FCF [1]



- FCF in a mine-to-metal development is ~155 US$M/annum higher as compared to a theoretical mine-only option and eliminates current & future risk of marketing

1 – Treatment Charge: 93 US$/t concentrate; Refining Charge: 0.09 US$/lb Cu (Wood Mackenzie); Arsenic Penalty: 81 US$/t, Ocean Transport Concentrate: 100 US$/t; Cathode Premium: 100 US$/t; Cathode Transport: 100 US$/t

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FINAL REMARKS

- Teck & Aurubis have developed a hydrometallurgical process for the treatment of arsenic-bearing copper concentrates and demonstrated that it is a sustainable option for the processing of ores and concentrates from arsenic-challenged copper resources
- The process achieves high metal extractions from enargite bearing material and fixes arsenic in a stable, safe and manageable residue
- Long-life mine-to-metal projects have attractive returns at long-term metal prices. Economics are improved with brownfield sites where SX-EW capacity is in place
- Teck & Aurubis' strategy is to use the technology to develop new copper deposits with challenged metallurgy or improve those already in operation with increasingly complex metallurgy
- Teck & Aurubis are open to evaluate and assess opportunities with third parties

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