IS MINING SUSTAINABLE?

Roberto C. Villas-Bôas, Mauricio L. Torem – Coordinators.

Robin Batterham, Kari Heiskanen, Roberto Sarudiansky and Diana Drinkwater – Chairpersons
INTRODUCTION

Sustainable development, or SD, as usually it is referred to, is a concept, in reality, a “working concept” proposed by BRUNDTLAND in her excellent 1987 UN report, best known as “Our Common Future”, readily available at the internet for reading.

Little by little, as in “baby steps”, forward, sometimes, the defined and involved stakeholders in promoting SD had taken actions towards the effective and achievable goals therein proposed.

Indicators for SD are available in the literature and at the internet in several formats, depending on the particular issue of “sustainability” that one is addressing to. Overall indicators, and their discussions on uses and abuses as well as applications, are the objects of the “goals of the millennia” events, best known as” Rio+10” and “Rio+20”!

Since SD is a WORKING concept, it changes and adapts as time passes and today it is well recognized that the application, and revision, of SD is rather for a “region” in a space, rather than a “point” in a space, as several stakeholders were addressing the issue in the 90’s!

As for the mineral based industries, SD challenges are in MINIMIZING MASSES – water included -, MINIMIZING ENERGY – searching for alternative sources as well -, MINIMIZING ENVIRONMENTAL IMPACTS – soil, gases, liquids, landscape, etc.- and ,last but not least MAXIMIZING SOCIAL SATISFACTION – an item where “social license to operate” plays a significant role.

If such is the case, we as scientists and engineers, as mining and mineral processing operators have a lot to contribute to the challenges posed by the three principles of MINIMA and in doing so our collaboration to society on the MAXIMA one will be very much appreciated.

The “IMPC 2014 SUSTAINABILITY STMPOSIUM” was designed to promote ideas, discussions of such ideas, proposals, and discussions of such proposals on specific areas of the FUTURE OF MINING, PROCESS
ENGINEERING & INNOVATION, SOCIAL LICENSE TO OPERATE and SD IN ENGINEERING EDUCATION.

In order to shorten the time gap between the vivid presentations at the Santiago’s IMPC and to allow ready access to these same presentations by the interested parties and stakeholders it was decided to present this “book” in an “internet format”, informal, thus hoping that the minor eventual errors that are still present may compensate the enormous and not readily available time of the presenters to prepare a formal edition.

Thus, in the next pages –or slides- you will find the pdf of the said presentations.

Hoping you all enjoy “reading and seeing” what follows, please accept the warmest regards of the 2014 IMPC Sustainability Symposium coordinators

Rio de Janeiro, November 2014

Roberto C. Villas-Bôas
Chairman IMPC Commission on Sustainability
Emeritus CETEM

Mauricio L. Torem
Professor of Extraction Metallurgy at PUCP-RJ
Editor-in-Chief, International Journal of Mineral Processing, Elsevier
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In the sequence they were presented and discussed. The discussions, unfortunately, are not part of the slides:

ROBIN BATThERHAM - Progress toward the Sustainable Mine of the Future.

JERRY PERKINS - CAPICHE Project Development in Chile.

HARIKRISHNAM TULSIDAS & ROBERTO C. VILLAS-BÔAS – UNFC and Sustainability in Mining


C.J. KELSEY & J.R.KELLY - New Crushing Concepts

MARKUS REUTER & A. VAN SHAIK - Product Centric Design for Recycling (DfR) - Simulation based prediction of recycling rates and environmental impacts.

FRANCISCO VELLOSO – Trayectoria de ANTOFAGASTA MINERALS: evolución de un compromiso con la sociedad.

DAMARIS FERNANDEZ - The Role of new technologies and new approximations to implement synergic advances within the societal relationship of raw materials industry.

CRISTIAN CIENFUENTES - Challenges in sustainability for the mining project portfolio in Chile

JACQUES V. WIERT - Sustainability education in Chilean undergraduate programs

MARIA JOSE GAZZI SALUM – Eco efficiency concepts and social responsibility in engineering curricula: a Brazilian case.

JENNY BROADHURST, J.P. FRANDISIS, SUE HARRISON, HARRO BLOTTNITZ - Educating Managers and Leaders for Sustainable and Socially Responsible Mining in Africa
Sustainability Symposium

Session 1 Progress toward the sustainable Mine of the Future

Co-Chairs:

Mr Fidel Baez  
Corporate Manager Underground Mining - Codelco

Prof. Robin Batterham  
Kermit Professor of Engineering – Melbourne University

IMPC 2014 – Santiago, Chile  
22 October 2014

• Recent significant changes in sustainability
  • Long term – the Mine of the Future
  • Shorter term steps to the long term
Mining is not getting easier:

- Grades we know about...

Sustainability is not getting any easier

- Grades and energy moving in the wrong direction.
- The licence to operate is ever more complex.
- And now we add transparency.
Australian trends for all mining:

- 1980 – 2010
  - average grade reduced by 50%
  - average energy increased by 70%

We will soon get used to world energy “cost curves”

Copper comminution energy intensity curve

The good new is:
No scarcity of energy and mineral resources which will continue to become more widely available at lower cost

The reality is:
we move down the resource pyramid and rely on innovation

The license to operate is part of sustainability

And in future, will a public demand reduction of steam plumes…

The power industry in Germany has already committed to not building cooling towers, due to public concern at the plumes
Socio-environmental conflicts are world wide

Of the 223 registered socio-environmental conflicts recorded in Peru for the first six months of 2013, 72.3% were against mining operations


And now we add transparency

Social
★ Safety
★ Communities
★ Health
Remote site health and medical emergency response
Managing occupational health risks
Managing fitness for work
★ People
Resettlement and compensation

Environment
★ Air
★ Biodiversity
★ Climate change
★ Energy
★ Land
★ Waste
★ Water

Economic
★ Economic contributions
★ Non-managed operations and JVs
★ Suppliers
★ Tax

Governance
Business resilience
★ Closure
Engagement
★ Human rights
★ Integrity and compliance
Internal controls
Product stewardship

Source: Rio Tinto, September 2014
• Recent significant changes in sustainability

• Long term – the Mine of the Future

• Shorter term steps to the long term

The Mine of the Future (IMPC 2003)

Deep, fractured by caving, in place leaching using advanced biohydrometallurgy and the copper won electrochemically underground
"Smart Mine of the Future"
(Stockholm Nov 2010)

Mining industry - moving in stages from full mechanisation to a fully controlled process industry.

Continuous

In-situ mining

Autonomous continuous process

Evolutionary

Revolutionary

Mechanical excavation

Drill & Blast

Batch

Future Deep Mining

Mineral Research Organisation

MANUFACTURE 2011 conference, Wroclaw, Poland, 24-25 October 2011

Delivering Sustainable Solutions

Source: "SMART MINE OF THE FUTURE", VIEWS ON MINING BY 2030", SveMin Hållbara, Stockholm, Nov 26th 2010. Goran Blacklom, MITURTC.,

Source: Miro - Manufacture 2011 Conference, Poland
http://www.mondfact2011.eu/presentations/10-6-Future%20mining/mr01%20nejzgjmhr01%20nejzgjm.pdf
• Recent significant changes in sustainability

• Long term – the Mine of the Future

• Shorter term steps to the long term
And much of this is happening:

- South Africa CSIR robotic detection of loose rock before re-entry.
- Anglo-American target of full automation – “the technology exists but must be configured in a cost effective way”.
- Anglo-Ashnanti targeting gold to 5000m.
- Codelco large scale testing of continuous mining – “the largest project that Codelco has ever developed to validate a new technology” (Baez, Next Generation Mining Latin America Summit Jan 2012).
Smart Mine of the Future

1. One control room. The control room receives on line processed information from the rock, from the people and from the machines and equipments that allow for controlling and fine-tuning the complete operation (process control and product control) from resource characterisation to the final product. Sensors and extensive use of cameras and image techniques permits “live performances” in the control room or elsewhere as needed.

2. No human presence in the production areas. All work processes (including rock characterisation) are remote controlled or automated. Special robots are developed for the preventive maintenance of equipment and safe retrieval operations. The maintenance of the robots as well as necessary equipment repair is executed in structurally safe underground vaults. All equipment underground is electrical and the use of diesel banned.

3. Continuous mechanical excavation. The continuous flow is a key issue for lean mining and further automation. The future mine is a continuous process and therefore continuous mechanical operation is used also in hard rocks.


Smart Mine of the Future

4. Pre-concentration. Barren rock is separated underground to minimise energy for haulage and transport as well as environmental impact on the surface.

5. Resource characterisation – mineralogy. Systems are in use that permit product control (geometallurgy) and maximisation of the inherent values in the rock.

6. Resource characterisation – structural control. Systems are in use that describes the rock with its structures to aid process control.

7. Final product. From a sustainable point of view waste rock should be turned into products. The metal should, if possible, be manufactured at the mine site to avoid unnecessary transportation. More value generated at the site should also contribute to a richer social life at the mine site.

Above ground, again automation is racing ahead:

**Rio Tinto Mine of the Future™**

- 1 mt/day by autonomous trucks by end 2015
- 150 autonomous trucks and drills, currently over 53 trucks
- $518m invested in autonomous trains
- remote operation centres and “Centres of Excellence”

None of these things can happen without leadership from the top

Codelco to harness world’s largest solar plant for mining

Codelco’s Energy & Water senior manager Andres Alonso said “internal resistance within companies is the biggest challenge for implementing projects such as Pampa Elvira Solar. The mining industry finds it hard to be innovative because we produce 24 hours a day, seven days a week, if you say ‘let’s have a new way of operating, let’s change this issue’, this tends to be resisted as people want to keep on producing. “It requires a great commitment from management. Fortunately there was great support from our management and we were able to overcome internal barriers that all mining companies have.”
To lead into our discussion:

- The vision for the sustainable mine of the future is clear, but is requires
  - Proactive embracing of sustainability by companies
  - Innovation
  - Simultaneous focus on the FOUR pillars
    - Social
    - Environmental
    - Economic
    - Governance
Understanding the Stakeholders

**Desire**
- Maximise profit
- Retain license to operate

**Challenge**
- Changing government expectations
- Government requirements for royalties, taxes, profit share, and social spend can erode profitability
- Can't always meet community expectations
- Don't always understand community needs

**Outcome**
- Risk and uncertainty

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**DesIRE**
- Maximise revenue to the state
- Provide infrastructure and social services

**Challenge**
- Multiple arms of government not aligned
- Policy often unclear / unstable / inconsistent

**Outcome**
- Have not delivered to communities
- See mining companies as a vehicle to achieve their objectives

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**DesIRE**
- Share in the mining wealth
- Social growth and expansion

**Challenge**
- Government has not delivered
- Mining industry's ability/willingness to share wealth is limited

**Outcome**
- Social unrest and frustration

*Reggio R and Lane A. (2012). "Monitor Perspectives: Mining in Africa: How Inclusive Solutions can Mitigate Risk"*
Caspiche project development in Chile

Jerry Perkins
CASPICHE SPECIFIC FACTORS

- High
- Dry
- Cold
- Remote
- No neighbours
- Massive
- Low grade
- Deep
- Complex
- Indigenous land & territory
- In Copiapó basin
- Near Altiplano.

DEVELOPMENT OPTIONS STUDIED TO DATE

PFS & PEA
LARGE OPEN PIT

- Distributed Area (ha): 2,570
- Initial Capex (AUS$): 4,800
- NPV (%): 11.5
- Reserves (Mt): 1,890
- Cu Grade (%): 0.24
- Au Grade (g/t): 0.38
- Cu Contained (Mt): 2.4
- Au Contained (Moz): 15.3
- Energy Consumption (MW): 245
- Water Consumption (l/s): 900
- MineLife (years): 17

HYBRID – OPEN PIT & UNDERGROUND

- Distributed Area (ha): 1,690
- Initial Capex (AUS$): 3,990
- NPV (%): 10.4
- Reserves (Mt): 853
- Cu Grade (%): 0.26
- Au Grade (g/t): 0.43
- Cu Contained (Mt): 1.7
- Au Contained (Moz): 16.0
- Energy Consumption (MW): 160
- Water Consumption (l/s): 390
- MineLife (years): 24
**FULL UNDERGROUND**
- Distributed Area (ha): 1,019
- Initial Capex (MUS$): 4,840
- IRR (%): 7.3
- Reserves (Mt): 586
- Cu Grade (%): 0.3
- Au Grade (g/t): 0.35
- Cu Contained (Mt): 12
- Au Contained (g): 1.8
- Energy Consumption (MWh): 123
- Water Consumption (M3): 200
- Mine Life (years): 22

**STAND-ALONE OXIDE - 10 YEARS**
- Distributed Area (ha): 260
- Initial Capex (MUS$): 250
- IRR (%): 5.2
- Resources (Mt): 107
- Cu Grade (%): 0.61
- Au Grade (g/t): 0.44
- Cu Contained (Mt): 11
- Au Contained (g): 1.5
- Energy Consumption (MWh): 4
- Water Consumption (M3): 45
- Mine Life (years): 10
FIVE YEAR OXIDE + 27 KTPD OPEN PIT

- Distributed Area (ha): 780
- Initial Capex (MUS$): 3.70
- IRR (%): 22.7
- Resources (Mt): 350
- Cu Grade (%): 0.27
- Au Grade (g/t): 0.55
- Cu Contained (Mt): 0.3
- Au Contained (oz): 4.5
- Energy Consumption (MW): 40
- Water Consumption (L/s): 185
- Mine Life (years): 18

FIVE YEAR OXIDE + 27 KTPD UNDERGROUND

- Distributed Area (ha): 50
- Initial Capex (MUS$): 390
- IRR (%): 17.6
- Resources (Mt): 460
- Cu Grade (%): 0.35
- Au Grade (g/t): 0.79
- Cu Contained (Mt): 1.2
- Au Contained (oz): 18.9
- Energy Consumption (MW): 0.5
- Water Consumption (L/s): 150
- Mine Life (years): 41
## Options Summary

<table>
<thead>
<tr>
<th>Option</th>
<th>Capex (MUS$)</th>
<th>IRR (%)</th>
<th>Life (y)</th>
<th>Energy (MW)</th>
<th>Water (l/s)</th>
<th>Area (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Initial</td>
<td>Total</td>
<td></td>
<td>Avg</td>
<td>Max</td>
<td></td>
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<tr>
<td>Large Open Pit</td>
<td>4,000</td>
<td>5,650</td>
<td>11.5</td>
<td>17</td>
<td>245</td>
<td>300</td>
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<tr>
<td>Hybrid - Open Pit &amp; Underground</td>
<td>3,990</td>
<td>5,480</td>
<td>10.4</td>
<td>24</td>
<td>168</td>
<td>190</td>
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<tr>
<td>Full Underground</td>
<td>4,340</td>
<td>4,970</td>
<td>7.3</td>
<td>22</td>
<td>125</td>
<td>140</td>
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<tr>
<td>Stand Alone Oxide 10 years</td>
<td>250</td>
<td>295</td>
<td>30.2</td>
<td>10</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Five-Yr Oxide - 7 Mtpd Open Pit</td>
<td>370</td>
<td>1,480</td>
<td>22.7</td>
<td>18</td>
<td>40</td>
<td>45</td>
</tr>
<tr>
<td>Five-Yr Oxide - 7 Mtpd Underground</td>
<td>390</td>
<td>1,670</td>
<td>17.6</td>
<td>41</td>
<td>65</td>
<td>75</td>
</tr>
</tbody>
</table>

## PFS Large Open Pit (Superpit)

- Maximum energy and water use
- Maximum footprint and area disturbed
- Maximum construction and operating workforce
- Large infrastructure and transport requirements
- Max annual production and total production of Au, Cu
- Max reserve utilization and recovery
- Low technical risk
- Shortish life (17 years) if no more reserves discovered
- Preferred approach - until 2012.

### Main sustainability initiative

- In Pit Crushing and Conveying (IPCC)
- Use of waste to form a seismically safe TSF
- Reduction in truck numbers – workforce, fuel, maintenance
- Reduction in mining cost of 25% to 33%.
PFS Hybrid and Full Underground

- Smaller footprints, energy and water use
- Longer project lives; 22 and 33 years
- Lower IRR and NPV
- Higher overall technical risk
- But low technical risk on initial Oxide project
- Long lead time to DFS and project development for block cave underground operation
- Most workforce at 3,500 m, not 4,300 m in block cave underground
- Higher impact on useful community land in lower Valley.

PEA Project Options

- Smaller throughput, more selective mining, higher grade, lower Capex
- Even longer project lives; up to 40 years with lower grade options beyond
  - Infrastructure re-sited to minimise impact on Community property
    - Significantly lower energy and water usage
  - Low technical risk and early cash flow on oxide aspects
  - High technical risk on underground open stoping
    - Reasonable economic parameters.

Right direction from a sustainability perspective?
Current Conclusions and Directions

Phased development
- Oxide open pit
- Low capex, small footprint, good returns,
- Confirm and build on operating and project skills
- “High” grade sulphide open pit & concentrator
  - Production lift
  - Complexity rises but with time to develop optimum routes
  - UG development during open pit operations
- Long term, long life underground operation.

Good potential for a sustainable mining project
Environmental Sustainability

From the outset, and at every stage of development and operation

➢ Minimise footprint, surface disturbance
➢ Identify potential impacts and hazards, especially
  ✓ Acid Rock Drainage
  ✓ Water quality
  ✓ Glaciers, permafrost.

➢ Develop an Environmental Management Plan (EMP)
  ✓ Protect
  ✓ Respect
  ✓ Report transparent
  ✓ And frequently
  ✓ Restore
  ✓ Repair
  ✓ Re-habilitate
  ✓ Improve.

Social Sustainability

"Social Sustainability - The ability of a community to develop processes and structures which not only meet the needs of its current members, but also support the ability of future generations to maintain a healthy community" www.businessdictionary.com

Within the regional context

➢ Respect, maintain and enhance culture and heritage
➢ Be part of the community
➢ Act from a community, not an enterprise, perspective
➢ Funding for long-term community outcomes

Within the project and work context

➢ Culture of shared ethics and teamwork
➢ Minimise impacts of working at Caspiche
➢ Leadership (clear objectives, train good leaders, communication).
Economic Sustainability

Greatest sustainability challenge for mining projects? Why?
- Few prospects become a project
- Capital intensive
- Long lead times!
- Sovereign risk
- Cyclical markets
- Permanent expectations...
  And often disappointment!

“Ideal” economic KPI’s for mining projects?
- NPV & IRR – High to reflect risk
- Payback – Short
- Tax – Minimise tax and maximise use of concessions.

So
We shape projects to maximise early cash flows
Which often means
- Lower profitability later in the mine life
- Conflict with Economic Sustainability.

*Economic Sustainability - The use of various strategies for employing existing resources so that a responsible and beneficial balance can be achieved over the longer term* - businessdictionary.com
Economic Sustainability

Main economic sustainability objectives for Caspiche?

- Robust economic design
- Long term contribution to the region
- Permanent benefits to compensate for the use of the resource
- Track record of cooperating and contributing to infrastructure
  - With Regional government and communities
  - With national government
  - With other mining companies.

Atacama Energy Availability - Conventional

Electrical power from grid
- 180 km
- 220 kV - 110kV for smaller projects
- Kinross 11.0 kV exists but limited capacity
- Construction costs of M$ 0.5 to M$ 1.0 per km
- Limited if any use after, except to other mines
- Ideal case for Government or Superfund invest
  - Long term infrastructure development
  - Reduce company impact and cost
  - Assists future development in the Maricunga
  - Or provides for renewable energy reticulation.

Fuel – diesel oil & petroleum products
- 180 km
- By road from Copiapo
  - Two steep switchback passes
  - Essential artery for one existing and two future projects.
Atacama Energy Availability - Renewable

- World class solar energy potential throughout upper areas
- Strong, persistent wind energy, especially Laguna Verde
- Neither available to same extent near the coast.

Solar energy potential – South America
Wind energy potential – II Region

- Geothermal energy potential – Non-existent!

Renewable Energy Characteristics

- Abundant – Wastage and inefficiency not a priority for now
- High Capex – Difficult to solve in the short term, but steadily improving
- Low Opex – Maintenance and amortization
- Clean? – Footprint; environmental factors
- Variable – Oversupply / Undersupply
  - Oversupply – Feed to grid and obtain credit
    - Catch 22 – Have to build a power line to grid
  - Undersupply
    - Draw from grid – Catch 22 again!
- Battery storage – Solutions being developed but when?
- Pumped Storage – Interesting possibilities.
Sustainable Water for Maricunga Projects

Some Alternatives?

- From Copiapó basin and river systems? No!
  - Current usage unsustainable.

- From seawater? Feasible but No.
  - 200 km and to 4500 masl
  - 1000 l/s: $1.0Bn capex and 1,800 MWh/day
  - Impact of salt on Jonquera and Copiapó river catchment.

- From desalinated seawater? Possible but...
  - 1000 l/s: $1.3Bn to $1.5Bn capex and 2,200 MWh/day
  - Better use as potable water in Copiapó and region
  - Help rivers recover.

Then... Other alternatives?

- Abundant subterranean water
  - In volcanic gravels and fractured andesites, 30 m to 500 m below surface
  - Almost all sourced from snow
  - Over 80% of snow sublimes
  - No connection with Copiapó river basin or coastal drainage

- Harvest water and pump to projects

- Sustainable?
  - With care and monitoring ... Probably
  - If we reduce snow sublimation and re-inject ... How?
    - Harvest snow
    - Melt or solidify snow – Solar energy, mechanically compact.
Caspiche – Remote and Hostile

Minimise number of people on site
- Make use of substantial instrument, control and automation advances
- Move control and supervision to Copiapo
  - Concentrator
  - Trucks and support equipment
  - Underground mining
- Reduce as much as possible routine or repetitive functions
- Create multi-purpose, multi-skilled task-force or focus teams for problems
- Take more care with people selection for site work
  - Prioritize EQ > IQ
  - Ensure shared values and goals for site work
  - Review these often, in the light of experience and outcomes
  - Provide best quality tools, especially communication tools.

Caspiche – Remote and Hostile

For construction and maintenance as well
- Maximise off-site (Copiapo area) fabrication and preparation
- Make the Caspiche construction site an assembly site
  - For example: Bolts and flanges over welding
- Modularise and transport
- On site maintenance - Removal and replacement of assemblies
- Copiapo for repair and re-assembly.
Caspiche Future Development

Mining
- If open pit
  - Use IPCC: Minimise mobile equipment and reduce energy and fuel
- If underground
  - Remote controlled equipment and conveyors
  - Maximise paste fill and return of tailings
- Driverless mobile equipment.

Process
- Over 80% of energy consumption in comminution
- Crushing and grinding? No clear direction for Caspiche ... HPGR?
  - Reduce energy consumption
  - Improve copper mineral liberation
  - Improve maintenance and plant footprint
- Development of finer product machines is of interest
- Large SAG mills
  - Poor energy efficiency but what are the alternatives?

Caspiche Future Development

Process
- Adopt new and efficient flotation technologies
  - Glencore XT’s Jameson Cell
  - Woodgrove Technology’s Staged Flotation Reactor (SFR).

Smaller footprint, power and air requirements
Growing evidence of more selective flotation
Caspiche Future Development

Process
- Staged liberation and more selective flotation
  - Flash flotation and other coarse flotation techniques
  - Maximum use of non-reactive grinding media
- Filtered tailings and dry stacking
  - Significant reduction in water consumption
  - Eminently suitable for high seismicity
  - More materials handling and equipment for compaction.

Transport (medium term)
- All logistics and transport by electric vehicles.

Caspiche-Maricunga Future Development

Energy supply
- Series of 100 MW wind farms on the E-W Maricunga – Argentina road
- Series of 50 MW solar stations on the N-S Maricunga axis
- 220kV ring main grid connection
  - From Cardones sub-station
  - Via N-S Maricunga
  - To Carrero Pinto sub-station
- Renewable energy distribution to grid via 66 kV and 110 kV lines
  - Pumped storage at Piedra Pomez; Peñas Blancas
  - Recirculation and re-injection of subterranean water using excess energy
  - In winter convert excess energy to heat, farm snow, re-inject water.

A dream?
- For any single company? Yes
- For a development consortium with mining companies and government? Maybe not.
Caspiche - Developing Sustainably

Acknowledgements:
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exeter
UNFC and Sustainability in Mining

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Roberto C. Villas-Boas, CYTED & CETEM

UNFC
UNFC

- SD in mining meaning:

- Min MASSES water included
- Min ENERGY
- Min EN DAMAGES

Max SOCIAL SATISFACTION

UNFC

- engineers & geologists:
  - F axis
  - G axis
  - others: including society

- E axis (includes SLO)
Case Study: ANATASE x RUTILE

- PAT US4176159 A: Process for concentration of titanium containing anatase ore

The process basically consists of the removal of the impurities contained in titanium minerals, in which titanium is present in the form of oxides in complex association with other minerals which cannot be eliminated by the conventional hydro-metallurgical processes.

UBFC & SD

- Comprehensive Extraction

- F and G axis: interesting features and opening up possibilities, i.e., eventually you may have an F2 situation for given mineral but a F1 one for a comprehensive extraction (Th alone and REO + Th); the same valid for G and E
Case Study: Finland’s ProMine
Nano-particle products from new mineral resources in Europe

- **STRATEGIC RESERVES**: the first pan-European GIS-based database containing the known and predicted metalliferous and non-metalliferous resources, which together define the strategic reserves (including secondary resources) of the EU
- **CALCULATE** the volumes of potentially strategic metals (e.g. cobalt, niobium, vanadium, antimony, platinum group elements and REE) and minerals that are currently not extracted in Europe
- **DEVELOP** five new, high value, mineral-based (nano) products
- **ENLARGE** the number of profitable potential targets in Europe
- **SUSTAINABILITY**: establish a new, cross-platform information group between the European Technology Platform on Sustainable Mineral Resources (ETP-SMR) and other platforms.
- **INDIGENOUS LANDS**: exploration and Mining in Finland’s Protected Areas, the Sami Homeland and the Reindeer Herding Area;
E, F, G
Outotec

Towards Minimum Impact Cu Concentrator
a conceptual study

IMPC
19-23th of October 2014, Santiago Chile
Kaj Jansson
Director, Mineral Processing Site Water Management

Project background
- Setting up the scene -

- **Project scope**
  - Total site costs of conventional, thickened, paste and filtered tailings
    - concentrator + tailings mgmt (variable) + water mgmt (variable)
  - Finnish cost basis
  - Costs are based on net present costs – no financing costs included
  - Accuracy +/- 30%

- **Concentrator**
  - Cu (porphyry copper)
  - Capacity 20 Mt/a
  - 15 years mine lifetime
  - Fresh water distance 10km, static head 25m
  - Tailings distance 10km, static head 25m

- **Site conditions**
  - Located in temperate climate
  - Flat mine site
  - No mine water, freezing, dust control or earth quakes events are taken into account

15.11.2014
New Crushing Concepts

CG. Kelsey  JR. Kelly

IMPTEC
(Innovative Mineral Processing Technologies)

IMP Technologies Pty. Limited

The IMPTEC Super Fine Crusher

- Compression chamber drive
- Feed chute
- Mandrel gyration drive
- On-line adjustment posts
- Product outlet

Scope
- An operating duty band ranging from tertiary to ultra-fine.
- Complete flexibility between wet and dry operating modes.
- Ultra-fine products from single stage reduction of coarse or fine feeds.
Super Fine Crusher Description

» A rotating compression chamber with an internal gyrating mandrel.
» The axis of rotation of the mandrel is displaced relative to the axis of the vertically mounted compression chamber.
» The inner surface of the compression chamber is tapered at an angle equal to the displacement angle of the mandrel.
» The compression chamber shell also carries a product discharge impeller.

Operating Sequence

» Feed entering the crusher is accelerated into a compressed particle bed, which lines the inside of the compression chamber.
» The depth of the bed progressively increases until the mandrel is engaged and free to rotate with the compression chamber.
» Additional pressure on the bed triggers the mandrel’s gyratory motion, directed counter to the direction of rotation.
» Product is transported to a collection facility or classification circuit.
» The closed side set of the crusher is adjusted hydraulically.
Open Circuit Pilot Tests

<table>
<thead>
<tr>
<th>Test</th>
<th>Feed $d_{50}$ (microns)</th>
<th>Product $d_{50}$ (microns)</th>
<th>Power (kWh/t)</th>
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</thead>
<tbody>
<tr>
<td>Perlite</td>
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<td>545</td>
<td>20</td>
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</tbody>
</table>

Progressive Particle Size Reduction

Consistent & even breakage over the full size range
Comminution into the Future

» Advanced conventional cone crushers have the capacity to generate product d$_{50}$'s of 2 mm to 4 mm at less than 2 kWh/t.

» Super Fine crushing in combination with advanced conventional fine crushing could add a whole new dimension to comminution practice.

» This combination also has the potential to significantly reduce current capital, operating and maintenance costs.

» As the technology matures lower cost options are envisaged for each of the following:
  • SAG milling
  • Primary media grinding
  • Secondary media grinding
  • High pressure rolls grinding
  • Fine & ultra - fine high intensity media grinding

Comminution into the Future

Conventional Wet

| Primary crusher | SAG mill | Primary media mill | Secondary media mill | Regrind media mill | Ultra - fine media mill |

Conventional Dry

| Primary crusher | Fine crusher | Fine grinding mill | Ultra-fine grinding mill |

Super Fine Wet or Dry

| Primary crusher | Fine crusher | Super Fine crusher |

Single stage fine product
Single stage ultra-fine product
One method for all fine and ultra-fine duties.
Comminution into the Future

Example - Options for preparation of flotation or leach circuit feeds.

Low cost wet or dry open circuit options.
Eliminate grinding and avoid deleterious flotation pulp chemistry effects.

Gold Leach Feed Preparation

Current Circuit
Pyrite / Gold Flotation conc. $d_{90} \ 150\ \mu m$
  \rightarrow \text{Regrind Ball Mill}
  \rightarrow \text{Cyclones}
  \rightarrow \text{H.I. Stirred mill}
  \rightarrow \text{Ceramic media}
  \rightarrow \text{Carbon in Leach}
  \rightarrow \text{Stripping E.W. & Refining}

Super Fine Crushing Option
Pyrite / Gold Flotation conc. $d_{90} \ 150\ \mu m$
  \rightarrow \text{Super Fine crusher}
  \rightarrow \text{Cyclones}
  \rightarrow \text{Carbon in Leach}
  \rightarrow \text{Stripping E.W. & Refining}

» Eliminates regrind mill, H.I. stirred mill and ceramic media.
» Enables greater feed size flexibility.
» Open circuit eliminates cyclones.
SUPER FINE CRUSHING

Mineral processing technology for the 21st century

- Adds a new dimension to particle size reduction methodology.
- Offers robust options for bypassing conventional milling constraints.
- Introduces new operating concepts with the potential to revolutionise flow-sheet development.
- Has the potential to set lower capital, operating & maintenance cost benchmarks.

Super Fine Crushing - Innovation for the Cement Industry

Mark Drechsler, Consulting Engineering Geologist, WorleyParsons Services Pty Ltd, Adelaide, Australia

impc2014.org
Super Fine Crushing – Innovation for the Cement Industry

IMPC14 Theme
Optimizing water and energy usage for sustainable mining

Sustainability Symposium
Innovation and Engineering Development

Mineral Processing Industry
Transfer of Innovation and Engineering Development

Construction & Cement Industries

Super Fine Crushing – Innovation for the Cement Industry
Global Cement Industry
2013 - 4 Billion tonnes of Ordinary Portland Cement (OPC)

<table>
<thead>
<tr>
<th>Country</th>
<th>2013 - Million t’s OPC</th>
<th>t/yr/person</th>
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<td>China</td>
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<td>Saudi Arabia</td>
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</table>
Super Fine Crushing – Innovation for the Cement Industry

4 Billion tonnes of OPC in 2013
Second largest source of Green House Gases (GHG)

\[0.65 – 1.1 \text{ t CO}_2 \text{ per 1t OPC production}\]

What strategies can the cement industry undertake to reduce costs and GHG emissions

- Improve OPC production efficiencies
- Improve OPC reactivity
- Increased use of Supplementary Cementitious Materials (SCM)
- Replace OPC’s with geopolymer concrete

Super Fine Crushing – Innovation for the Cement Industry

Research program by University of Adelaide to determine the improvement of reactivity of slags with super fine crushing
Super Fine Crushing – Innovation for the Cement Industry

Geopolymer Concrete Strength Results

Normal concrete 20MPa at 28 days, structural concrete 32-50 MPa at 28 days

Super Fine Crushing – Innovation for the Cement Industry

Geopolymer Concrete Strength vs Grain Size

Increasing Strength with Increased Fineness
Super Fine Crushing – Innovation for the Cement Industry

4 Billion tonnes of OPC in 2013
SFC will reduce cement industry costs and GHG’s

Improve OPC production efficiencies
- SFC potentially reducing clinker grinding energy costs
- SFC reducing capital and operating costs

Improve OPC reactivity
- SFC producing finer cements with increased strength and durability, and reduced porosity of concrete

Increased use of Supplementary Cementitious Materials (SCM)
- SFC improving reactivity of SCM’s such as slags and fly ash

Replace OPC’s with geopolymer concrete
- SFC improving reactivity of slags, fly ash and other waste materials for use in geopolymer concrete

Super Fine Crushing – Innovation for the Cement Industry

Super Fine Crushers (SFC’s) could replace ball, hammer or vertical roller mills in current (+660) or new cement plants.

Two or three SFC modules in parallel could:
- Improve production flexibility, product grade and quality.
- Process a wide range of materials - hardness & abrasion.
- Reduce operating costs and downtime by staggering maintenance of modular SFC units using common parts.
- Reduce capital costs and equipment footprint in plants.
- Lower energy consumption, especially for hard materials.
- Reduce startup power loads on power networks.
Super Fine Crushing – Innovation for the Cement Industry

Demonstrating and evaluating Super Fine Crushing technology through the Cement Industry and then transition to the Mineral Processing Industry as the SFC technology proves itself, and scales up.

IMPTEC

THE UNIVERSITY OF ADELAIDE AUSTRALIA

WorleyParsons

resources & energy
Target: The smallest total cost
-The true cost of operating a mineral process over its lifetime -

- Unpredictable cost
  - Operational risks
  - E.g. production loss due to water stress
  - Regulation / Environmental / Rehabilitation
  - Reputation
  - Financial risks

- Indirect costs
  - Legal
  - Official procedures
  - Etc.

Alternatives for tailings & water mgmt:
- Risk matrix -

- Conventional tailings mgmt
- Paste mgmt
- Filtered mgmt

1. Dam wall breakage (upstream)
2. Pollution of both surface and ground water through seepage
3. Socio political acceptance
4. Image risk for whole group
5. Water shortage during dry months
6. Risk of total operation
Environmental conditions
- Selecting the tailings dam design 16km2, 30m high

- **Upstream**
  - Lowest initial cost and most popular design in low risk seismic areas.
  - **Highest risk**

- **Downstream**
  - Most stable design, should be used in areas with higher seismic risks
  - **Lowest risk**

- **Centerline**
  - Compromise between both the upstream and downstream designs
  - More stable than the upstream model
  - Cannot be used as a large water retention facility

- **Modified Centerline**
  - Compromise between the upstream and centerline methods to reduce the volume of construction material

---

Environmental conditions
- Impact of local weather pattern -

- **Water shortage and quality risks** should be evaluated together:
  - Fresh water quality and quantity is changing during the year,
  - Poor reuse water quality can mix pH control loops
  - Formation of harmful chemical components in tailings dams
  - Seasonal and annual rainfall change – pond volume risk
Environmental conditions
- Risk related to tailings seepage / water mgmt risk -

- Possible surface and ground water pollution
- Active pond area is calculations basis for seepage loss
- Collected seepage – potential AMD/ARD that needs a treatment/monitoring

Water balance: Conventional tailings mgmt
- 20Mt/a – Optimal steady state -

- Fresh water usage
  - 0.6-0.9 m3/t ore
  - Raw water need
    - Avg 1 400 m3/h (+15%)
  - ETP needed

- Risk mgmt
  - Dam risks
  - Water mgmt issues
  - Environmental risks
  - Socio political issues
  - Vulnerable to weather conditions (negative, positive water balance)

- Disadvantages
  - Huge tailings dam
  - Very costly to own and operate

- Benefits
  - Known technology

Operational: Seepage, rainfall and evaporation may mix the water balance and increase fresh water input drastically
Water balance: Thickened tailings mgmt
- 20Mt/a – Optimal steady state -

- Fresh water usage
  - 0.5-0.8 m³/t ore
  - Raw water need
    - Avg 1 200 m³/h (+15%)
  - ETP needed

- Risk mgmt
  - Dam risks
  - Water mgmt issues
  - Environmental risks
  - Socio political issues
  - Vulnerable to weather conditions (negative, positive water balance)

- Disadvantages
  - Huge tailings dam
  - Very costly to own and operate

- Benefits
  - Known technology

Operational: Seepage, rainfall and evaporation may mix the water balance and increase fresh water input drastically

Water balance: Paste thickening mgmt
- 20Mt/a - Optimal steady state -

- Fresh water usage
  - 0.45-0.6 m³/t ore
  - Raw water need
    - Avg 1 100 m³/h (+15%)
  - Small ETP needed

- Risk mgmt
  - Reduced dam risks
  - Reduced water mgmt issues

- Disadvantages
  - Paste pumping

- Benefits
  - Smaller tailings area needed than pervious ones
  - Smaller water usage than previous ones

Operational: Seepage, rainfall and evaporation do not influence on water balance and fresh water storage can be minimised
Water balance: Filtered tailings mgmt
– 20Mt/a - Optimal steady state -

- Fresh water usage
  - ~0.15m³/t ore
  - Raw water need
    - Avg: 310 m³/h (+15%)
  - Small ETP needed
- Risk mgmt
  - Smallest operational risk
  - Dust control
- Disadvantage
  - Extra thickener + filter + conveyor
- Benefits
  - Savings on fresh water & effluent volumes
  - Smallest –
    - tailings dam
    - environmental risk
    - socio political issues

Operational: Seepage, rainfall and evaporation do not influence on water balance and fresh water storage can be minimised.

Estimated Full costs of 15 years lifetime of a 20Mt/a Cu Concentrator with concentrator, different tailings mgmt and water management, k€

<table>
<thead>
<tr>
<th>Method</th>
<th>Labour</th>
<th>OPEX</th>
<th>CAPEX</th>
<th>CONSUMPTION</th>
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<tbody>
<tr>
<td>Conventional</td>
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<tr>
<td>Thickened tailings</td>
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<tr>
<td>Paste tailings</td>
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</tr>
<tr>
<td>Filtered tailings</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: with DOWNSTREAM dam
Water price: 0.001 €/m³
Electric price: 100 €/MWh
Conclusion

• Water mgmt
  For minimal operational risks, future is in more closed and smaller water volumes

• Conventional & thickened
  Local weather and site conditions have a huge impact on the operational risk, Capex and Opex

• Paste
  If any kind of disposal place for the tailings exists (old mine...), then it’s a good alternative – thus it doesn’t solve the water mgmt issues.

• Filtered
  For minimal operational risks, including tailings and water mgmt is far the best

Outotec’s sustainable concentrator
If you always do what you’ve always done,  
You will always get what you’ve always got  
-A. Einstein-
Outotec

Product Centric Design for Recycling (DfR)
Simulation based prediction of recycling rates and environmental impacts

Markus Reuter & A. van Schaik
Director Technology Management, Outotec Oyj & MARAS B.V., The Netherlands

MARAS
Material Recycling and Sustainability

Leveling the global playing field
Quantified sustainability, attract the bright, entrepreneurial & innovative

  - Explore the opportunities, limits and infrastructure for metal recycling – a free textbook.
- Gives detail how to increase metal recycling rates.
- Promote a Product-Centric Recycling approach.
- Over 40,000 downloads (May'13-May'14)
  - www.ubrainty.com/watch.php?id=842
- “Wheels of Metals” MOOC @ Leiden ca.5,000 students:
  - https://www.coursera.org/course/metals
Metals are key to society
Technology elements linked to copper in minerals and solvent during recycling

A field open to bright young talent to innovate

Mine
Primary Resources, Mineralogy

Urban Mine
Secondary Resources, Designed "Mineralogy"

Maximize Handprint
Minimise Footprint

Recycling

(Source: Handbook of Recycling (2014) - Warrant E & Reuter, M.A. Elsevier)
Quantifying losses through simulation

System Integrated Metal Production: Digitalization
Minerals Centric ≈ Product Centric: Key understanding to “close” loop!
System Integrated Metal Production: Digitalization
Minerals Centric ≈ Product Centric: Key understanding to “close” loop!

Geological Copper Minerals
>15 minerals e.g., Au, Ag, PGMs, Se

Designed Copper “Minerals”
>40 elements complexly linked as alloys, compounds, materials

Geological Linkages
Various copper sulphide minerals on quartz and calcite

Product Design & Material Combinations create new “Minerals”

Functional Material Connections

Joined Materials Multi-material particles


System’s techno-economic & physics based limits

Processes, Plants or Systems

Industry Range

Upper Limit
Least Resource Efficient

Lower Limit
More Resource Efficient

BAT

Fundamental Process and System Benchmark
Techno-economic based

The ultimate benchmark of industry sector

New Process/System Benchmark
Technology and Systemic Innovation (Digitalization)

Present

Time (Years)
Outotec technology for recyclates & residues
Techno-economic reality, a selection of over 30 Outotec applications

Design for Resource Efficiency (DfRE): LED Lamps

Outotec: HSC Sim

PE-International: GaBi

BAT, Flow Sheets & Recycling System Maximizing
Resource Efficiency – Benchmarks

Recyclability Index (based on system simulation of whole cycle)
Energy: GJ & MWh / t Product (CAPEX & OPEX)
Exergy: GJ & MWh / t
kg CO₂ / t Product
kg SO₂ / t Product
kg NOₓ / t Product
m³ Water / t Product (including ions in solution)
kg Residue / t Product (including composition)
kg Fugitive Emissions / t Product
kg Particulate Emissions / t Product
Etc.

Environmental Indicators based on BAT
Driving Benchmarks of Industry
ReCiPe (and similar) – Endpoint estimation
Global Warming Potential (GWP)
Acidification Potential (AP)
Eutrophication Potential (EP)
Human Toxicity Potential (HTP)
Ozone Layer Depletion Potential (ODP)
Photochemical Ozone Creation Potential (POCP)
Aquatic Ecotoxicity Potential (AETP)
Abiotic Depletion (ADP)
Etc...
Linking CAD to simulation key to quantification of RE

HSC simulates recycling system: input designed "mineralogy" for LED

Results produced for:
geenelec
eniac

Linking CAD to simulation key to quantification of RE

HSC Sim recycling system simulation

Environmental assessment (GaBi & HSC)

Recycling / recovery rate calculations

15/11/2014 Reuter & Van Schaik | IMPC 2014 - Sustainability Seminar
Distribution of materials to recyclates in sheet #11
Recovery/losses/dispersion for Design A

Analyses of ferrous recyclate fraction
High presence of multi-material (non liberated) particles – containing steel + other materials (Design A)
The grades of 3 recyclates for designs A & B
Design B designed for liberation of aluminium

Element and compound recovery to recyclates
Deep-drawn aluminium with and without potting (added for rigidity)
Final recovery after metallurgical processing
Total % (on right) after processing in steel, aluminium and copper smelters

DfR ≈ Design of recycleate qualities/grades for recycling
TRAYECTORIA DE ANTOFAGASTA MINERALS:
EVOLUCIÓN DE UN COMPROMISO CON LA SOCIEDAD

Francisco J. Veloso, Vice Presidente Asuntos Corporativos y Sostenibilidad

Estamos aquí
El Chile de los ‘60 y ‘70

PIB per cápita: US$2300 – US$2500

Chile versus Zambia*

692.000 1973 754.000
5.800.000 2013 798.000

* Toneladas de cobre fino
PIB per cápita actual: US$23.165
(Salto al desarrollo en una generación)
Chile cambió gracias al cobre

De chicos a grandes en 20 años...

Antofagasta Minerals

50.000

700.000

(TcuF/año)
Un largo recorrido

Una herencia filantrópica
Apoyamos fundaciones

Hacia una nueva consciencia
La sociedad también cambió ...

De la RSE a la Sustentabilidad
Año 2008: Minera Esperanza

Procesos sustentables

Esperanza se inaugura usando 100% agua de mar
Relaves espesados

Cambia el tratamiento de depósitos

Se contratan 400 trabajadores locales, mediante “Programa de Aprendices”

El 10% corresponde a mujeres
Sin embargo, hoy seguimos evolucionando

Con una mirada de futuro

Planificación participativa en el territorio [gestión territorial]
Reconociendo impactos; brindando oportunidades
Con un nuevo modelo de relacionamiento

Aún nos quedan muchos desafíos
Está en nuestra historia saber enfrentarlos
Trinity College Dublin

Plays an active role in addressing the challenges related to raw materials, promoting activities in R&D for:

a. Technology areas (mining, recycling and substitution of hazardous/scarc materials)

b. Non-Technology areas (transversal)

c. International perspective (actions relating local to global context)
A 420 year old University in the heart of Dublin City Centre

- 61st in the World and 18th in Europe across all indicators (QS 2013)
- 44th in the World in terms of Research Impact (THE 2012)
- 48th in the World and 9th in Europe for Research Performance (LU 2013)

The Global Innovation Index 2013
The Local Dynamics of Innovation

<table>
<thead>
<tr>
<th>Country/Economy</th>
<th>Score (0–100)</th>
<th>Rank</th>
<th>Income</th>
<th>Rank</th>
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Outline

I. Context of challenge in Raw Materials sector
II. Set the dimensions
III. Identify the tools

I. Context

The role of **new technologies** and **new approaches** on:
- The integration of society
- The achievement of:
  - Environmentally-friendly targets
  - Traceability of RM
  - Remanufacturing / Recycling
  - Circular Economy / Sustainability / **Resource Efficiency**

Resource Efficiency

- Material
- Human
- Time

Monetary balance
Raw Materials activities are a concern of local and global community:

Sustainability

Social

Trading

Training

II. Set dimensions

To be followed

Innovation

Breakthrough solutions

To be integrated

Above and beyond

Continuous improvement

To be tolerated

Globally

Duty: comply with regulations to the best standard

Locally

Where are we Today? 2020? 2030?
II. Set dimensions

Definition of Scope of Action: Who – What – When
Targets and strategies.

“Above and beyond duty” leads to a more elaborated concept of Quality not just material performance but where Excellence is now incorporated, daily practice achieved through Resource Efficiency (material, human, time).

To that end: identify the right tools.

III. Identify tools

In the development of targets and strategies, the role of different actors / stakeholders must be recognized, observed, revisited if necessary, and integrated in an effective way.

Requires communication ↔ feedback

Based on integrated needs:
- sense of shared responsibility
- shared / common goals
- sense of TRUST in one another’s work
III. Identify tools

However, trust is NOT a dogmatic belief.

“TRUST, BUT VERIFY”

Implement best means / actions possible to build, over time, trust.

Where / How to start?
Observe, listen, map WITHIN & OUTSIDE:
- excellent ideas, gaps, synergies
- opportunities to improve are always win/win
- good examples and scrutinize errors

Identify who are driving change / who have trust / do best business

How did they achieve social validation? (not acceptance but validation)

“DATA: The Undeniable TRUTH”

References are cited to validate a myriad of affirmations and reviews. Today everything is reviewable.

Bilateral reviews can serve the critical function of providing a sense of trust (concept of shared responsibility).

Use of best available technologies and best approach for integration with community has been in practice for years in some cases.
III. Identify tools

Case of good practice in proximity for plant treating secondary resources
III. Identify tools

FRAMEWORK (GOV)

ACADEMIA AND RESEARCH INSTITUTES FUNDS

Exploitation of R&D

INDUSTRY FUNDS

Basic research
Concept validation
Prototype demonstration
Trial in real environment
Deployment

III. Identify tools

FRAMEWORK (GOV)

ACADEMIA AND RESEARCH INSTITUTES FUNDS

Exploitation of R&D

INDUSTRY FUNDS

Basic research
Concept validation
Prototype demonstration
Trial in real environment
Deployment
III. Identify tools

The Innovation Pyramid

Goal: examine and re-define our roles according to strategic targets.

Remarks

- Turning challenge into stepping stones, using data and integrating the innovation pyramid.

- Transforming a Deadlock into Growth via inclusive leadership and implementation of new technologies (aim to reduce material non-material costs).

- Promote the use of resources as a tool for shared growth.

- **Inspire** your community that through your leadership they can accomplish what otherwise might seem impossible.

  Thank you!
Challenges in sustainability for the mining project portfolio in Chile

IMPC 2014
Sustainability Symposium
22 October 2014

Cristian Cifuentes
Mining Analyst
Chilean Copper Commission

Contents

1. Mining Investment Portfolio in Chile 2014 – 2023
2. Challenges of the Mining Industry
3. Final Comments
1. Mining Investment Portfolio in Chile 2014 - 2023

Mining projects portfolio

Portfolio of **53 initiatives** to be developed between 2014 and 2023 with a total investment of **US$ 104.9 billion**.

![Diagram showing mining projects portfolio]

*Source: Cochilco*

*Chilean Copper Commission*
1. Mining investment portfolio in Chile 2014 - 2023

**Copper mining**

Projected Investment in Copper Mining to 2023

<table>
<thead>
<tr>
<th>Copper Mining Sector</th>
<th>Number of projects</th>
<th>Investment (MMUSS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CODELCO</td>
<td>8</td>
<td>28,137</td>
</tr>
<tr>
<td>Large-Private Mining</td>
<td>19</td>
<td>48,722</td>
</tr>
<tr>
<td>Medium-Scale Mining</td>
<td>6</td>
<td>3,273</td>
</tr>
<tr>
<td>Metallurgical Plants</td>
<td>2</td>
<td>490</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>35</strong></td>
<td><strong>80,622</strong></td>
</tr>
</tbody>
</table>

Distribution of investment in copper mining according to condition
(Total investment : MMUSS 80,622)

- Base 25%
- Potential 47%
- Probable 2%
- Possible 26%

Chilean Copper Commission

1. Mining investment portfolio in Chile 2014 - 2023

**Gold, iron and industrial minerals**

Projected Investment in Other Mining Industries* to 2023

<table>
<thead>
<tr>
<th>Mining</th>
<th>Number of projects</th>
<th>Investment (MMUSS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gold &amp; Silver</td>
<td>10</td>
<td>17,382</td>
</tr>
<tr>
<td>Iron</td>
<td>5</td>
<td>4,519</td>
</tr>
<tr>
<td>Industrial minerals</td>
<td>4</td>
<td>2,328</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>19</strong></td>
<td><strong>24,229</strong></td>
</tr>
</tbody>
</table>

Distribution of investment in Other Mining Industries according to condition
(Total investment : MMUSS 24,229)

- Base 15%
- Potential 44%
- Probable 19%
- Possible 22%

* Other Mining Industries: it is understood as the mining of gold and silver, iron and industrial minerals. Copper mining is excluded.
Copper production forecast 2013 – 2025 by condition

Copper production forecast by product

Chilean Copper Commission
2. Challenges of the Mining Industry

Main challenges for the mining project portfolio

Challenges of the Mining Industry
2. Challenges of the Mining Industry

Geology

Mines are getting older

- Deeper mines
- Lower ore grades
  - Longer hauling distances
  - Increasing material transport

Chilean Copper Commission

2. Challenges of the Mining Industry

Energy

Consumption forecast

Source: Cochilco, 2014.

Source: Cochilco, 2013.
2. Challenges of the Mining Industry

Energy

Power cost

![Graph showing power cost in mining from 2000 to 2014](image)

Unitary Power Cost in some mining countries in 2012 (US$/MWh)

<table>
<thead>
<tr>
<th>Country</th>
<th>Cost (US$/MWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chile</td>
<td>143</td>
</tr>
<tr>
<td>Argentina</td>
<td>104</td>
</tr>
<tr>
<td>Brazil</td>
<td>96</td>
</tr>
<tr>
<td>Mexico</td>
<td>96</td>
</tr>
<tr>
<td>平均铜矿开采</td>
<td>88</td>
</tr>
<tr>
<td>澳大利亚</td>
<td>82</td>
</tr>
<tr>
<td>Peru</td>
<td>74</td>
</tr>
<tr>
<td>加拿大</td>
<td>69</td>
</tr>
<tr>
<td>南非</td>
<td>61</td>
</tr>
<tr>
<td>美国</td>
<td>59</td>
</tr>
</tbody>
</table>


Chilean Copper Commission

2. Challenges for the Mining Industry

Water

Copper Mining

Consumption of fresh water per ton of processed mineral 2009 - 2013

![Graph showing consumption of fresh water per ton of processed mineral](image)

Extraction of fresh water by region in 2013 (l/s)

<table>
<thead>
<tr>
<th>Region</th>
<th>Extraction (l/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>1,320</td>
</tr>
<tr>
<td>II</td>
<td>1,412</td>
</tr>
<tr>
<td>III</td>
<td>1,085</td>
</tr>
<tr>
<td>IV</td>
<td>1,338</td>
</tr>
<tr>
<td>V</td>
<td>1,582</td>
</tr>
<tr>
<td>VI</td>
<td>794</td>
</tr>
</tbody>
</table>

2. Challenges for the Mining Industry

Water - Current status

Chilean Copper Commission

2. Challenges for the Mining Industry

Water consumption forecast to 2021

Forecast of fresh water demand in copper mining

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>m³/s</td>
<td>13.1</td>
<td>13.6</td>
<td>14.8</td>
<td>14.2</td>
<td>14.2</td>
<td>16.0</td>
<td>17.2</td>
<td>17.7</td>
<td>18.0</td>
</tr>
</tbody>
</table>

Forecast of sea water for new mining projects

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>m³/s</td>
<td>0.7</td>
<td>1.2</td>
<td>1.3</td>
<td>2.6</td>
<td>3.6</td>
<td>4.4</td>
<td>5.2</td>
</tr>
</tbody>
</table>

Source: Cochilco, 2013.
2. Challenges of the Mining Industry

Innovation

Geology, energy and water
- Mega mines
- Underground mining
- Complex mineralogical species
- Costs increase

Innovation

? 

BUT: investment in R&D and innovation in Chile is the lowest among OCDE members.

Chilean Copper Commission

2. Challenges of the Mining Industry

Innovation

Competitiveness and Productivity

Copper production and cash cost production in Chile

Some factors that affect the cost increase:
- Increasing price in strategic supplies
- Declining productivity by structural and non-structural effects

Source: COCHILCO, Wood McKenzie, 2013
2. Challenges of the Mining Industry

Human Capital

Rising labor will directly affect further efforts to maintain a very important feature in the mining industry.

SAFETY

- Increasing demand for HR
- Work disruptions
- Increasing labor costs

Chilean Copper Commission

2. Challenges of the Mining Industry

Communities

Criticizing society

Environmental awareness

Chilean Copper Commission
2. Challenges of the Mining Industry

Move on citizen participation

Some duties of the EIS

- To establish mechanisms to ensure the informed participation of the community.
- The responsibility of the owner to publish a summary of the EAS
- EAS obligation to respond (consider) citizens’ comments.

Some rights of people in environmental assessment

- The rights of natural and legal persons to know the contents of the EIS.
- The right to submit comments on the environmental draft within 60 working days (Monday through Friday).
- The right to claim of those who consider that their observations were not adequately considered.

Chilean Copper Commission

2. Challenges of the Mining Industry

Application of the ILO Convention 169

Initiatives on indigenous consultation process by productive sector 2014

- Mining 15%
- Farming 3%
- Cellulose 4%
- Other 1%
- Energy 77%

Due to the location and size of these mining projects they have an important participation in the processes of indigenous consultation.

Source: EAS, 2014.

Chilean Copper Commission
3. Final Comments

Geology, Energy and Water

- Growth of the mining industry implies:
  - an increase in consumption of strategic consumables such as water and energy.
  - Pressure on power grids and water sources.
- Sustainability of the mining industry ⇒ responsible management and efficient use of strategic consumables.
- Energy ⇒ Cooperation of the mining and energy sectors.
- Optimize the use and consumption of water resources.
3. Final Comments

Human Capital and Innovation

- The industry has been concerned to create a culture of safety, with emphasis on the process of induction of workers.
- On the public side, Sernageomin has focused on more and better control in the approval and regulation of mining projects and safety training of employees who work in the industry.
- Present challenges of the Chilean mining sector are an opportunity for highly innovative companies from all over the world.

3. Final Comments

Communities

- The difficulty of obtaining “social license” to operate is getting harder. In this sense is important to work on:
  - Greater legitimacy of assessment institutions of the environmental impact of projects (to avoid arbitrary pronouncements).
  - Effective and timely communication of the externalities of projects to the affected communities.
- The incorporation of the indigenous consultation process is a tool that gives greater legitimacy to the industry, being important for its sustainability.
Sustainability education in Chilean undergraduate programs

Jacques V. Wiertz
Dpto. de Ingeniería de Minas, Universidad de Chile

Chile: a land of beauty, a land of contrast
The Context

Chile: an economy based on natural resources

Chilean exports 2012
MMUS$ 78,813

- Mining 60%
- Industry 34%
- Forestry, Agriculture and livestock, fishing 6%

The Context

Water stress

Air contamination

Unsustainable energy
The Context

[Graph showing trends in GDP, extreme poverty, Gini index, and Human Development Index from 1990 to 2010.]

The Great Challenge

[Diagram illustrating the relationship between Society, Environment, and Economy.]

Business as usual / “Mickey Mouse” Model  ➔ Sustainable development
Are our engineers prepared for this challenge?

Engineering education in Chile

- 5 to 6 year programs
- Focused on engineering sciences
- Mainly based on problem solving
- Technically well prepared

BUT:
- Poor communication skills
- Deficient in soft skills
Mining Engineering – U de Chile

- Mining Engineering is the only program that includes “Sustainability” as obligatory lecture
- 3 years ago, “Environmental management” lecture has been replaced by “Sustainability”
- Outcomes:
  - Concept of sustainable development and its different dimensions (awareness)
  - Environmental and social impact assessment (analysis)
  - Environmental and social management tools (application)
Mining activity

- Mining is essential for the sustainable development of mankind
- Mining is a temporary use of the land
- Mining is invasive and produces changes and impacts

- Extraction of non-renewable resources is “per se” hardly sustainable
- Mining activity produces community rejection

Decrease of ore grade

- Average decrease of 0.13% of the ore grade every 10 years
- Between 1998 and 2008: decrease from 1.5 to 1.0%
- Increase of 50% in ore to be processed

Source: Cochilco, 2009
Learning by doing

- Clean Production Agreement (APL) subscribed by Chilean Universities; it is a Chilean environmental soft instrument that seeks to implement the cleaner production using productive promotion.
Sustainable campus

• **1st goal to achieve:** clear sustainable commitment, as part of the institution guidelines.

• **2nd goal to achieve:** identify and promote sustainability as part of academic curriculum.

• **3rd goal to achieve:** design and implementation of extension program on sustainability and/or clean production, involving local community

• **4th goal to achieve:** identify and promote sustainability as part of academic research activities.

• **5th goal to achieve:** train at least 20% of students and 10% of professors and employees on sustainable management and clean production

---

Sustainable campus

• **6th goal to achieve:** measure carbon footprint of all facilities

• **7th goal to achieve:** reduce in at least 5% energy consumption in all facilities (measured as KWh/m²)

• **8th goal to achieve:** reduce in at least 5% fresh water consumption in all facilities (measured as L/person)

• **9th goal to achieve:** implement a management system to minimize, classify and recycle solid wastes

• **10th goal to achieve:** implement risk assessment and prevention to minimize labor risks

• **11th goal to achieve:** identify, quantify and characterize all liquid effluents
Environmental literacy in minerals education

- International Joint Conference held in Perth in 1999 organized by the Chamber of Minerals and Energy of Western Australia and the United Nations Environment Programme (UNEP).
- The meeting was a continuation of earlier work by various organisations. In 1997, UNEP co-organised in Paris a conference on “Engineering Education and Training for Sustainable Development”.

Key findings

- **Educators and mining schools** should show leadership in **increasing the environmental literacy component** of the undergraduate and postgraduate programs they offer; this requires willingness to change delivery modes, course content and curriculum structure.
- **Mining companies** should ensure that **environmental literacy is a core competence** of all new mining employees.
- **Professional associations** should play a catalytic role in the **exchange of teaching and learning experience and resources** between academics, and thereby assist individual mining schools and educators in overcoming the resource limitations.
- **International organizations** should **stimulate activity and raise awareness** at the international policy level. They should also play a **catalytic role** in the exchange of teaching and learning experience and resources between academics.
Sustainability Symposium

ECO EFFICIENCY CONCEPTS AND SOCIAL RESPONSIBILITY IN ENGINEERING CURRICULA BRAZILIAN CASES

MARIA JOSE GAZZI SALUM
Federal University of Minas Gerais
Mining Engineering Department

Engineers Profile - CHANGES OVER THE YEARS

In the 80's
- appreciation of the professional was fixed only on technical knowledge

In the 90's
- Technical Knowledge
- skills in communication, teamwork, leadership, foreign languages, etc.

2000's
- Technical knowledge + skills in social science and humanity
- Familiarity with environmental issues
Establishment of a New Engineer Profile in Brazil

2002: Act of the Ministry of Education

<table>
<thead>
<tr>
<th>Guidelines for Engineering Education</th>
<th>Graduate’s profile</th>
</tr>
</thead>
<tbody>
<tr>
<td>An engineer with a general, humanistic, critical and reflexive education, that is able to absorb and to develop new technologies. He/she should also be able to identify and to solve problems, considering their political, economical, social, environmental and cultural aspects, in order to attend societies demands.</td>
<td></td>
</tr>
</tbody>
</table>

Recommendations of the Brazilian National Guidelines

- To integrate contents from different courses and areas of knowledge in the curriculum.
- To focus the students evaluation on the whole engineer profile (established by the course program) and not on isolated subjects.
- To stimulate the activities outside the classroom.
Recommendations of the Brazilian Guidelines (cont.)

To emphasize social and human contents in the curriculum, attending the demand for an engineer with a broad profile.

To integrate environmental issues in the curriculum.

To focus education on the: “learn to learn” process, continuous learning, development of creativity, pro-active and ethical attitudes.


Interdisciplinary and holistic education: learning for sustainable development embedded in the whole curriculum, not as a separate subject.

Critical thinking and problem solving: leading to confidence in addressing the challenges of sustainable development.

Participatory decision-making: students participating in the decision on how they will learn;

Applicability: learning experiences are integrated in day to day personal and professional life; Locally relevant: addressing local as well as global issues.

Great similarity between Brazilian Guidelines for Engineering Education and the UNESCO Guidelines for ESD.
Different ways to insert environmental and social issues in the engineering programs

Model Adopted by UFMG (1998)

Assumptions:
Technical contents are essential;
Social responsibility is not necessarily taught as a course in the curriculum;
All engineers, regardless of ability, should meet the environmental and social impacts of their activities and must be prepared to act on them.

Challenge:
How to integrate environmental and social issues in the curriculum without:
overextending students stay in the undergraduate program.

Solution adopted:
Insertion of these issues into traditional technical courses.
Gain in parallel with the use of this model: technical contents became supported by sustainability concepts.

Case Study - Civil Engineering Course at UFMG

It was implemented three mandatory courses, distributed over the 5 years of the program. These courses are characterized by the development of a project that:

- integrates different subjects that were taught
- applies sustainability concepts
Students Practicing the social responsibility of civil engineers

Tutorial program in towns with low Index of Human Development (IHD) where students develop infrastructure projects for the local municipality and empowered the community on sanitation and environmental issues.

Another Example of Social Practice

Federal University of Juiz de Fora (Minas Gerais State)

- Students of Electrical Engineering Course developed a toolkit that allows some experiments in chemistry and physics within the classroom.
- The toolkit is available for public high schools that are poor in laboratories infrastructure.
Mining Engineering Education at UFMG

Since 2013 it is in a changing process
- Commission responsible by the new curriculum:
- Professors representing each area of knowledge
- Students representatives.

Main Changes
- Integration of sustainability concepts in various mining and mineral processing courses, with:
- Focus on clean technologies (reduced of water and energy consumption, less generation of waste and CO2 emission, etc);
- Focus on social gains brought by mining activity;
- Focus on mining closure: actions to be done in order to prepare communities to deal with the economic losses after mining closure.

HOW?

Project Courses
- Mining projects addressing solutions to environmental problems.
- Mining projects, addressing solutions to the demands of the communities surrounding the mining site.
- Development of projects including social, economical and environmental aspects of mining closure.

Social Practice: Technical and Administrative Support to Artisanal and Small Scale Mining
The introduction of sustainability concepts in the engineering curriculum is a mandatory question, in response to the behavioral changes occurred in the world over the past 50 years.

It is not a simple question, because:

- it demands an interdisciplinary and integrated knowledge, which makes it dependent on the environment offered by the university for its practice;
- it depends, strongly, on how well sustainable concepts are internalized in teachers.

In Brazil, several undergraduate engineering courses, including those directly related to mineral area, offer contents addressing environmental science and social science.

However, few are those that provide students with an integrated view of technical contents supported by sustainability concepts.

To graduate an engineer able to identify and to solve problems, from the perspective of sustainability, should be the goal of all engineering programs, particularly those related to the mining area.

Otherwise, ever more mining activity will have difficulty in implementing their projects, in getting the environmental and social license to operate.
Thank you for your attention!

maria@demin.ufmg.br

gazzisalum@hotmail.com
Educating Managers and Leaders for Sustainable and Socially Responsible Mining in Africa

Jenny Broadhurst, J-P Franzidis, Sue Harrison & Harro von Blottnitz

So how did it come about?

Education for Sustainable Development in Africa (ESDA) Initiative

Sustainable Rural Development
- University of Ibadan
- University of Ghana
- Kwame Nkrumah University of Science & Technology
- University of Development Studies

Sustainable Urban Development
- Kenyatta University
- University of Nairobi

Mining & Mineral Resources (MMR)
- University of Cape Town
- University of Zambia

United Nations University
Institute for Sustainability and Peace
MMR programme coordinators

Prof J-P Franzidis  
Minerals to Metals, UCT

Prof Sue Harrison  
Centre for Bioprocess Engineering Research, UCT

Prof Harro von Blottnitz  
Environmental & Process Systems Engineering Group, UCT

Dr Jenny Broadhurst  
Minerals to Metals, UCT

Prof Stephen Simukanga  
Vice Chancellor, UNZA

Dr Jewette Masinjia  
Dept of Metallurgy & Mineral Processing, UNZA
Rationale

- Mineral wealth has the potential to serve as a vehicle for significant economic growth, but there are challenges.
- A sustained programme of research and human capacity development is essential in meeting these challenges.
- Of key importance is the need to generate managers and leaders, who have an understanding of the critical and inter-related issues involved and a sensitivity on how to project such in the context of different stakeholders.

Aims & approach

- Integrate critical and inter-related factors for sustainable development in the context of mining and minerals beneficiation.
- Provide opportunity to experiment with real-life case studies.
- Bring together a diverse cohort of students from across a spectrum of disciplines.
- Review and piloting of existing courses by three master’s students: UCT, UNZA and Kyushu University.
Master of Philosophy (MPhil)
specialising in
Sustainable Mineral Resource Development
offered at the
University of Cape Town (UCT)
and the
University of Zambia (UNZA)

### Curriculum content

<table>
<thead>
<tr>
<th>Course Description</th>
<th>Convening Institute</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction to Sustainable Development</td>
<td>Sustainability Institute, US</td>
<td>16</td>
</tr>
<tr>
<td>Strategic Social Engagement Practice</td>
<td>GSB, UCT</td>
<td>16</td>
</tr>
<tr>
<td>Environmental Stewardship in Mining &amp; Minerals Beneficiation</td>
<td>School of Mines, UNZA</td>
<td>12</td>
</tr>
<tr>
<td>Research Communication &amp; Methodology</td>
<td>EBE Faculty, UCT</td>
<td>16</td>
</tr>
<tr>
<td>Practical Training in SD/Internship</td>
<td>EBE Faculty, UCT</td>
<td>0</td>
</tr>
<tr>
<td>Master’s Dissertation</td>
<td>EBE Faculty, UCT</td>
<td>120</td>
</tr>
</tbody>
</table>

1 credit is equivalent to 10 hours, with 1/5 hours as contact time
Introduction to Sustainable Development

- Professor Mark Swilling and Eve Annecke, Sustainability Institute at University of Stellenbosch
- How can the extraction, use and disposal of resources be reorganized to ensure greater levels of social equity, and the long-term survival of the ecosystems that sustain all life?

“Excellent, dynamic, life-changing, emergent”
“Made you hang out deeply”

Strategic Social Engagement Practice

- Convened by Corporate Learning Department at the UCT Graduate School of Business
  - Elspeth Donovan, A/Prof Chris Breen, Prof Ralph Hamann & A/Prof Mills Soko, guest lecturers
- How to engage with and manage the relationships between an organization and the communities and other social partners that populate its context?
  - Managing relationships and conflicts; the challenge of collaboration; the practice of dialogue; tensions and innovation (dealing with wicked problems); developing inclusive business models
Environmental Stewardship in Mining & Minerals Beneficiation

- New course at UNZA School of Mines, Lusaka
  - convened by Dr Jewette Masinja, with guest lectures from UCT
- Principles, criteria and practices for **environmentally conscious** development of mineral resources
  - cradle-to-grave mine design; cleaner production, eco-efficiency; industrial ecology; material stewardship, mine waste impacts & management, carbon neutrality, life cycle analysis, legislation.
- Mine site visit and case study

Research Communication & Methodology

- Modified course at the Faculty of Engineering & Built Environment, UCT
  - Professor Sue Harrison, Prof J-P Franzidis, Dr Jenny Broadhurst, guest lecturers
- How to execute meaningful **research** in a structured way, and **report** the results?
  - Literature review & writing skills
  - Research philosophy, methodologies & planning
  - Hypothesis development & research communication
  - Synthesis & application of programme learnings
The first student cohort (2014)

- 15 students – 8 at UCT, 7 at UNZA
- 4 chemical engineers, 3 foresters, 2 lawyers, 2 mining engineers, 1 geologist, 1 geographer, 1 economist, 1 social anthropologist
- Represent 3 African countries & Australia
- 8 males, 7 females
- Ages 21 to 51

Research topics

- Community involvement in rehabilitation of degraded mine land
- Performance analysis & decision-making frameworks for mineral value chains
- Life cycle based indicators for eco-efficient processing of PGMs
- Entrepreneurship in communities around the mining & minerals beneficiation
- Measuring the sustainability signature of mining assets by integrating models
- A systemic approach to mining accident causality analysis
- Legal frameworks for encouraging sustainable communities post mining
- Broader implication of deforestation by mining companies
- Downstream uses of mine wastes: opportunities, challenges & implications
- Reconciling different stakeholders: A Zambian case study
- Challenges & opportunities for revenue collection from mining companies
- The effectiveness of EIA protocols and legislation in relation to mining
Towards developing integrative knowledge

The Big Questions

- What were the key take-home messages from the courses and how are related?
- How can this integrative knowledge be used to develop an understanding of challenges and required responses to selected problems?

Selected Outcomes

- Enhanced self-awareness and personal growth
- Speaking a common language
- Developing mutual respect

So what did the students learn?

- Understanding the complexity and inter-related nature of sustainability challenges
- The need for value-based leadership and governance
- Creating shared value as a business model
- Constructive and inclusive stakeholder engagement
- Respect for nature (deep ecology)
- Effective planning & monitoring – Go slowly upfront
- Adopt systemic perspectives and principles
Going forward

- 2014/2015 cohort
  - Currently completing coursework assignments and project proposals
  - Internships: late 2014/early 2015
  - Complete research dissertations by end 2015

- 2015/2016 cohort
  - Recruitment in progress (October-November 2015)
  - First course commences in March 2015
  - Further information [www.mineralstometals.uct.ac.za](http://www.mineralstometals.uct.ac.za)

Thank you for your attention
Social Responsibility

Lic. Roberto Sarudiosky
Centro de Estudios para la Sustentabilidad
Instituto de Investigación e Ingeniería Ambiental
Universidad Nacional de San Martín

- Extractive industries are usually located in undeveloped areas
- They may be considered as places where different interests, different cultures, languages, etc., meet
- In meeting places like this may be conflicts
- There are three principal players: industry, government and communities
- All of them have social responsibility
Social Responsibility is the way in which all stakeholders integrate social, environmental and economic values into their decisions and actions, in a transparent and accountable manner, to contribute to socio-economic welfare.

**Principles**

- Adopt responsible governance and management
- Apply ethical practices
- Respect Human Rights
- Commit to project Due Diligence and Risk Assessment
- Engage host communities and other affected and interested parties
- Contribute to community development and social wellbeing
- Protect the environment
- Safeguard the health and safety of all the stakeholders
First stage: Voluntary SR

• CSR as a strategy for improving competitiveness, image and market
• Development of social programs as a "good will gesture"
• Companies replaced - supply the State
• CSR as a strategy to avoid conflicts
Second stage: technical and conceptual SR

- Measurement of SR with social indicators
- Issues such as sustainability, conflict management, cooperative systems, mediation, consultation models are included
- Compatibility of water resources and mining
- SR is institutionalized
- Improving the quality of life of the people is the fundamental goal of the different models of RS
- Confluence of the Public and the Private
Third stage?

- UN “Protect, Respect and Remedy” Framework in order to better manage business and human rights challenges: Guiding Principles for Business and Human Rights - John Ruggie:
- ISO 26000: "corporate" social responsibility is a subset of social responsibility in general
- Creating Shared Value: simultaneous promotion of competitiveness and economic and social conditions in the communities
Muchas gracias – Thank you

rsarudi@gmail.com