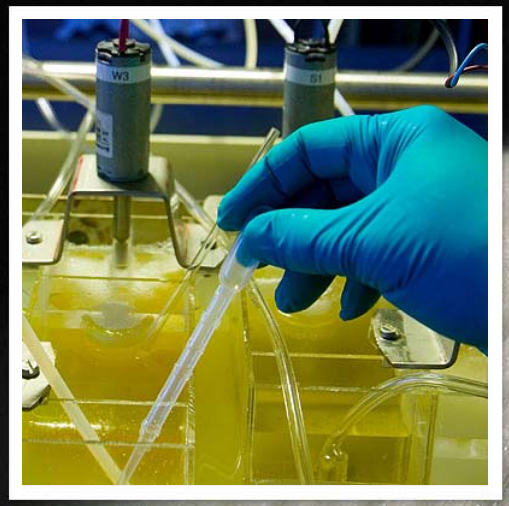


Leading Technologies in Mineral Processing

Overcoming Challenges in Mineral Processing Through Technological Innovations

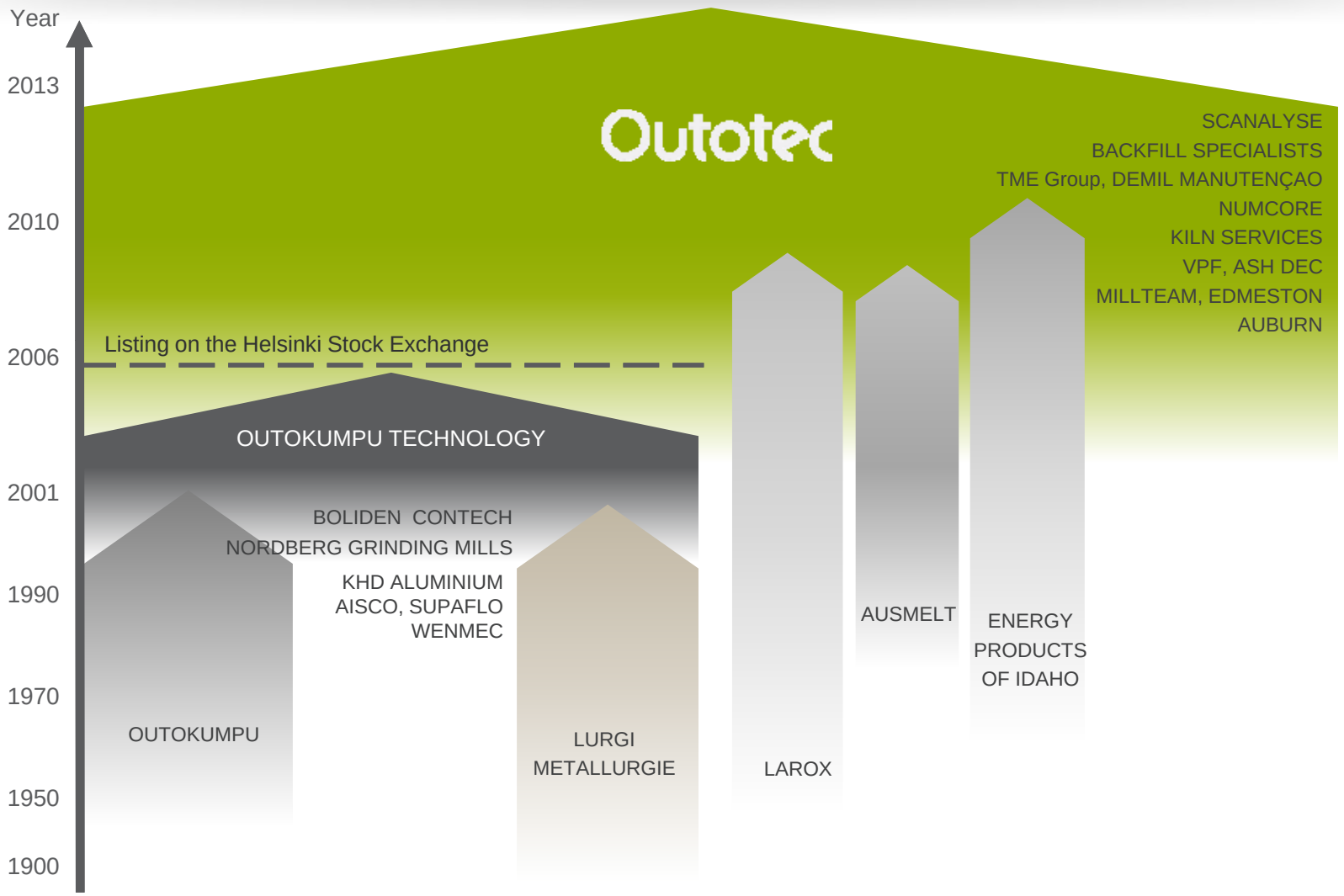
Michael Sue

March 4, 2014

Outotec

More out of ore

Who is Outotec?



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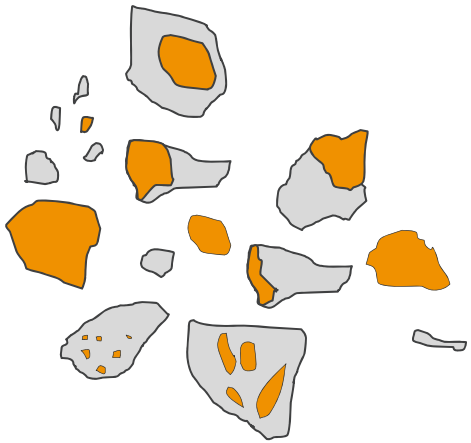
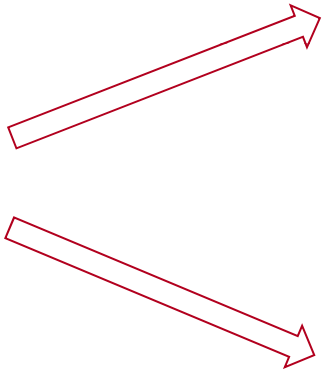
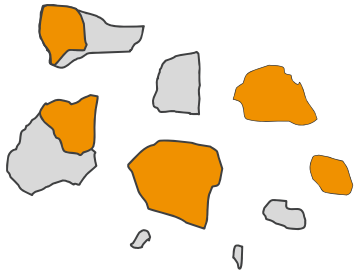
Role of mineral separation/concentration

Ore



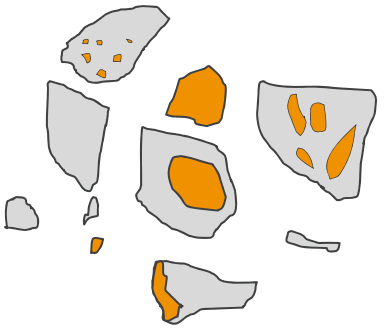
Selectivity of separation?





Concentrate

Grade?



Tailing

Recovery?

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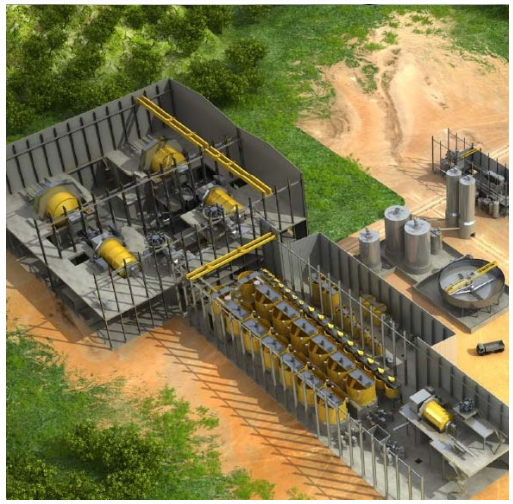
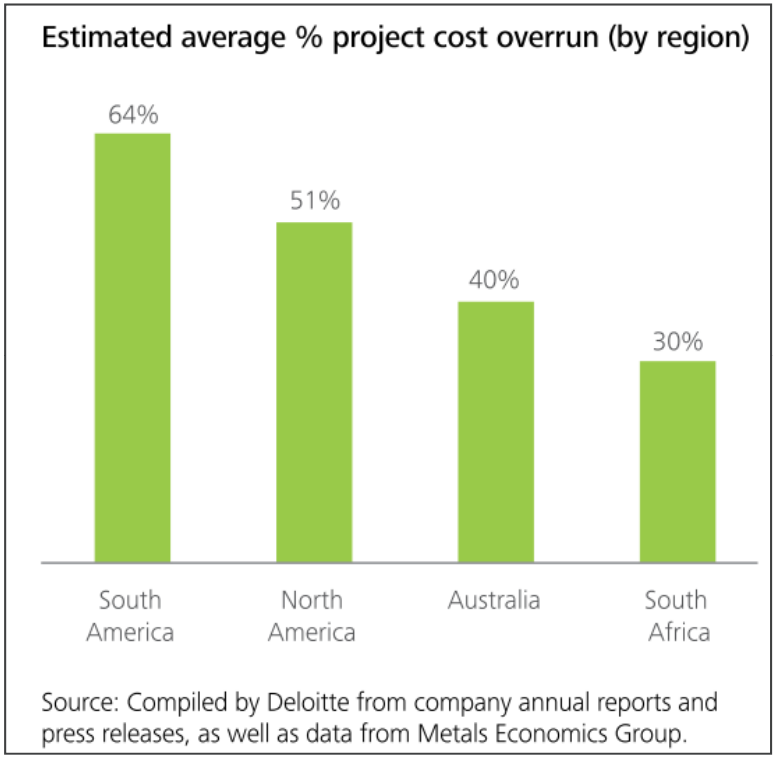
Challenges that mining projects face today

- Mining projects have experienced huge cost overruns lately, some sources indicating total of 18 B$, which is an investment with **NO RETURN**
- From 1970 – 1997 a 30 year commodity price fall was followed by volatile but strong increase from 2000 to present
- During the 30 year decline education and resources in general were “adjusted” to the demand
- When the rise started the industry was caught with the proverbial pants down in the areas of geology, metallurgy and project management expertise on the new mega sizes of projects was severely lacking.
- Projects with lower grade ore bodies were developed with previously unheard of individual project investment groups. Projects generally 3 B$ and up for typical Copper project
- Simultaneously in the world greed took over and various investment schemes were developed to achieve fast large returns (finance industry), which in turn had it’s effect in mining pushing projects forward with, also unheard of, urgency with **too light front end development work resulting in “optimistic” feasibility results** (need to perform better than the peer group or be able to raise money)
- **Result: Schedule and cost overruns, lots of rework, loss of credibility**



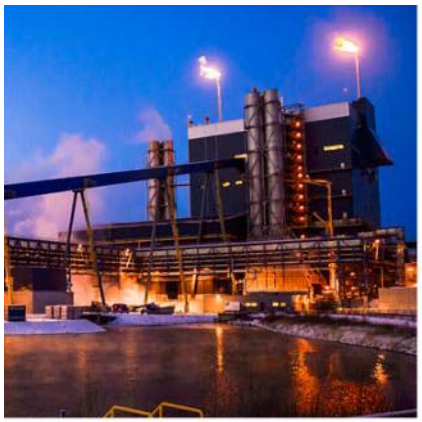
Project cost overruns



Valid reasons for these overruns exist:

1. **Lower ore grades** mandate the construction of more technically challenging mines
2. Both skilled **labor** and specialized mine **equipment** are in short supply
3. **Compliance** costs are rising
4. **Local governments** demanding a bigger piece of the pie
5. Companies need to negotiate with more diverse **stakeholders**
6. Competition for **land and water** use is becoming more prevalent
7. **Infrastructure** bottlenecks are interfering with project delivery

Some Keys to Overcoming Challenges



Evaluation - Finding and accessing to the ore bodies is only part of the challenge. **Declining ore grades and increasingly complex mineralogy** are making mineral extraction technically, economically, and environmentally challenging. The industry must take more time to evaluate projects and make sure it is technically and economically viable.

Training - "The industry is on the verge of a critical shortage of skilled labor, with some estimates predicting B.C. alone will need more than 10,000 workers over the next 10 years. Across the country, the shortfall of workers could be more than 100,000 as older miners retire and new mines begin production"[1]

Technology Innovation - The **key is to understand exactly what is happening within each area of a plant** and with each aspect of the processing being undertaken. By improving our understanding of the various processes (i.e., grinding, flotation, dewatering, etc.) **new technologies can be developed** to improve efficiency, reduce the energy consumption, and reduce the plant footprint.

1. *The Canadian Press Posted: Dec 15, 2013 3:09 PM PT*
2. *Mineral Processing: Innovations and Challenges -*

Constantly increasing demand for sustainable technologies

 Ore grade	Ore grades are declining and ores are becoming more complex.	We have a deep knowledge of minerals and metals processing technologies for low-grade and complex ores.
 Energy	Making metals is energy-intensive.	We provide the most energy-efficient process technologies in the industry.
 Emissions	Cleaner solutions must be developed to reduce CO_2 and other emissions.	Adoption of our best practice technologies worldwide could save 40-70 million tonnes of CO_2 in non-ferrous metals production only.
 Water	Water availability and pollution are critical issues.	Our solutions provide significant reduction in fresh water consumption and water loss by recycling the process water.
 Peak oil	Alternative energy sources are needed.	We enable environmentally sustainable use of oil shale and oil sand as well as biomass and waste as alternative energy sources.
 Recycling	More recycling is needed.	We provide technologies for metals recycling and waste to energy solutions.

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Technological Development in Flotation

- Flotation described as "the single most important operation used for the recovery and upgrading of sulphide ores."[1] Flotation improves the recovery of valuable minerals and allows processing of much lower grade ores to be economical viable.
- Flotation process originally invented around 1905.
- Flotation process enabled mining of ore bodies and deposits that were previously considered uneconomical
  - Low-grade ores and complex ores
- Outokumpu's Orijärvi Mine in Finland tested flotation process for the first time in 1911
- Increasing throughputs and lower ore grades started to set up new requirements for flotation equipment → Large enough equipment was not commercially available in the early 1970's and Outokumpu decided to start developing own flotation cells.
- Same trend has been continuing since that time and there has been a continuous need for even larger cells.
- New flotation and drive mechanisms have been developed along with increasing flotation machine sizes

1. *http://en.wikipedia.org/wiki/Froth_flotation*

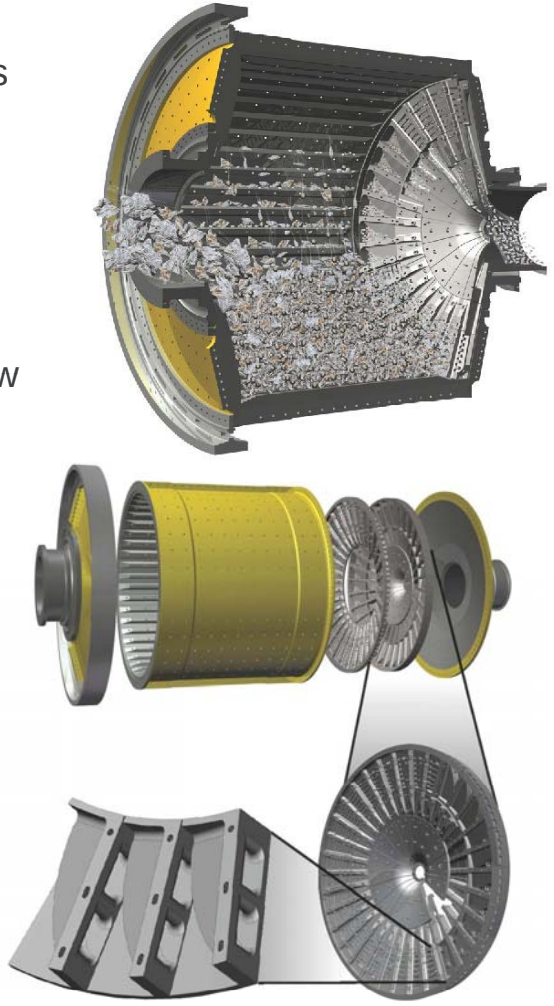
Equipment Sizes Through the Years.

- Evaluating different cell designs
- Increasing cell sizes / scale-up
- Controls and automation

- Before 1969 virtually all flotation cells were below 3 m^3 volume
- 1970 - 16 m^3 Outokumpu, Finland
- 1976 - 38 m^3 Outokumpu, Finland
- 1982 - 60 m^3 Pyhäsalmi, Finland
- 1995 - 100 m^3 Escondida, Chile
- 1997 - 150 m^3 Australia
- 1997 - 160 m^3 Chuquicamata, Chile
- 2002 - 200 m^3 Century Zinc, Australia
- 2007 - 300 m^3 Macraes, New Zealand
- 2013 - 500 m^3 Kevitsa, Finland

Technological Development in Grinding

- The ore must be ground fine enough to liberate the mineral grain from the associated rock, but producing too small a particle size is both expensive and detrimental to recovery.
- Outotec Turbo Pulp Lifter (TPL™) enhances mill discharge for AG/SAG, Ball and Pebble mills.
- The TPL is a twin chamber twin curve pulp lifter.
- Compared to conventional or curved pulp lifters TPL improves flow and energy efficiency in grate discharge mills by eliminating inherent material transport problems of mill discharge through the grate.
- The TPL can significantly improve the energy efficiency for total grinding circuit. **TPL's will increase capacity & reduce the energy (kWh/t)** required to grind the ore to the desired size.
- The SAG mill load becomes more stable and easier to operate.



Outotec's BAT Rated Technology

- Flash smelting and flash converting for copper and nickel
- Zinc direct leaching
- Electrolytic refining of copper, nickel, zinc
- Direct reduction of iron ore fines
- Traveling grate process for iron ore pelletizing
- Emission optimized sintering for iron ores
- Ferrochrome process
- Alumina calcination
- Aluminum smelting (rodding plant, green paste plant)
- Partial roasting of copper concentrate
- Zinc roasting in fluidized bed
- Pyrite roasting
- Sulfuric acid production (single/double absorption)
- Spent acid regeneration
- Wet electrostatic precipitator
- Top submerged lance technology

BEST AVAILABLE TECHNIQUE - EU rated -

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Our Commitment to Sustainability

- Sustainability is a core element in our mission and values.
- Outotec has signed the United Nations Global Compact initiative and has committed to its principles of human rights, environment, labor and anti-corruption.
- 87% of order intake (2011) classified as Environmental Goods and Services (OECD definition).
- Outotec included in the Carbon Disclosure Leadership Index by Carbon Disclosure Project (CDP) and OMX GES Sustainability Finland Index
- Reporting based on GRI guidelines level B+ since 2010.
- Outotec's sustainability reporting awarded with an honorary mention in the competition evaluating the reporting of Finnish listed companies in 2011.
- Outotec is member of Cleantech Finland.
- Outotec supports the rehabilitation of the Baltic Sea.
- Outotec named the 3rd most Sustainable Company on the Global 100 List.

THE GLOBAL COMPACT
WE SUPPORT

BSAG
Baltic Sea Action Group

CARBON DISCLOSURE PROJECT

OMXSUSTAIN INDEX
NASDAQ OMX
OMX GES SUSTAINABILITY FINLAND

Member of CLEANTECH FINLAND

VASTUULLISUUS RAPORTOINTI

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