Energy Savings and Carbon Footprint Reduction - Jameson Vs Conventional Copper Concentrator

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ABSTRACT

Traditional concentrator design involves the use of large mechanical cells of up to 630 m3 to provide sufficient residence time for flotation of ever lower grade ore bodies. Increasingly, companies are required to release Environmental Social Governance (ESG) disclosures for projects and demonstrate savings in both Scope 2 and Scope 3 emissions. However, very few benchmarks of emissions in flotation and regrind circuits are available in publications.

An alternative approach using the Jameson Concentrator has previously been demonstrated at New Britannia, Philex and Ozernoye which combines both IsaMill and Jameson Cell technology into a full-concentrator flow sheets to drastically reduce footprint, power, operating cost (OPEX) and capital cost (CAPEX) requirements. However, the benefits in terms of Scope 2 and 3 emissions have yet to be determined.

This paper presents a comparative case study between the Jameson Concentrator and a conventional copper concentrator. Each design is compared on a consistent basis in terms of plant footprint, power consumption, height, and Scope 2 and 3 carbon emissions.

The results demonstrate that the Jameson Concentrator approach results in savings in power consumption and footprint. In addition, both Scope 2 and Scope 3 emissions are reduced both during construction and during operation. It was found that the carbon savings during operation of the plant outweighed the emissions savings during construction by several orders of magnitude.

INTRODUCTION

As emissions of greenhouse gases (GHG) around world continue to grow, mining companies are under increasing pressure to innovate new methods of production which lower emissions, and drive towards net-zero production. In fact, mining operations generate 2-3% of CO_2 worldwide (Legge et. al., 2021), so they clearly have a responsibility to reduce emissions. According to climate scientists, global carbon dioxide emissions must be cut by as much as 85 percent below 2000 levels by 2050 to limit the global mean temperature increase to 2 ^{o}C above pre-industrial levels (Metz et. al., 2007). Achievement of this goal will require leadership and innovation from all companies, including technology suppliers, Engineering, Procurement and Construction Management (EPCM) and operators, in the mining sector in general, to lower the carbon footprint so that the commodities as an example, which are essential to a zero-carbon future, are produced.

The World Resources Institute (WRI) divides emissions into three categories as shown in Figure 1. Scope 1 consists of direct emissions from owned or controlled sources (e.g. diesel powered mining equipment). Scope 2 emissions consist of indirect emissions from the generation power consumed by the operation, and Scope 3 consist of all other indirect emissions that occur in a company's value chain (e.g. steel, concrete, reagents and grinding media). Copper producers generated 97 Mt of CO_2 equivalent in 2018, of which concentrators contributed almost a third. Flotation is responsible for about 20% of energy and emission intensity (Sykes et. al., 2007). In addition, the energy intensity of concentrators becomes exponentially higher with lower grade ore bodies (Northey et al., 2013).

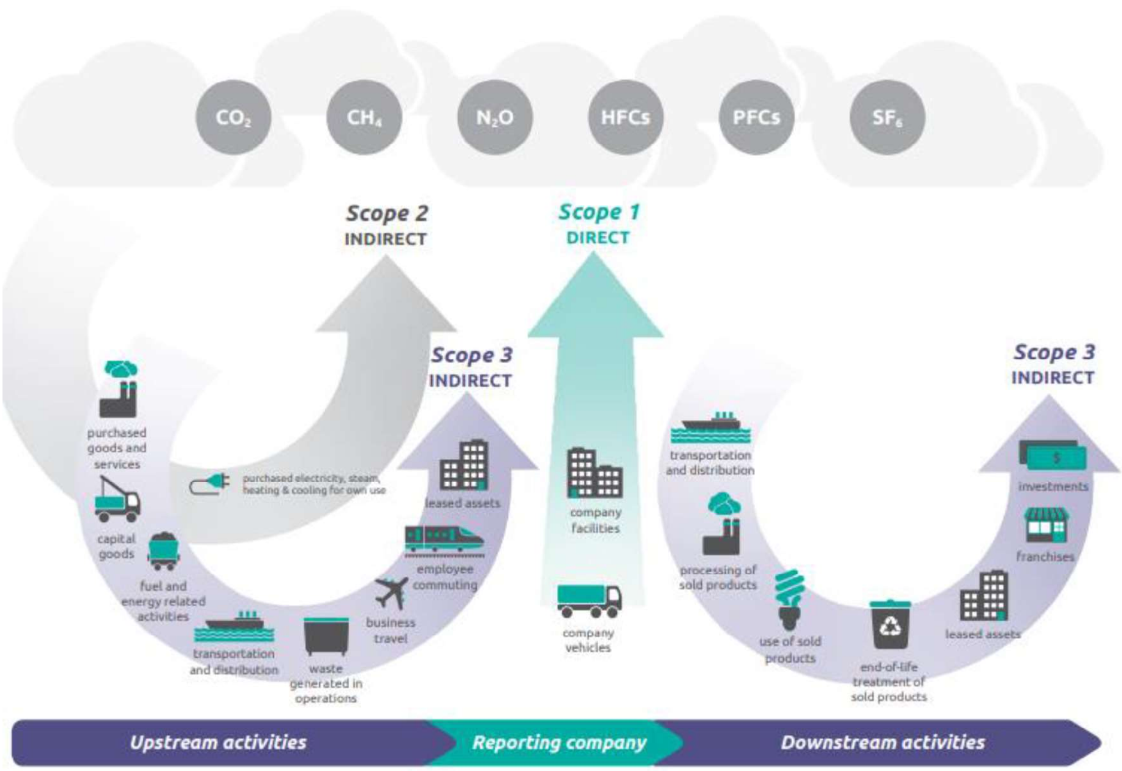

Figure 1: Overview of the GHG Protocol Scopes and Emissions across the Value Chain (Protocol, 2011)

To cut carbon emissions, mining companies have typically divested coal assets and the most visible and largest operators have set grandiose carbon emission targets for Scope 1 and 2 emissions. The copper miner giant, Codelco, uses solar power at one of its operations in Chile while BHP and Fortescue Metals are investing in renewable energy as a few examples. However, energy-efficient new technologies can also be a large contributor to Scope 1 and 2 emissions (Ballantyne et al. 2023).

The Jameson Concentrator is a combination of high-intensity Jameson flotation cells for minerals separation and IsaMill fine grinding to achieve acceptable mineral liberation. The high efficiency of Jameson Cells typically translates into fewer cells in each duty and a reduced number of cleaning stages, which significantly decreases concentrator footprint and power consumption (Anderson, 2022).

The following discussion investigates the extent to which applying the Jameson Concentrator approach can reduce GHG emissions, both during construction of the plant and during its operation.

BASIS OF ASSESSMENT

Ausenco, a global engineering company and frontrunner in delivering sustainable projects in the mining industry, undertook a comparative Class 4 (AACE) engineering study to determine the capital and operating cost differences between a Jameson Concentrator, offered by Glencore Technology, and a conventional plant for a major copper project. Furthermore, the study identified the differences in carbon emissions between the Jameson and conventional concentrator over the 15-year life of mine (including Scope 2 and 3 emissions) – including a high-level understanding of the carbon associated with the production of concrete and steel.

The study was nominally based on a recent copper concentrator project in North America to provide a basis for the mineralogy and ore characteristics, with a throughput of 14 Mtpa. The study included the following objectives:

- To capture the savings in steel and concrete between the Jameson and conventional concentrator,
- To identify the differences in environmental impact including but not limited to carbon footprint between the Jameson and conventional concentrator over the 15-year life of mine (including Scope 2 and 3 emissions) – including a high-level understanding of the carbon associated with the production of concrete and steel.

Design Basis

Each option was based on the following design basis.

Table 1: Plant Design Basis

Item	Units	Value
Plant design capacity	Mt/y	14.0
Life of mine (LOM)	years	15
Operating availability	%	91.3
Feed grade, average	%Cu	0.39
Feed grade, max for design	%Cu	0.79
Metal recovery, design	%	91.0
Concentrate grade, nominal	%Cu	26.0
Ore specific gravity	t/m3	2.73
Feed size, P_{80}	µm	75
Regrind size, P_{80}	µm	40
Specific grinding energy	kWh/t	7.8
Media Consumption (Vertical Mill - Steel Media)	g/kWh	6.5
Media Consumption (IsaMill - Ceramic Media)	g/kWh	8.0

Flow sheets and mass balances were developed for both the conventional and Jameson Concentrator circuits. A preliminary 3D model was developed for each option, with preliminary material take-offs (MTOs) for bulk earthworks, concrete, steel and platework developed based on the 3D model, as well as reference projects in Ausenco’s database.

Battery Limits

Battery Limits for the trade-off study were as follows:

- Feed to rougher flotation (excluding conditioning tanks)

- Media addition (bag splitter)
- Flotation tailings – discharge of the flotation tailings stream to tailings thickener
- Final concentrate – final concentrate stream reporting to concentrate thickener
- Process water to concentrator – considered as a flanged connection within 5 m of the flotation and regrind circuits.
- Gland and raw water supply – considered as a flanged connection within 5 m of the flotation and regrind circuits.
- Plant air and instrument air – considered as a flanged connection within 5 m of the flotation and regrind circuits.
- Flotation reagents – addition points within conventional and Jameson concentrators.

Key Input Assumptions

The following rates were assumed for carbon emissions:

Table 2 Summary of GHG emission equivalents

Parameter	Units	Value	Source
Steel	kgCO2e/ kg	1.89	Hammond & Jones, 2008
Concrete	kgCO2e/ kg	0.14	Hammond & Jones, 2008
Steel (media)	kgCO2e/ kg	1.82	Hammond & Jones, 2008
Ceramic (media)	kgCO2e/ kg	0.97	Calculation
Electrical energy	kgCO2e/ kWh	0.389	ClimeCo LLC, 2023

Conventional Circuit Design

The conventional circuit design is summarised in Figure 2. The head feed is processed in a bank of five 630 m3 tank cells, with the concentrate sent to a closed-circuit vertical stirred regrind mill to reduce the particle size from 80% passing 75 µm to 80% passing 40 µm. The regrind circuit product is sent to a three stage cleaner circuit comprised of seven 70 m3 tank cells, with the cleaner tails reporting to a cleaner-scavenger consisting of five 70 m3 tank cells. The circuit is designed to produce a 25.77% Cu product at a nominal recovery of 91.0%.

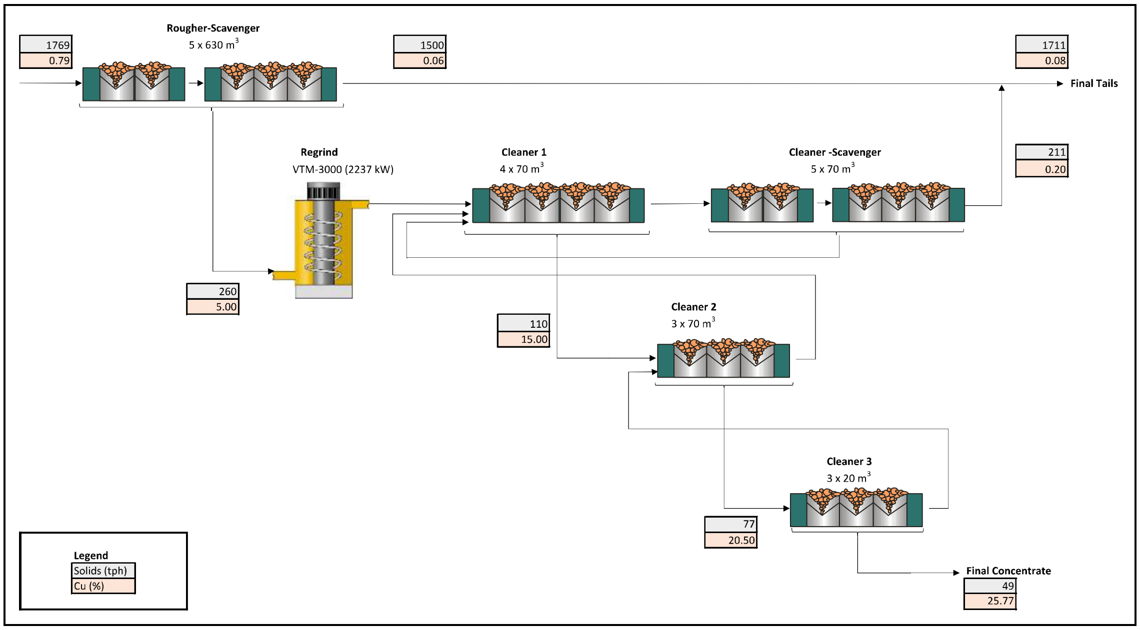

Figure 2: Simplified Flow sheet – Conventional Circuit

The plant layout for the conventional circuit is shown in Figure 3. The layout is based on a flat terrace arrangement with a focus on minimising the step height between successive cells, as well as the final tails sump to keep the building height to a minimum. Cognisance is given to crane access for agitator removal during maintenance.

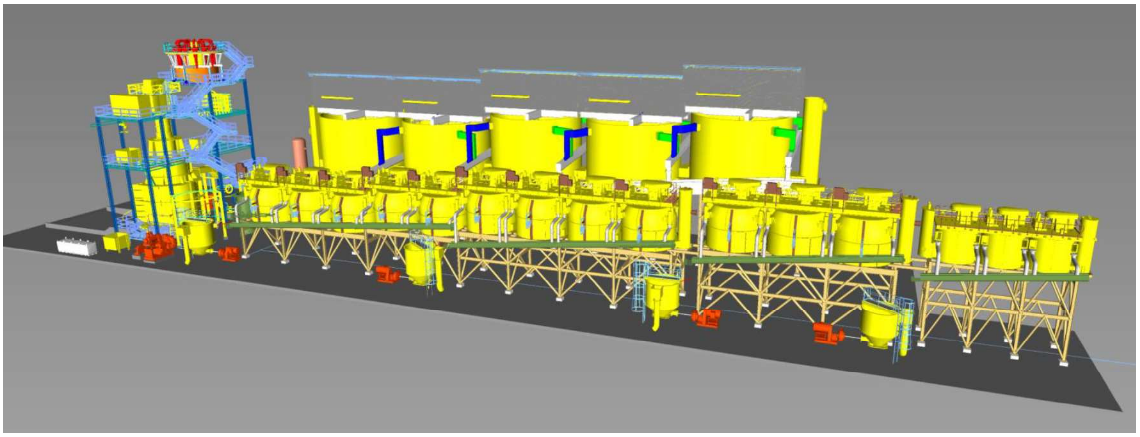

Figure 3: Plant Layout - Conventional Circuit

This plant layout results in the following quantities in terms of concrete and steel:

Table 3: Preliminary Quantities – Conventional Circuit

Quantity	Units	Value
Footprint (L x W x H)	m	120 x 32 x 25
Structural Steel	t	426
Equipment Steel	t	662
Concrete	t	10 391

The power consumption for the conventional circuit option is summarised in Table 4

Table 4: Power Consumption Summary – Conventional Circuit

Area	Units	Conventional Circuit
Flotation	GWh/y	30.1
Regrind Mill	GWh/y	7.7

Jameson Concentrator Design

Head feed is processed in a rougher-scalper Jameson Cell which is operated with a deep froth and high wash water rate to generate a final concentrate grade. Typically, rougher-scalper Jameson Cells can achieve between 60-80% recovery in this duty depending on the liberation of the material. The tails of the rougher-scalper is processed in a scavenger Jameson Cell which is operated at a low froth depth and high air rate without wash water in order to generate a high mass pull and low tailings grade.

The regrind mill operates in open-circuit with a cyclone and is sized as an M7500 primarily due to the high volumetric flow rate. The low specific grinding energy of 7.8 kWh/t means that the mill will only draw 729 kW under nominal conditions and 1131 kW under design mass pull conditions. 5 mm ceramic media is used to reduce the feed from an F_{80} of 75 µm to a P_{80} of 45 µm.

The regrind product to feed a B4500/12 Jameson Cell which operates with a deep froth and high wash water flow rate to scalp out the newly liberated material and produce a final concentrate. The remaining middlings particles in the tailings of the cleaner-scalper are fed to the cleaner-scavenger Jameson Cell. This cell is set up to run aggressively without wash water, with low froth depth and high air rate to drive a high mass pull and low cleaner tails grade. The resulting concentrate is passed to a smaller E2514/3 Jameson Cell, which operates with high froth depth and wash water to produce a concentrate from the middlings material, which can be blended into the final concentrate.

A key feature of the resulting circuit is that each cell has been given only one function in the circuit: either grade-focussed, or recovery-focussed. This means that each cell can be set up with appropriate operating conditions and can make use of the Jameson Cell's tails recycle mechanism to absorb a wide range of feed fluctuations to maintain overall circuit stability despite any fluctuations in feed grade and mass pull.

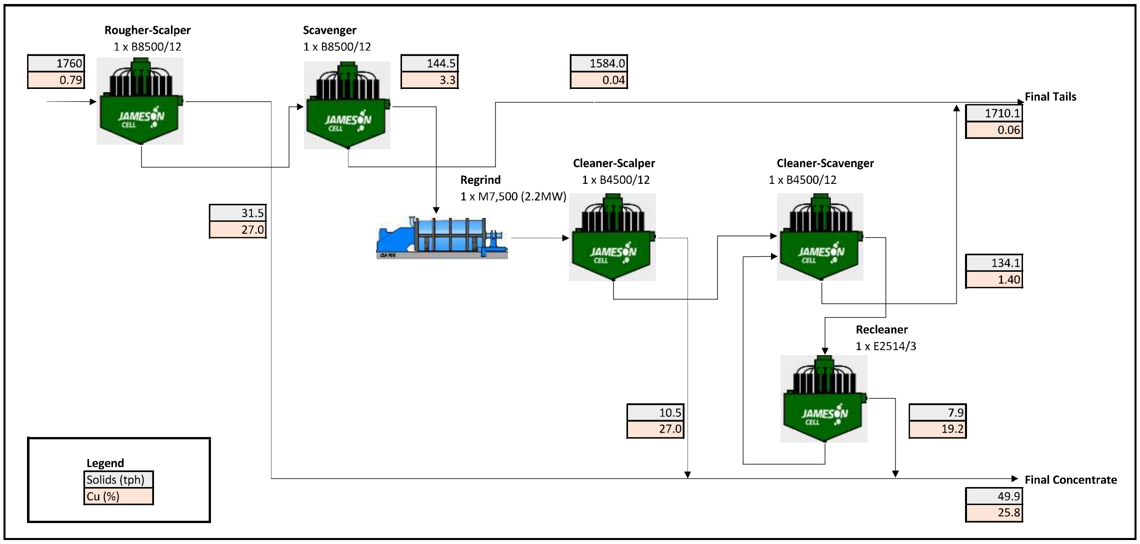

Figure 4 Simplified Flow sheet – Jameson Concentrator

The plant layout for the Jameson Concentrator is shown in Figure 4. Once again, the layout is based on a flat terrace arrangement, where the height of the structure is driven by the feed into the bottom of the Jameson Cell, as well as the height of the tails sumps into which the Jameson Cells discharge. The larger rougher-scavenger Jameson Cells are supported on concrete, whereas the smaller Jameson Cells in the cleaners are supported on a steel structure. Cognisance is given to pump and valve access for maintenance. Unlike conventional cells, the Jameson Cells do not require frequent overhead crane access. Maintenance on the downcomer and slurry lens can be done by hand, while the cells are operating.

Figure 5: Plant Layout - Jameson Concentrator

This plant layout results in the following quantities in terms of concrete and steel.

Table 5: Preliminary Quantities – Jameson Concentrator

Quantity	Units	Value
Footprint (L x W x H)	m	45 x 41 x 18
Structural Steel	t	87
Equipment Steel	t	155
Concrete	t	5679

Due to the fewer equipment in the flow sheet, the Jameson Concentrator required 846 t less steel and 1963 m³ less concrete compared with the equivalent conventional concentrator.

The power consumption for the conventional circuit option is summarised in Table 6.

Table 6: Power Consumption Summary – Jameson Concentrator

Area	Units	Jameson Concentrator
Flotation	GWh/y	18.5
Regrind Mill	GWh/y	5.8

COMPARISON OF GREENHOUSE GAS EMISSIONS

The GHG emissions for both option is compared in Figure 6.

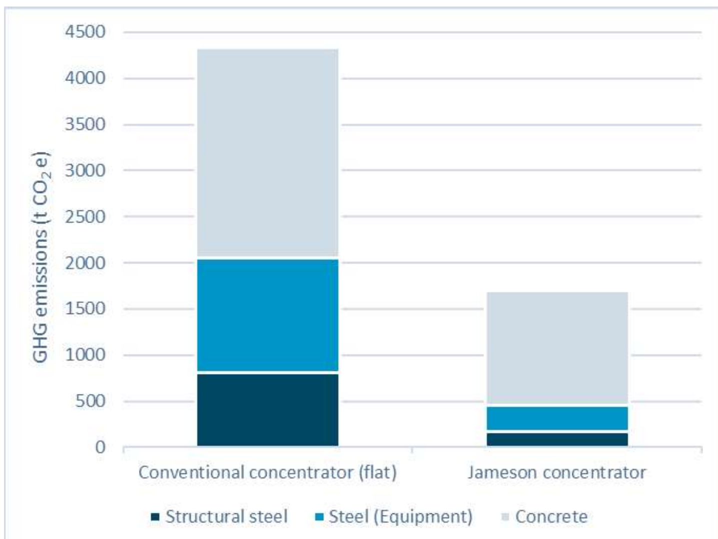

Figure 6: Comparison of Conventional and Jameson Concentrator Construction GHG Emissions

The increase in footprint and structure required in the conventional flotation circuit option resulted in 2.5 times the GHG emissions in the construction phase than the Jameson cell circuit.

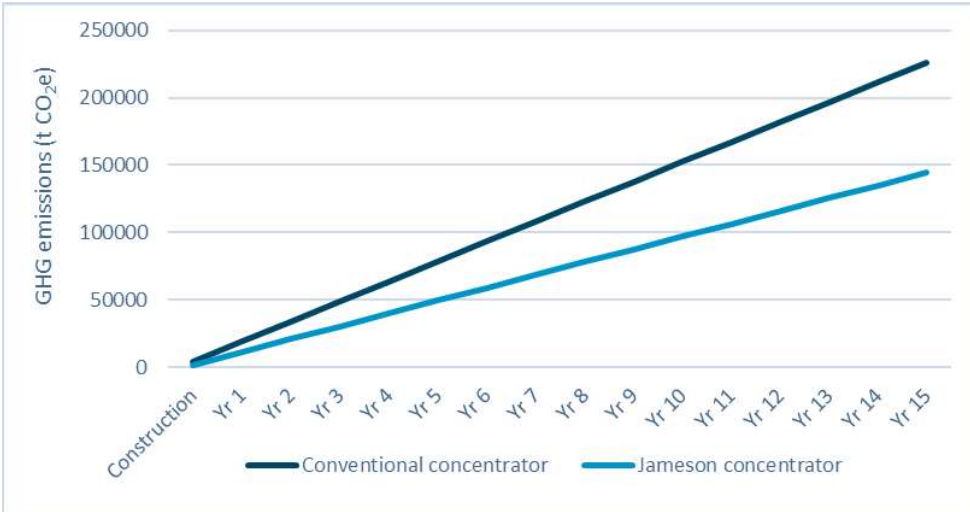

Figure 7: Comparison of Conventional and Jameson Concentrator Total GHG Emissions

The annual Scope 2 emissions, associated with electricity required in the conventional circuit resulted in a 59% increase when compared to the Jameson Cell circuit. This increase was predominantly related to the agitation power required in the tank cells.

Interestingly, operational emissions far outweigh construction emissions by two orders of magnitude. In fact, the plant produces emissions equivalent to the construction emissions every three to four months in the case of a conventional concentrator and every two months for the case of a Jameson Concentrator. This suggests that efforts to reduce GHG emissions should be focussed on reducing operational emissions as a priority.

CONCLUSIONS

A trade-off study between a conventional circuit and a Jameson Concentrator circuit has been conducted to an AACE Class 4 level. The results demonstrate that the Jameson Concentrator approach results in savings in power consumption of 35% which has a significant impact both on operating cost and on GHG emissions during operation of the plant. Due to fewer equipment in the flow sheet, the Jameson Concentrator required 78% less steel and 19% less concrete compared with the equivalent conventional concentrator.

In terms of GHG emissions, the Jameson Concentrator approach resulted in a 61% reduction in emissions during construction and 42% during operations. Interestingly, the GHG emissions over the life of mine far outweighs the emissions savings during construction by two orders of magnitude. This demonstrates that reduction of the total kWh/t processed is critical to reducing the carbon footprint of future metallurgical plants.

REFERENCES

Anderson, C., Csicsovszki, G., Stieper G., How the Jameson Concentrator Drives Reduced Energy Consumption and Smaller Footprint. Proc. of 18th International Conference on Mineral Processing and Geometallurgy. Procemin Geomet 2022.

Ballantyne G, Pyle M, Foggiatto B, Martin K and Lane G (2023) 'The Impact of Greenhouse Gas Emission Costs on the "True Economics" in Comminution Trade-Off Studies'. *SAG 2023 Conference, Vancouver, Canada.*

ClimeCo LLC, 2023, https://carbonfund.org/calculation-methods/, [Retrieved 28/08/2023].

Hammond, G.P. and Jones, C.I., 2008. Embodied energy and carbon in construction materials. *Proceedings of the Institution of Civil Engineers-Energy*, *161*(2), pp.87-98.

Legge, D.C. Müller-Falcke, H., Nauclér, C., and Östgren, E., 2021. Creating the zero-carbon mine. *Mckinsey & company. https://www. McKinsey. com/industries/metals-and-mining/ourinsights/creating-the-zero-carbon-mine [Retrieved April 23, 2022]*.

Metz, B., Davidson, O.R., Bosch, P.R., Dave, R. and Meyer, L.A., 2007. Summary for policymakers. *Climate change*.

Northey, S., Haque, N. and Mudd, G., 2013. Using sustainability reporting to assess the environmental footprint of copper mining. *Journal of Cleaner Production*, *40*, pp.118-128.

Protocol, G.G., 2011. Corporate value chain (Scope 3) accounting and reporting standard. *World Resources Institute and World Business Council for Sustainable Development, Washington,*

Sykes, C., Brinson, A., Tanudisastro, G., Jimenez, M. and Djohari, J., 2020. Zero emission copper mine of the future. *Zero Emission Copper Mine of the Future*.