CEEC
What's Next for improved energy efficiency in copper processing?

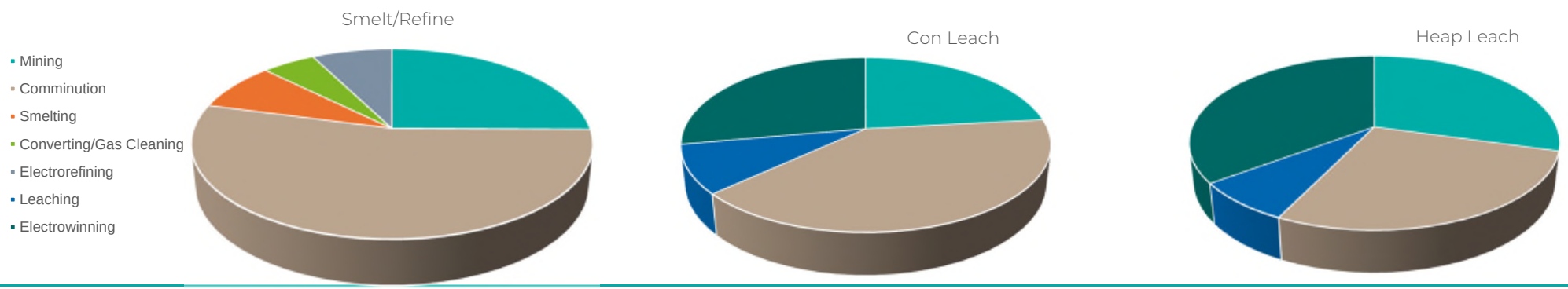
November 2018

GLENCORE

Energy Usage in Copper Processing

Gj/tonne of refined cathode (LME A)

Processing Step	Mine/Float/Smelt/Refine	Mine/Float/Concentrate Leach/EW	Mine/Heap Leach/EW
Mining	23.3	23.3	23.3
Comminution	50.0	40.0	22.0
Smelting	8.6		
Converting/Gas Cleaning	6.7		
Electrorefining	8.0		
Leaching		9.0	6.0
Electrowinning		27.9	27.9
Total	96.5	100.2	79.2



Opportunities for Energy Savings and Improved Efficiencies

Improved energy efficiency in crushing/grinding

- Coarse particle flotation
- DEM assisted design – example in regrind duties

Reducing smelter energy demand

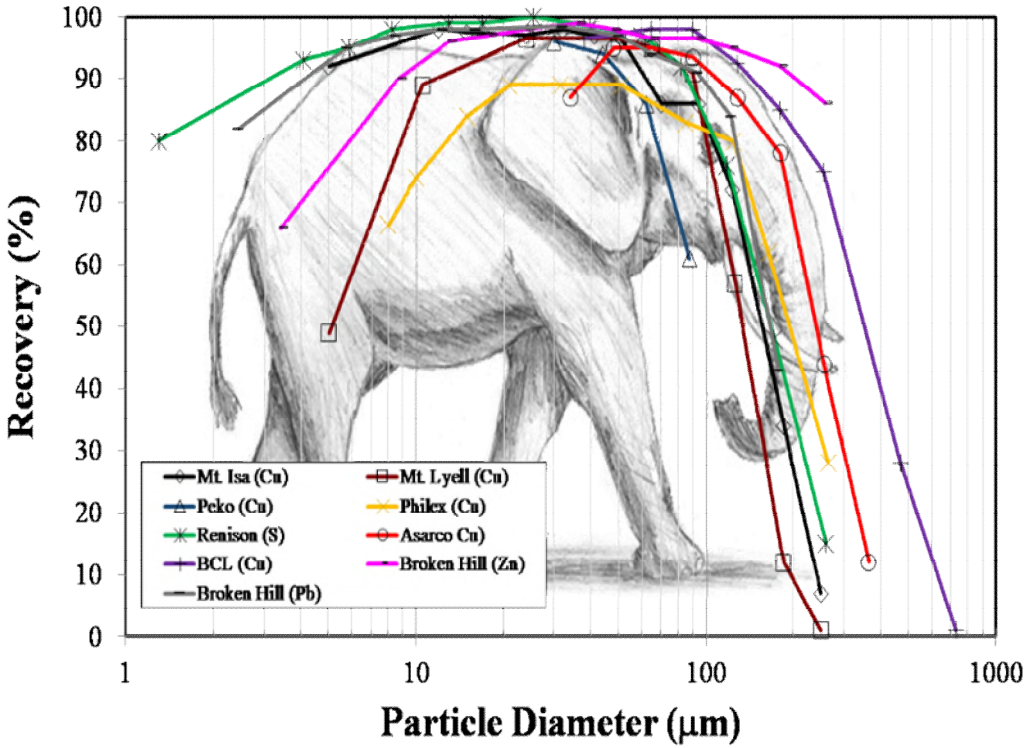
- Improved oxygen and acid plant energy efficiency
- Combined flowsheets for selective leaching of impurities such as arsenic and antimony

Reducing Electrowinning Energy Demand

- Chloride assisted leaching of chalcopyrite
- Improvements in Electrowinning energy consumption

Coarse Particle Flotation

Reducing primary grinding energy

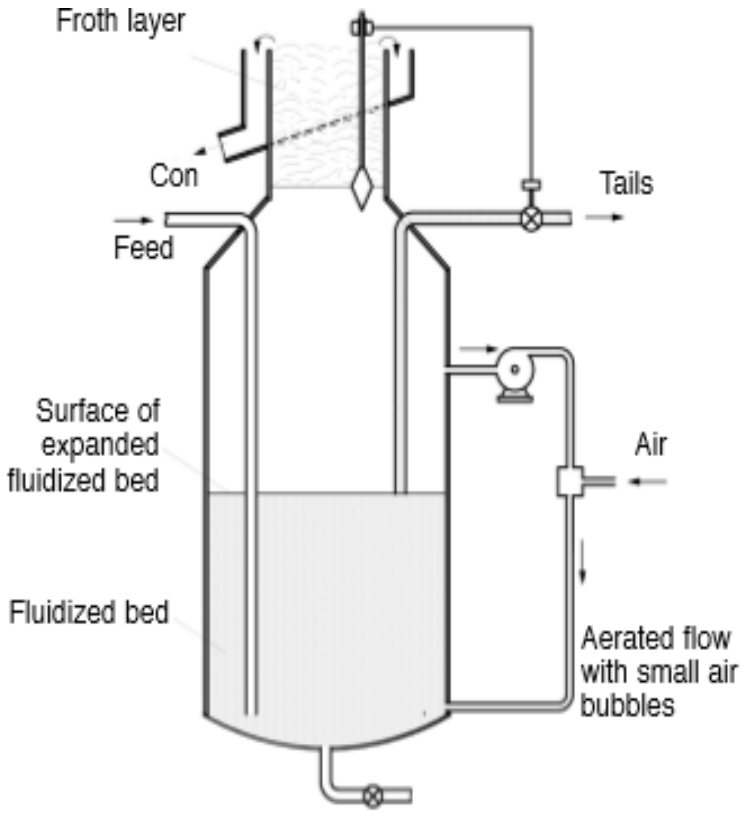


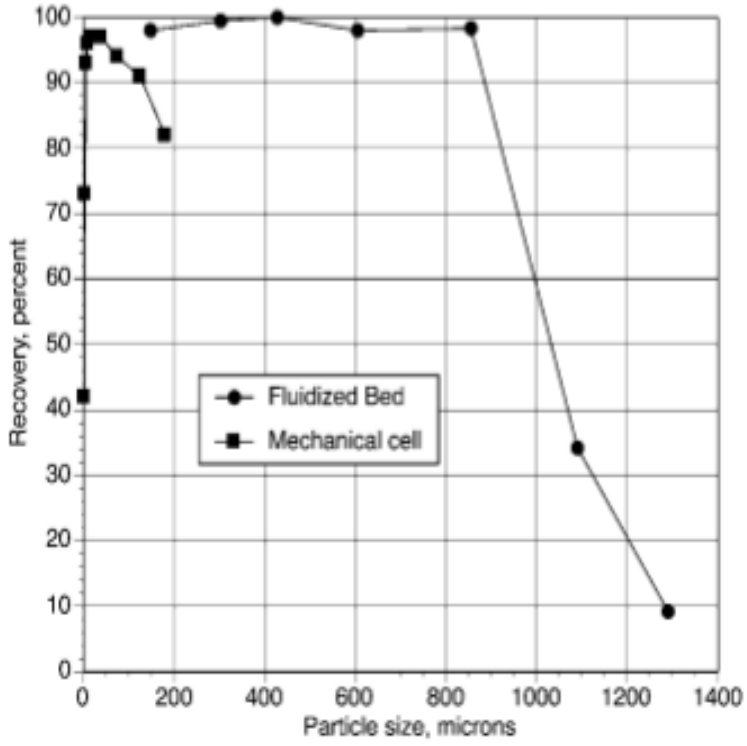
The Elephant Curve
loss of recovery at sizes coarser than 150 microns

- In traditional mechanical cells, shear forces overwhelm those of surface tension, requiring a grind to 150 microns or finer.
- Advances require bubble-particle collisions in a lower shear environment
- The NovaCell combines a high-shear reactor for the capture of ultrafine particles, with a fluidised bed for recovery of coarse particles.
- Hydrofloat also uses a fluidized bed to reduce shear
- These technologies are emerging and several years from widespread commercial application
- The potential is to extend the recovery curve to 800 microns or possible coarser – this could represent a saving of 10 – 15 Gj/tonne of copper for lower grade deposits
- Most likely to find applications on tailings treatment at first

Coarse Particle Flotation

NovaCell results on Galena ore





Improved Regrind Mill Efficiency through DEM assisted design

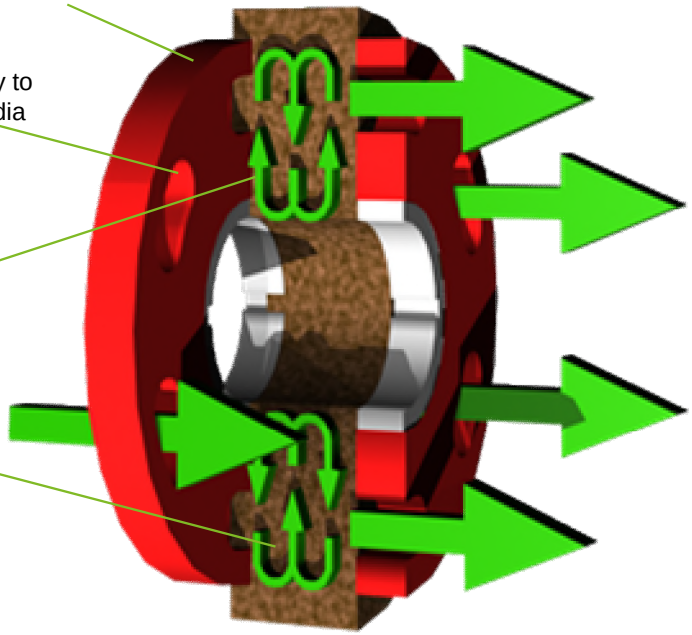
IsaMill™ Grinding Mechanism

1. Shaft Rotating at high speed generating disc tips speeds of between 16-20 m/s.

2. Disc Kidneys impart energy to (accelerate) the grinding media

3. Media centrifuged to outside of grinding chamber by high centrifugal force.

4. Coarser particles centrifuged into zone of high media concentration for size reduction before passing to next stage of processing.



Cylindrical Spacer

- "Inactive volume" immediately adjacent the spacer
- Lower media velocity in this region

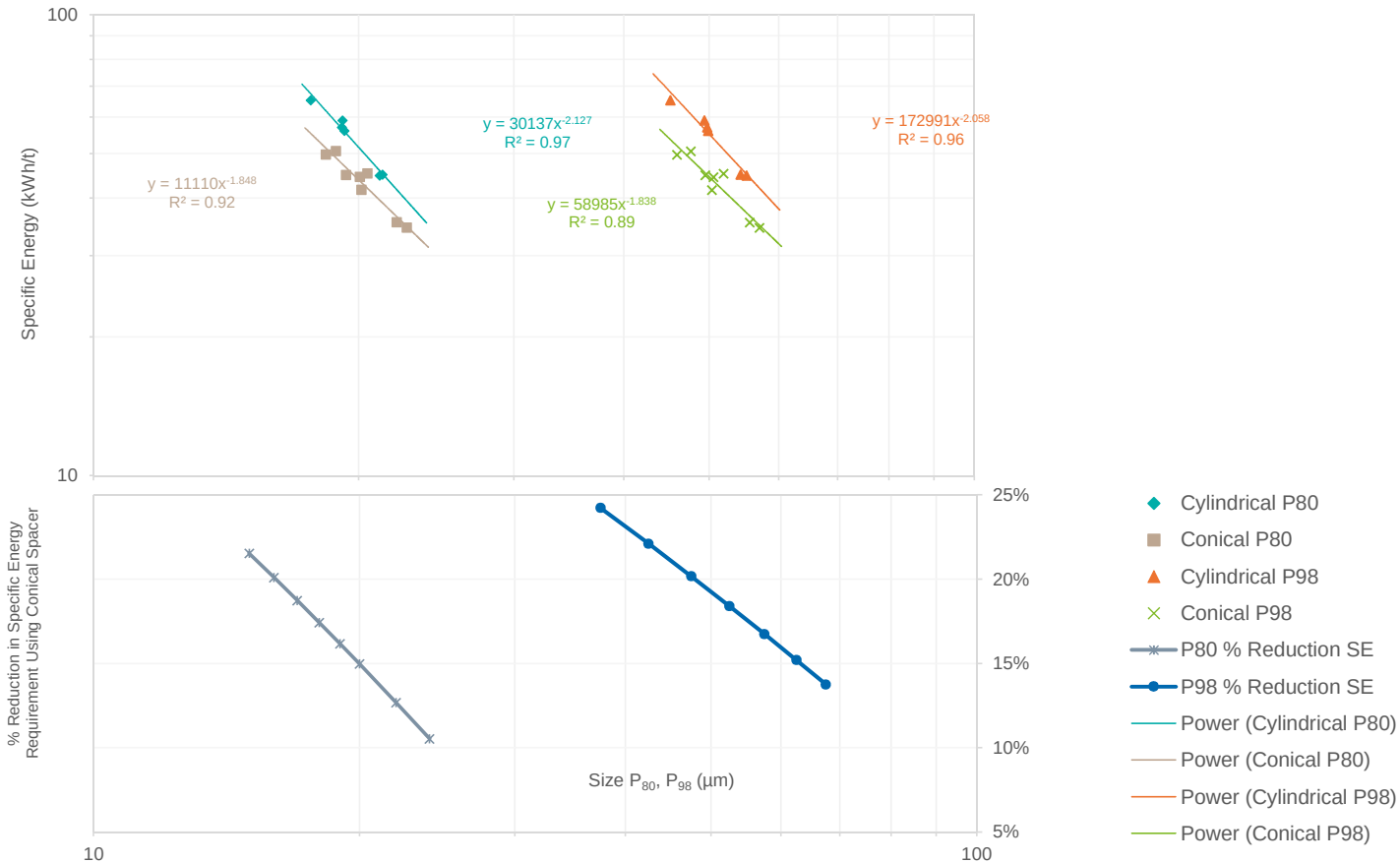
Conical Spacer

- Addresses the "inactive volume" of the cylindrical spacer
- Accelerates media into disc kidneys
- Significantly increases minimum media velocity

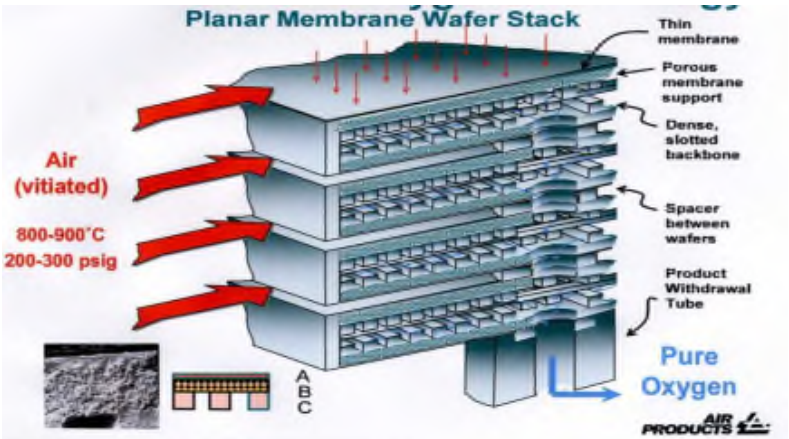
Full Scale Trials

Full Scale Plant Trial Conducted on M1,000 IsaMill at Gold Operation in New Zealand

22 % Reduction in Specific Energy Draw



- Since 1900, smelter energy consumption has dropped by a factor of 30
- Double Flash, IsaSmelt/PS, Mitsubishi all use around 12 Gj/tonne Cu
  - Oxygen generation and acid production account for half of this total
- O_2 enrichment has been central to smelter power improvements
  - Cryogenic plants are only 10 % efficient – 2 Gj/tonne
  - Metal oxide Ion Transport Membranes (800 ^{o}C) – 0.6 – 1.2 Gj/tonne



- More efficient Acid plant - currently 56 % efficiency
  - Chemetics Bayer Isothermal converter technology and improved waste heat recovery credits (0.5 Gj/tonne)
  - Continuous Converting to reduce air dilution – Flash and IsaConvert
- Synergistic smelter/hydromet flowsheets to improve smelter grades and deal with impurities
  - Combining the best of smelting and leaching can save up to 2 - 5 Gj by moving the fuel load to the leach

Glencore African Copper Project

Chalcopyrite concentrate leaching offers potential smelter synergies

Oxidative Leach circuit

First Cathode

Project Details

- Location– Zambia
- Feed – Chalcopyrite Copper Concentrate
- Production rate – 8,000 tpa copper cathode
- Recovery = 99.8 % w/w copper

Potential Smelter Synergies

- Processing of low grade middlings to improve smelter concentrate feed grade
- Production of intermediates for feed to converters as heat sink
- Use of smelter low grade waste heat in the leaching circuit
- Potential use of low grade oxidizing SO_2/air streams in place of oxygen
- Processing high arsenic/antimony smelter dusts
- Processing of lower grade slag concentrates

IsaConvert – Continuous TSL Converting

IsaConvert Plant

IsaConvert

Feed systems

Project Details

- Location – Zambia
- Feed – Copper Matte
- Throughput – 70,000 tpa copper

Potential Energy Improvements

- Highly flexible in feed grades with a combined TSL flowsheet allows good synergies with a hybrid hydromet circuit
- Improved off gas strength to the acid plant
- Decoupling with stored matte provides good process flexibility
- Allows for easy feeding of intermediates from a hybrid leaching circuit

Copper Electrowinning

Improvements in leach/EW flowsheet efficiency

- Electrowinning consumes 27 Gj/tonne in heap leach and concentrate leach flowsheets
- Recent advances have helped to improve this energy demand:
  - Sulphate - Titanium Anodes to replace CaSnPb = 3 – 5 % reduction (~1 Gj)
  - Sulphate – Steerhorn cathodes with improved contacts = 3 – 5 % reduction (~1Gj)
  - Sulphate – Ferric/ferrous couple to replace hydrolysis = 10 - 15% reduction (~ 3 – 5 Gj)
  - Chloride systems – Electrowinning from Cu(i) = 40 % reduction in EW power, with a potential saving of 10 Gj
    - Most materials issues are now addressed
    - Depending on sale of powder product – market is limited and additional energy may be required to re-melt and cast the product
    - Commercially applied on small scale, but could be commercialized in the next 10 – 12 years

Chalcopyrite Heap Leaching

Extend Heap Leach/EW Energy Savings to Primary Copper Resources

- Chalcopyrite heap leaching has been in development for over 30 years
- Recently, good advances have been made by miners such as BHP and FMI with cupric chloride leaching of chalcopyrite
- The solution is to control the potential within the heaps to prevent chalcopyrite passivation using copper ions and chloride levels of 100 – 190 g/l in a sulphuric acid background
- Intermittent aeration will increase the overall energy demand
- Controlled potential via chemistry, irrigation rates and rest cycles have shown recoveries of up to 90 %
- Total Mine to Cathode energy demands in the range of 75 Gj/tonne are possible – a saving of 20 Gj/tonne over the current smelt/refine benchmark.
- Development is probably 10 – 12 years away from broad commercialization.


Thank You