Challenges resulting from lower ore grades

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Average head grades of copper and nickel mines

Copper

Nickel

Source: Citi 2011 and 2018
Average copper grades, 2015

Source: G Mudd and S Jowitt. Growing Global Copper Resources, Reserves and Production: Discovery is Not the Only Control on Supply, Economic Geology, Vol 113, 2018

Long run copper and nickel ore grades

Challenges of lower ore grades

• Resource availability
• Energy requirements
• Waste management
Theoretical grade-tonnage function

Nickel deposits: ore grades and resources

Relationship between ore grades and resource availability is not straightforward

- Grades are not the only determinant of economic viability
- Productivity growth may be harder to sustain in the future
Costs of mine production 2013-15 vs 2000-02

% increase in average cash cost of global production between 2000-02 and 2013-15 in nominal and real (constant dollar) terms


Challenges of lower ore grades

- Resource availability
- Energy requirements
- Waste management
Nickel: effect of ore grade on energy expended for mining, milling and concentration

Source: UNEP 2013 (after Eckelman 2010)

Total energy use and tonnes of copper produced for all Chilean mines

Energy use in primary metal production*

![Bar chart showing energy use in primary metal production.](Image)


Energy use of metal sector

![Pie chart showing energy use of metal sector.](Image)

Source: BP, author’s calculations
Challenges of lower ore grades

- Resource availability
- Energy requirements
- Waste management

Copper ore throughput vs copper production

Source: BMO and Wood Mackenzie 2019
Frequency and severity of tailings storage facility failures

Source: L. N Bowker & D M Chambers, In the Dark Shadow of the Supercycle Tailings Failure Risk and Liability Reach All Time Highs, Environments, MDPI, 21 October 2017. See also https://worldminetailingsfailures.org/

Mine tailings are a growing challenge for:

• Development of safer disposal technologies
• Establishment of tighter industry standards
• Financial risk in the investment community
• Government regulation
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