Factors enabling copper beneficiation in Botswana

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Abstract

Botswana's Kalahari copper belt (KCB), which extends into the North-West of Botswana, is a prospective zone that offers the opportunity for a large copper production sector to provide diversity and growth for mining in Botswana. Despite good quality orebodies with good grades, the disadvantage of long and expensive logistical routes has softened project financial returns in the past and hampered the development of new mines on the KCB.

The Botswanan government identified the need to investigate the creation of in-country, downstream processing (beneficiation) facilities to improve the global competitiveness of in-country producers and provide future opportunities for job growth. While in-country beneficiation has been explored over the years by various stakeholders, the low quantity of primary copper sources and an uncertain outlook on exploration deterred further investment. The study further seeks out to improve the potential stakeholders' understanding of the relevant enabling factors and underlying risks of in-country beneficiation through practical discounted cash flow modelling.

Should Botswana want to drive in-country processing and enact a beneficiation legislation framework, it would need to explore options such as incentivising with tax structures and developing associated infrastructure to ensure electrification, water supply, rail network availability and other needs such as housing.

Tax incentives from the government are recommended to stimulate foreign direct investment. Viable government incentives such as i) granting special economic zone status, or more relevant ii) to divert 1% of the mineral royalties payable by miners to the government to this new facility in exchange for a proportionate minority equity state.

Four viable scenarios for in-country beneficiation were developed where the $NPV_{7.7\%,\text{real } 2022}$ of a new copper processing facility could range between US$ 358 – 422 million. Furthermore, the total value generated by the facility, undiscounted over life of operation, was estimated to be US$3.6 billion. 10.1% of the total project value generated would be recovered by the Botswanan government through corporate tax, dividend withholding tax, personal income tax and value added tax. The value added to the Botswanan economy would contribute an additional 2.2% to Botswana's gross domestic product. The total value generated towards nation building was calculated to be at least three times larger than the profit generated by the facility owners.

Keywords:

Botswana; Copper; Kalahari Copper Belt; Beneficiation; Capital Budgeting; Mineral Economics

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Nomenclature

Acronym/ abbreviation	Definition
AACE	Association for the Advancement of Cost Engineering
Amax	American Metal Climax
BCL	BCL Limited, *formerly* Bamangwato Concessions Limited
BCLI	BCL Investments
Beneficiation	Down-stream processing of metal concentrates to produceon producing refined metal products.
BMR	Base metals refinery
BPC	Botswana Power Corporation
BWP / P	Botswanan Pula
Capex	Capital expenditure (of a project)
CBM	Coal bed methane
CEPCI	Chemical Engineering Plant Cost Index
CGU	Cash generating unit
CIM	Canadian Institute of Mining, Metallurgy and Petroleum
CPI	Consumer price inflation
CSO	Central Statistics Office (of Botswana)
DCF	Discounted cash flow
DPMT	Dundee Precious Metals Tsumeb
DRC	Democratic Republic of the Congo
EAA	Equivalent annual annuity
EC	European Commission
EDF	European Development Funds
ENR	Empress Nickel Refinery
EPCM	Engineering, procurement and construction management (company)
ESG	Environmental, Social, and Governance
ESP	Electrostatic precipitator
FCE	Furnace
FCF	Free cash flow (or net cash flow)
FDI	Foreign direct investment
GDP	Gross domestic product
HDP	Hydrometallurgical Demonstration Plant
IMVAL	The International Mineral Valuation Committee
IRENA	International Renewable Energy Agency
IRR	Internal rate of return
KCB	Kalahari copper belt
kt (or ktpa)	Kilotonnes (kilotonnes per annum)

Acronym/ abbreviation	Definition
LME	London Metal Exchange
LOM	Life of mine
M (denoted with currency)	millions
Matte	An impure product of the smelting of sulphide ores, especially those of copper or nickel.
Mt (or Mtpa)	Mega tonnes (Mega tonnes per annum)
MDCB	Minerals Development Company Botswana
n/a	not applicable or not available
NCS	Namibian Custom Smelter
NDP	National Development Plan
NPV	Net present value
OOM	Order of magnitude
Opex	Operating cost
oz	Troy ounce
PFS	Pre-feasibility study
PGE	Platinum group elements (Pt, Pd, Rh, Ru, Ir and Au)
REA	Re-Employment Account
RC	Refining charges (following smelting to produce pure metals)
ROM	Run of mine (ore)
SAMREC	The South African Code for the Reporting of Exploration Results, Mineral Resources and Mineral Reserves
SAMVAL	The South African Code for the Reporting of Mineral Asset Valuation
SEZ(A)	Special economic zone (authority)
SHEQ	Safety, health, environment & quality (department)
Slag	Silicate and oxide dominant material phase separated from metals during the smelting or refining of ore.
SPEDU	Selebi Phikwe Economic Diversification Unit
SX/EW	Solvent extraction/ electrowinning (process)
Sysmin	System for the Stabilization of Export Earnings from Mining Products
TAP	Tati Activox® Project
TC	Treatment charges (of a smelter)
TFP	Total factor productivity (growth)
TNMC	Tati Nickel Mining Company (Pty) Ltd
TSL	Top submerged lance (furnace technology)
TC/RC	Treatment (smelting) and refining charges
UoM	Unit of measure
US$	United States of America Dollar
WACC	Weighted average cost of capital

Acronym/ abbreviation	Definition
WSA	Wet gas sulphuric acid (process), a patented process of Haldor Topsoe

SI measurement units were used unless indicated otherwise.

Symbol	Element
Ag	Silver
Cu	Copper
Ni	Nickel
S	Sulphur
SO_2	Sulphur dioxide

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1. Introduction

1.1 Background

The development of new mines in Africa is often constrained to only mining and mineral beneficiation. The mining companies export the intermediate metal product (often referred to as a concentrate) to global foreign processors due to the competitive processing charges received from these established economies.

It is often a marginal business to produce saleable metals via downstream processing (or beneficiation) and, therefore, small scale in-country beneficiation is seldom profitable. The mining volume production from a single small-scale (junior) miner is often not enough to produce the significant economies of scale required for downstream processing.

Botswana's Kalahari copper belt (KCB), which extends into the North-West of Botswana, is a prospective zone that offers the opportunity for a large copper production sector to provide diversity and growth for mining in Botswana. Despite good quality orebodies with good grades, the disadvantage of long and expensive logistical routes has softened project financial returns in the past and hampered the development of new mines on the KCB.

The Botswanan government identified the need to investigate the creation of in-country, downstream processing (beneficiation) facilities to improve the global competitiveness of in-country producers and provide future opportunities for job growth and semi-finished product fabrication. While in-country beneficiation has been explored over the years by various stakeholders, the low quantity of primary copper sources and an uncertain outlook on exploration deterred further investment.

This study presented analyses the current copper industry of viable Botswanan and Southern African resources and deliberates on practical tactics to improve Botswana's emerging copper industry and benefit the Botswanan economy. The study further seeks out to improve the potential stakeholders' understanding of the relevant enabling factors and underlying risks through practical discounted cash flow modelling.

1.2 Research problem

A centralised processing facility, scaled to the near-term production profile, built in a moderately industrialised area of Botswana, would not be financially viable in its base case. The study objective is to conceptualise a viable business case through a combination of optimisation opportunities. Should Botswana want to drive in-country processing and enact a beneficiation legislation framework, it would need to explore options such as incentivising with tax structures, developing associated infrastructure to ensure electrification, water supply and other needs such as housing, or taking a stake with its state-owned enterprise, the Minerals Development Company of Botswana.

1.3 Research approach

The capital budgeting approach was applied to interpret the near-term copper concentrate production scenarios in Botswana and furthermore included blue-sky copper supply sources from Southern Africa.

The study developed the base case and identified production scale, new capital, and operating cost estimates for copper and silver smelting and refining operations.

The study used the financial valuation of the base case to explore how government-influenceable benefits would contribute to the base case. Factors that were tested include:

- The sources of government revenue from mining and processing were unpacked by quantifying the distribution of revenue from corporate income tax, mineral royalties, personal income tax, import duties and local industry expenditure on items such as logistics.
- The realisable benefits when rail infrastructure can be used were explored, and the possible benefits when Botswana's coal bed methane sources would be developed and used to power the processing facility directly were also quantified.
- The potential of different tax incentives, such as declaring a special economic zone, allowing duty-free tax on imported project capital, and utilising additional unredeemed capital provisions, were evaluated.
- A conceptual tax strategy incentivising the processing facility with a portion of mineral royalties was modelled.
- Different capital structures, using various equity and debt weightings, were evaluated from both private institutions' and government institutions' attainable rates.

A financially viable business case would generate a positive net present value and favourable internal rate of return, while minimising the maximum negative drawdown the investors would need to finance.

1.4 Research hypotheses

It is hypothesised that the individual junior copper producers would likely not be able to reach the required economies of scale to support downstream beneficiation of its mined output.

It is hypothesised that a centralised copper processing facility would allow increased margins for copper producers operating in Botswana with the prevalence of the Kalahari copper belt, containing a massive exploitable orebody for copper extraction over at least 40+ years mine life.

The base case centralised facility may be marginally financially viable and may require optimisation to generate sufficient returns.

The increasing demand for copper due to the continued electrification and greenhouse gas reduction demands globally creates a robust, long-term market for copper products.

The centralised copper processing facility would off-take from various smaller mines.

This new processing facility would increase the value generated from the Kalahari Copper Belt, especially when considering the current challenges of land-locked Botswana.

The facility would create new jobs and encourage skills development in Botswana, setting the Botswanans up to engage in other mineral beneficiation projects of this nature on other prospecting opportunities or commodities.

It is hypothesised that this new facility would contribute significantly to the gross domestic product of Botswana through the application of the applicable corporate tax, personal income taxes, import duties, dividend withholding taxes and other indirect taxation. The gross domestic product benefits would substantiate the application of government sanctioned enablers such as granting a special economic zone, approving environmental, legislative, and other applicable permits and considering investment through government bodies such as the Minerals Development Council of Botswana.

Additionally, while proven metallurgical technologies such as smelting are preferred due to their robustness and proven industrial application, the need to build a facility of the future that focus towards global decarbonisation drivers may also need to be considered. A conceptual hydrometallurgical circuit is presented to quantify the potential economic benefits of alternative technologies.

1.5 Research contribution

This work defines how a copper processing facility in Botswana can be financially viable from the perspective of government bodies such as the Chamber of Mines Botswana and the Mineral Development Company of Botswana.

This research illustrates how different policies will affect all stakeholders in the mining industry and can be used to inform a Botswanan beneficiation legislation framework to be mutually beneficial to all relevant stakeholders.

This research lastly seeks to inspire African governments to drive change towards the way mining and metallurgy is conducted, aiming to stimulate the host country’s economy and to boost its gross domestic product and foreign direct investment.

2. Literature review

2.1 Capital Budgeting

Capital budgeting refers to the process undertaken by companies to assess potential significant projects or investments. When evaluating a productive asset like a beneficiation facility, the focus lies on analysing the anticipated future cash flows generated through the asset's sales (Ross, et al., 2013). Subsequently, the facility's profit-generating capability is compared to the investment criteria established by management. The investment criteria include financial and strategic desired objectives to be met, with an illustrative view, inferred from mining company annual reports, presented in Table 2-1 (Glencore AG, 2021).

Table 2-1: Investment criteria (illustrative)

Investment criteria	Target (Example)
Strategic	
Geography	Politically stable
Commodities	Copper
Longevity	>10 years
Scale (Annual production)	Annual production of 100 ktpa Cu
Environmental, Social, and Governance (ESG)	Net zero 2035 compliant
Financial	
Annual free cash flow (FCF)	>US$ 50 M per annum
Net Present Value (NPV)	Positive
Internal rate of return (IRR)	>15 %
Payback period	< 5 years
Capital intensity (Total Capital)	>US$ 200 M

The payback period computes after how many years an investment will be paid back, with undiscounted cash flow. It is a useful metric to do early elimination of mutually exclusive projects, but effective capital budgeting would rely on NPV and IRR calculations.

The net present value (NPV) derives the present value of future cash flows and expresses it in today's monetary terms. The present value of cashflow *C* in period *1*, at a rate of return *r* is:

$$PV = \frac{C_1}{1+r}$$

The net present value for multiple cash flow periods, with C_0 representing the investment capital is presented (Ross, et al., 2013):

$$NPV = C_0 + \frac{C_1}{1+r} + \frac{C_2}{(1+r)^2} + \cdots + \frac{C_T}{(1+r)^T} = C_0 + \sum_{i=1}^{T} \frac{C_i}{(1+r)^i}$$

A positive NPV generates more value than was invested, a signal that the investment should be pursued.

The internal rate of return computes the percentage rate at which the NPV of the project would be zero. As such, it does not depend on the prevailing capital market interest rate (Ross, et al., 2013).

The maximum negative drawdown of a project is important to consider from financiers' perspectives of mining and mineral exploitation projects because revenues of these large projects are locked up in working capital activities such as up-front exploration, development, the processing pipeline and reaching steady-state production. The maximum negative drawdown will be more than the total project capital and is the actual capital a financier needs to provide.

The investment decision precedes the financing decision and the aim of capital budgeting is to first establish whether a project is economically viable (Crundwell, 2010). Sunk costs are excluded from discounted cash flow analysis.

Project risks are difficult to quantify and include items such as uncertain feed material supply, commercial agreements with off-takers, future commodity pricing, future labour and utility pricing. These risks can be partially accounted for by use of sensitivity analysis on input variables and applying Nominal Escalation factors in a Nominal Discounted Cash Flow Model.

2.2 Mineral Resource valuation

Towards the evaluation of available copper Resources in the target region, the quantification of difference resource categories is required and elaborated below:

A Mineral Resource is a natural occurrence of concentrated minerals on intrinsic economic interest, but with a reasonable prospect of its economic extraction. The locality, metal concentration, total quantity and the continuity of the orebody is reasonably known from a geological perspective. Mineral asset properties are classified in four categories, according to the level of confidence (Cairns & Davis, 1998):

- i) Speculative
- ii) Exploration
- iii) Development
- iv) Producing

The assigned category of the mineral asset will depend on the level of understanding of the potential ore body. I) Speculative properties have very little assurance of exploitable mineral presence, whereas confidence in the mineral presence of ii) Exploration properties may warrant further technical investigation. iii) Development properties results from successful exploration activities and the subsequent investment of an extraction plan may lead to a iv) Producing asset that produces the target commodity.

Mining companies spend a proportionate amount of their budgets to define and classify their assets, depending on commodity cycles. Mining company exploration budgets are reported as it is expended on Grassroots (Speculative & Exploration), Late stage (Development & Producing), or Mine site (Producing) (S&P Global, 2019).

As the confidence in the mining property information and viability decreases from Producing assets systematically to Speculative properties, the contained mineral commodity information on its extraction become increasingly more conceptual, to the extent that projections of future income become difficult to ascertain (Davis, 2002). Mineral resource certainty has a prominent role in the valuation of mineral assets. The creation of mineral asset valuation standards is a recent development (Canadian Institute of Mining, Metallurgy and Petroleum, 2000). Valuation is the estimation of the Value of a Mineral Asset in money or a monetary equivalent. The valuation standards were developed as a result of the fusion of widespread methods developed in the financial industry by auditors and analysts, including specialists in technical valuation.

Of local significance in Southern Africa, the South African codes for the reporting of i) exploration results, mineral resources and mineral reserves (SAMREC) and ii) mineral asset valuation (SAMVAL) sets out the minimum standards for the reporting and valuation of mineral reserves. Furthermore, the appropriate international valuation standard, IMVAL, was developed in 2012 by representatives from the valuation committees from Australia, Canada, South Africa, the United Kingdom, and the United States of America. IMVAL harmonises the country-specific valuation codes but does not supersede them in their appropriate jurisdictions. The SAMREC and SAMVAL codes were developed to provide consistency, minimum standards, and guidance to perform mineral valuation and apply to Public Reports required for listing and financing activities (SAMVAL, 2016). The appropriate code to be applied depends largely on the stock exchange listings of the mineral asset holding company and the requirements set out by said exchanges.

The commonly accepted mining industry classification of geological confidence in mineral resources follows, which comprise the degree of mineralised estimates (developed through exploration) and is summarised in Figure 2-1 (Canadian Institute of Mining, Metallurgy and Petroleum, 2000):

Inferred – that part of a Mineral Resource for which quantity and grade or quality can be estimated based on geological evidence and limited sampling and reasonably assumed, but not verified, geological and grade continuity. The estimate is based on little information and samples gathered through appropriate techniques from locations such as outcrops, trenches, pits, workings, and drill holes.

Indicated – that part of a Mineral Resource for which quantity, grade or quality, densities, shape, and physical characteristics can be estimated with a level of confidence sufficient to allow the appropriate application of technical and economic parameters, to support mine planning and evaluation of the economic viability of the deposit. The estimate is based on detailed and reliable exploration, and testing information gathered through appropriate techniques from locations such as outcrops, trenches, pits, workings, and drill holes that are spaced closely enough for geological and grade continuity to be reasonably assumed.

Measured – that part of a Mineral Resource for which quantity, grade or quality, densities, shape, and physical characteristics are so well established that they can be estimated with confidence sufficient to allow the appropriate application of technical and economic parameters, to support production planning and evaluation of the economic viability of the deposit. The estimate is based on detailed and reliable exploration, sampling and testing information gathered through appropriate techniques from locations such as outcrops, trenches, pits, workings, and drill holes that are spaced closely enough to confirm both geological and grade continuity.

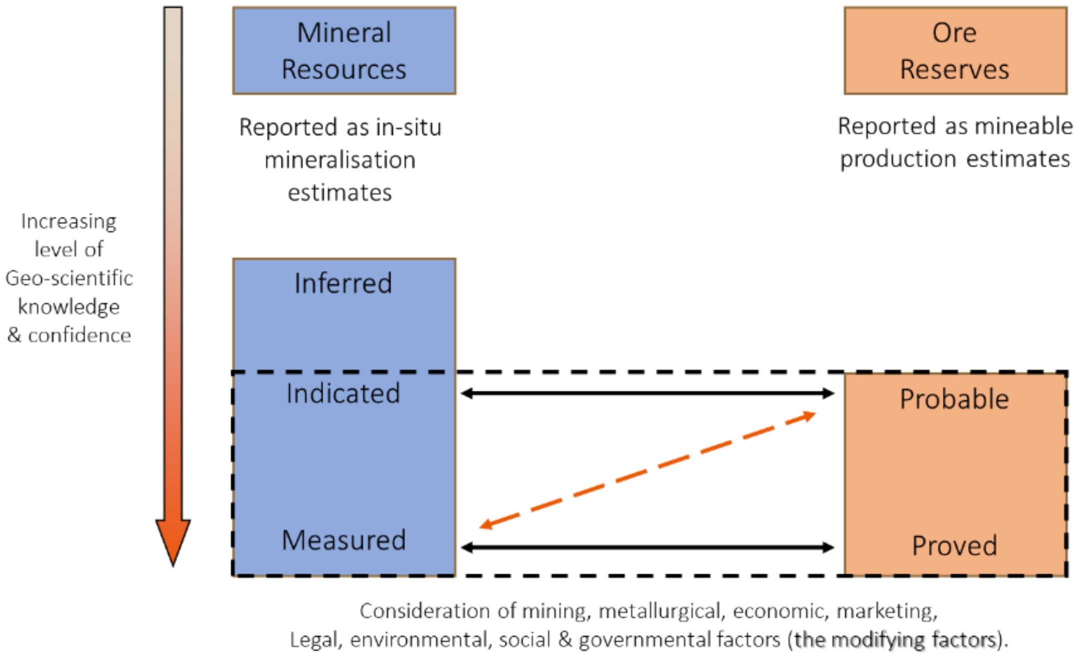


Figure 2-1: Mineral resource classification (Canadian Institute of Mining, Metallurgy and Petroleum (CIM), 2000).

From the definitions defined above, it follows that Inferred Resources are considered too speculative to derive income projections (Davis, 2002).

An extraction program results from an Ore Reserve classification with Probable and Proved Ore Reserves. An Ore Reserve is the economically mineable part of the Indicated and Measured Mineral Resource Defined, based on a practical extraction plan. The extraction plan includes reasonable assumptions to a high degree of accuracy regarding the mining method, metallurgical processes, marketing of products and environmental and jurisdictional factors. Towards the design of a down-stream copper processing facility, a reasonable degree of Ore Reserves needs to be defined to mitigate supply risks.

Exploration properties are discounted due to the uncertainty associated with its economic factors. Table 2-2 outlines the average transaction price during mergers and acquisitions for gold properties in the 1990s, per each category of reserves and resources (Ludeman, 2000). The market factors indicate that a premium is paid for operating mines. The quoted high market factors are disproportionately high, with one explanation being that geologists create a positive bias for the mining potential in early phases of the exploration phases (Davis, 2002). The mineral extraction risks are technical and reliant on additional test work to confirm and prove the soundness of estimates.

Table 2-2: Market Factors for various classes of gold reserves (Ludeman, 2000).

Resource category	Average price per ounce	Market factor
Proven and probable reserves (producing)	$60.50	1.00
Proven and probable reserves (development)	$34.10	0.56
Measured and indicated resources (exploration)	$10.30	0.17
Inferred resources	No value	

What needs to be inferred from the market value of the mineral resource is that the price per ounce for refined gold for 2020 ranged between US$ 1,500 – 1,900 per ounce. The full benefit of the exploited commodity is therefore not factored in by at least an order of magnitude.

2.3 Valuation approaches

The valuation approaches specified by SAMVAL include the i) Income approach, the ii) Market approach, and the iii) Cost approach (SAMVAL, 2016). IFRS 6 specifies the financial reporting for the exploration and evaluation of mineral resources. The recognition and allowance of expenses are outlined. The practical application of the valuation approaches can be further broken down according to best practices in the industry. Of relevance to this work, the Income Approach applies to this study and is elaborated below, as observed from Table 2-3.

Table 2-3: Valuation method application (SAMVAL, 2016).

Valuation approach	Early stage exploration	Advanced stage exploration	Development properties	Production properties	Dormant properties		Defunct properties
					Economically viable	Economically not viable	
Income	Not generally used	Less widely used	Widely used	Widely used	Widely used	Not generally used	Not generally used
Market	Widely used	Widely used	Less widely used	Quite widely used	Quite widely used	Widely used	Widely used
Cost	Widely used	Widely used	Not generally used	Not generally used	Not generally used	Less widely used	Quite widely used

2.3.1 The Income Approach

The Income Approach includes calculating the present value of future cash flows over the Mineral Asset's useful life and is based on the "value in use" premise (SAMVAL, 2016). The Income approach, therefore, encompasses the determination of the cash flow derived from the production of a commodity and can be considered the capital budgeting approach applied to mineral assets. The following methodologies apply (Lilford & Minnitt, 2005):

- Discounted cash flow (DCF)
- Tail margin method
- Option pricing valuation of Black-Scholes

The discounted cash flow determination is the baseline of the income valuation approach. The revenue and cost of sales, including operating expenses, capital expenditure, taxation and royalties and any other applicable costs, are factored in to derive an expectation of free cash flows. The cash flows are then discounted with an appropriate discount rate to determine the mineral asset's net present value (NPV). The application of economic inputs is necessary, such as commodity price forecasts, exchange rates, inflation rates and an appropriate derivation of the discount rate. Furthermore, the critical input data derives from the accompanying pre-feasibility, feasibility, or bankable feasibility study for the asset, extrapolated over the life-of-mine (LOM) of the project (Lilford & Minnitt, 2005). An overview of engineering project stages is presented in Table 2-4.

Table 2-4: Engineering project stages.

Role	***Stage of Project***			
Business Development	Opportunity Assessment	Business Case	Business Plan	Final Business Plan
Engineering Study	Concept	Pre-Feasibility	Feasibility	Detailed Engineering
Approval	Proceed to next study phase	Proceed to next study phase	Proceed to next study phase	Accept implementation plan

The level of study performed informs on the confidence of estimates presented.

The Association for the Advancement of Cost Engineering (AACE) is a professional organisation that provides guidelines and best practices for cost engineering and cost management (Stephenson, 2015). In the context of capital estimates, AACE has defined several classes of estimates based on their level of accuracy and the amount of detail included. Below follows a summary of the different classes of capital estimates defined by AACE:

Order of Magnitude (OOM) estimate (Class 5 or 4): This is a rough estimate of the cost of a project, typically made early in the planning process. OOM estimates are typically the least accurate type to within -25% to +75% of the actual cost.

Budget estimate (Class 3): This is a more detailed estimate of the cost of a project, based on more complete information about the project scope and requirements. Budget estimates are typically accurate to within -10% to +25% of the actual cost.

Definitive estimate (Class 2 or 1): This is a highly detailed estimate of the cost of a project, based on a completed and fully specified design. Definitive estimates are typically accurate to within -5% to +10% of the actual cost.

The capital for the facility evaluated in this work would be classified as a Budget estimate, as it utilises a detailed cost structure from several constructed or DFS level studies to inform applicable costs.

The modelling of processing facilities assumes fixed mining inputs from separate cash-generating units (CGU). Smelters either i) purchase metal concentrates at set payable terms or ii) perform toll treatment of the concentrates. When purchasing concentrate, the buying smelter buys the contained metal below 100% of an accepted commodity price. The payable terms of concentrate depends on the smelter's metallurgical recovery potential and the presence of deleterious elements to the smelting process such as bismuth and arsenic. Commonly, prices and contract terms, as listed on the London Metal Exchange (LME) or others (Shanghai Futures Exchange, Chicago Mercantile Exchange, Dubai Gold and Commodities Exchange or Tokyo Commodity Exchange) are used. The smelter's profit margin is the difference between the payable terms and the metallurgical recovery of the facility. Since concentrate purchasing requires a large balance sheet on inception and lot of up-front working capital, the toll-treatment route is preferred for the modelling in this work. Further to the payability deduction, toll treatment charges smelting (treatment or TC) and refining charges (RC) per commodity to the mine. These TC/RC terms are typically based on the terms of long-term contracts between the mining companies and the smelters, and can be influenced by several factors, including:

- The type and quality of the copper concentrates being processed.
- The capacity utilisation of the smelter.
- The availability of other concentrates on the market.
- The demand for refined copper.
- The cost of labour, energy, and other inputs used in the smelting process.

TC/RCs are typically expressed as a percentage of the value of the copper concentrates being processed. These charges are reviewed and negotiated annually but can also be adjusted during the year if market conditions change significantly. These charges follow supply and demand principles, with historic and forecasted future rates presented in Figure 2-2.

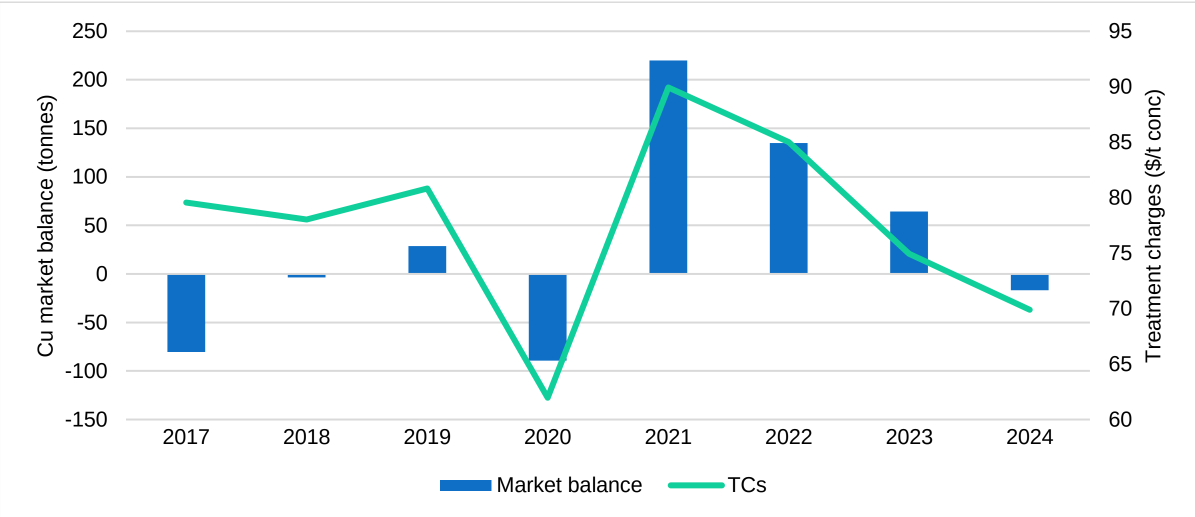


Figure 2-2: Treatment and refining charges forecast (China-domiciled) as on 12 October 2020 (Standard and Poor, 2020).

The tail margin method extends the DCF method to extrapolate operational data from steady-state operations outside the LOM boundary (Lilford & Minnitt, 2005).

Option pricing reflects the property's implicit option value and is intended to assist in the evaluation of investment options (Lilford & Minnitt, 2005). Current option pricing is often conducted by applying the

Black-Scholes model (Black & Scholes, 1973). It includes decisions such as the temporary closure of a mine when the market or operating conditions are unfavourable, the selective mining of high-yield sectors of the mining property and exit strategies or permanent closure of the mining property (Lilford & Minnitt, 2005). Therefore, in cases where current market conditions result in the generation of a negative NPV, as time progresses and market conditions changes, option theory will allow the determination of a relative intrinsic value of the mining property through an exercisable option or right at a future date.

A limitation of the Income approach is that in the absence of feasibility studies or, by implication, sufficient geological evidence to classify the Mineral Resource in the Indicated or Measured categories, the calculation of cash flows is unreliable. The Income approach cannot be used on Inferred resources, which is a core problem towards the valuation of a Greenfields smelter complex in Botswana. The concentrate supply from Indicated or Measured categories of this study only spans 14 years, whereas the planned processing facility would typically be constructed with a minimum lifespan of 20 to 40 years in design. A compromise needs to be made to evaluate whether payback occurs before 2035 (year 14 in valuation) and to consider whether the NPV will be positive on a shortened life of smelter (up to year 14) to comply the applied valuation with the Income approach.

2.4 Beneficiation and value creation

Regarding metallurgy, beneficiation refers to procedures that improve the metal content of "run of mine" (ROM) ore. The primary goal of metallurgical applications is to produce the materials needed for fabrication (Dworzanowski, 2013). The mining value chain comprises the following steps: i) mineral discovery, ii) exploration, iii) size reduction, iv) extractive metallurgy, and v) beneficiation, which may be smelting or hydrometallurgical means to ultimately vi) refining metals to pure commodities. Miners typically employ extractive metallurgy or mineral processing on-site before they export the intermediate products. At the same time, beneficiation in the sense of this work is referred to as pyrometallurgical (smelting) or hydrometallurgical (leaching) process routes that fundamentally alter the chemistry of the minerals to produce high-grade commodities. Depending on the resource and geology, multiple upgrading steps may be required, and different beneficiation methods would be preferred. Different processing technologies are also developed as time progresses.

Each upgrade step in the metallurgical process reduces logistical requirements of a mine to be feasible and creates more employment in the host country, albeit at higher levels of skill requirements, security and capital requirements.

With the construction of a copper beneficiation facility, Botswana can realise in-country value generation and unlocks the possibility to participate in the circular economy of e-waste scrap reprocessing in the future. A visual representation is provided in Figure 2-3.

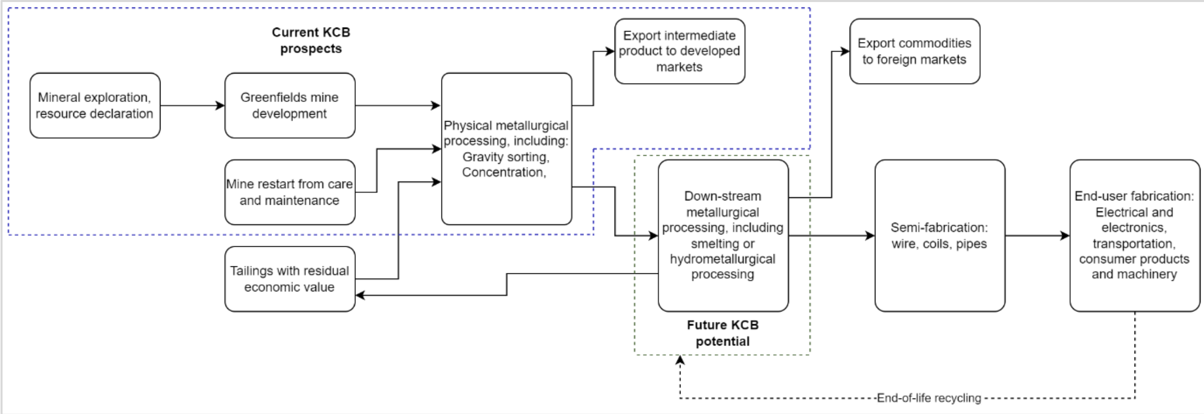


Figure 2-3: Beneficiation value chain.

50% of interviewed delegates at Mining Indaba 2019 affirmed that Southern African Development Community beneficiation is considered a key to economic development; stating that investment incentives, tax considerations and business enablers would be required to stimulate more beneficiation (Isheloke & von Blottnitz, 2020).

Upon analysis of a framework for mineral value chain barriers applied to the South African Manganese industry (including beneficiation), as presented in Figure 2-4, rising operational costs (electricity, labour and transport) ranked within the top 5 of 31 potential barriers identified. Other high ranking barriers depend on the commodity market, volatility thereof and exchange rate fluctuations (van Zyl, Bam, & Steenkamp, 2020). The framework showcased may be applied to the Botswanan Copper industry as well.

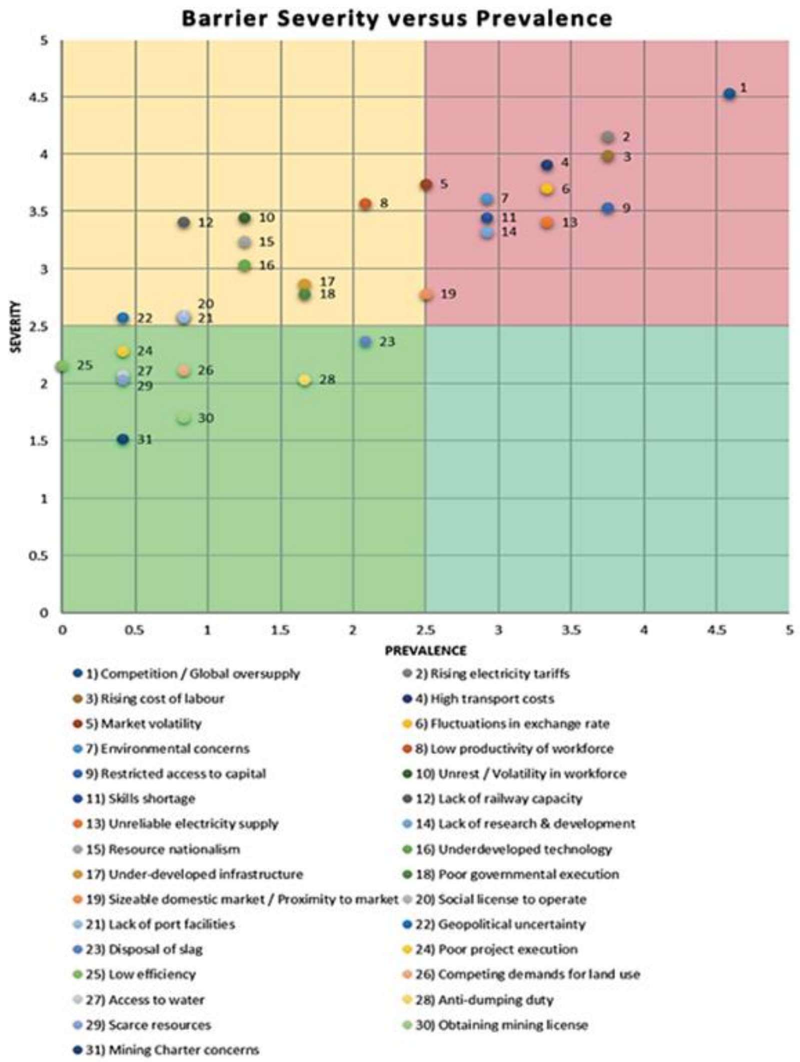


Figure 2-4: Mineral value chain barrier severity for the South African Manganese industry (van Zyl, Bam, & Steenkamp, 2020)

2.5 Base metal processing in Botswana

Base metal processing in Botswana was historically made-up of BCL Limited (BCL) and Tati Nickel Mining Company (Pty) Ltd (TNMC), which exploited Ni-Cu ores in the vicinities of Selebi Phikwe and Francistown (Botswana Chamber of Mines, 2022).

Minerals Development Company Botswana (MDCB), owned by the government of Botswana, has been responsible for managing and maximising the government's mining portfolio. MDCB, founded in 2015, acquired the government's ownership stake in BCL Limited (BCL) during its inception.

Later in 2015, TNMC was purchased from Norilsk Nickel to support and increase BCL's nickel and copper production goals. BCL Investments (BCLI), a fully owned subsidiary of BCL, owns all TNMC's issued share capital. TNMC owns an 83% share in Hunt Metals and a wholly owned subsidiary called Botswana Metal Refinery (Pty) Ltd.

Both BCL Limited and TNMC are no longer operational. These assets were placed in care-and-maintenance and in provisional liquidation on 9 October 2016, to be elaborated on below. While in-country beneficiation sounds lucrative and appealing, BCL Smelter’s failure in Botswana sketches a grim outlook for future in-country beneficiation.

2.5.1 BCL Limited at Selebi Phikwe

BCL Limited was founded following the 1967 discovery of copper in North-East Botswana. Known initially as Bamangwato Concessions Ltd, BCL was founded as a joint venture between the Botswana government with two foreign investors: American Metal Climax of the USA (Amax) and Anglo American Corporation of South Africa.

BCL constructed a nickel-copper smelter in 1973 to process bulk and low-grade Ni-Cu concentrates in Botswana, the first and only base metals processing facility in Botswana. The BCL smelter utilised flash furnace technology and received Ni-Cu concentrate from the four surrounding shafts at Selebi Phikwe, TNMC’s Phoenix and Selkirk mines, Ni-rich concentrates from Nkomati in South Africa and Agmet concentrates from the United States of America to fill its capacity. At design capacity, the BCL smelter could process 900 ktpa of Ni-Cu concentrates and was one of the largest installations of flash furnace technology globally (Malema & Legg, 2006).

BCL Limited employed about 4,300 direct employees, excluding contractors and service providers, to produce approximately 50 ktpa of Ni-Cu matte, which was exported for refining in Norway, Finland or Zimbabwe. After diamond miner Debswana, BCL was the second largest corporate employer in the country (Weekend Post Botswana, 2016).

During operation, the mine and smelter's capital costs ended up being more than twice as much as expected due to massive cost overruns and ongoing technical issues, and BCL was saddled with significant debt from the start. BCL has struggled to profit since, and this situation was made worse by the erratic metal prices in the 1970s. In 1978, the mining operation was anticipated to continue to be marginal since it would only be able to cover its expenses when metal prices were close to cyclical highs (Weekend Post Botswana, 2016). It was also stressed then, that more effective management could’ve offset some of the high operating costs.

The nickel market price had the most significant impact on the mine's future profitability. Investors, Amax and Anglo American Corporation ultimately pulled out of the project at a significant financial loss, leaving the government with a 93% equity interest and serving as the company's primary source of loans and guarantees. When nickel prices reached historic highs in the 2000s, BCL was profitable and accumulated substantial cash reserves. Nickel prices from 1997 to 2022 are presented in Figure 2-5. But aside from that time the business has struggled to profit. Nickel prices depressed steadily from its post-global post-2008 economic recession high of US$ 28,714/t in March 2011 to US$ 9,714/t in March 2016. BCL had been losing money at an unsustainable rate before the liquidation occurred.

Figure 2-5: Historic nickel price in US$/tonne (tradingeconomics.com)

The BCL smelter facility of this scale required substantial feed materials from various sources to maintain the required economies of scale. BCL had four shafts surrounding Selebi Phikwe and continual supply meant the increasing deepening of those mines. Notably, two of these shafts' ore grades decreased over its life and were becoming unprofitable to operate (Economist Intelligence, 2016). In 2014, BCL's reserves were graded at 0.67% nickel and 0.87% copper.

The company's core business, base metal mining activities, were under funded in its final years. Management's attention was diverted into unrelated activities such as steelmaking, iron prospecting and diamond prospecting through the turnaround strategy actioned at the time, Polaris II (Weekend Post Botswana, 2016).

The 2014 agreement with Norilsk Nickel, to purchase its assets in Southern Africa was a crucial part of the turnaround strategy. These sales included the 7% stake of BCL, 85% of Tati Nickel Mining Company (TNMC), the government of Botswana owning the remaining 15%; and 50% of the Nkomati Nickel mine in South Africa, with JSE-listed African Rainbow Minerals holding the remaining 50%. BCL would purchase these properties from Norilsk for US$ 337 million (BWP 3.5 billion). The various prerequisites for the Norilsk deal's completion had been met by August 2016.

BCL smelter underwent an extensive furnace refurbishment to accommodate the increasing Nkomati concentrate volumes expected, and during this refurbishment no matte product could be produced to generate revenue. BCL got permission to defer mineral royalty payments to the government of BWP 0.5 billion and depleted more than BWP 1.0 billion in funds that had been set up expressly for costs associated with end-of-life rehabilitation. Including corporate loans of BWP 1.1 billion, BCL also accumulated debts of approximately BWP 2.6 billion. BCL additionally needed capital of BWP 2.0 billion to spend on mining development at Selebi Phikwe and TNMC.

In summary, BCL required a total of BWP 4.6 billion to pay off its debts and make productive investments. The undisclosed price of the initial Norilsk Nickel acquisition was reduced due to the declining value of the copper and nickel reserves. BCL therefore needed to raise between c.BWP 5.5 billion and c.BWP 8.1 billion to stay solvent, as summarised below:

$$\begin{aligned} &Deferred\ royalties\ [BWP\ 0.5\ B] + Rehabilitation\ funds\ [BWP\ 1.1\ B] \\ &\quad + Mine\ development\ capital\ [BWP\ 2.0\ B] \\ &\quad + Norilsk\ transaction\ [BWP\ 0.9\ B - BWP\ 3.5\ B] \\ &\quad = Capital\ requirement\ [BWP\ 5.5\ B - BWP\ 8.1\ B] \end{aligned}$$

Recapitalisation through a cash injection was explored by BCL, but this option was declined by the BCL shareholders: BCL wanted to issue US$ 325 million in bonds (BWP 3.5 billion) in 2015. The market responded that BCL is not sufficiently credit-worthy and only a 100% government guarantee bond would be considered by prospective purchasers.

A combination of direct funding (as a subvention to give new capital) and indirect funding (via guarantees), depending on BCL's financial situation, would be required to provide all the organisation's finances. In the second scenario, the planned bond issuance would almost completely exhaust the government's capacity to borrow money or guarantee foreign debt, bringing it to the statutory maximum of 20% of GDP and limiting the government's ability to borrow money from abroad for other endeavours. Any government loans or capital subsidies for BCL would have to come directly out of the budget.

A choice had to be made because the Norilsk payment was due. In the event that BCL had breached the legally binding agreement they had made; Norilsk would have filed a petition to dissolve the business and sell its assets to satisfy the debt. The government decided that it could not afford to bail out BCL due to the numerous other demands on the budget, including those from other parastatals like the Botswana power corporation (BPC) and Water Utilities Corporation, as well as ongoing priority expenses like those for anti-retroviral medications.

TNMC and BCL Limited were placed in provisional liquidation on 9 October 2016. All the employees and contractors lost their jobs and resultantly the town of Selebi Phikwe turned into a near ghost town (Mguni, 2022). Similarly, TNMC’s 800 employees close to Francistown also lost their jobs, totalling job losses to approximately 5,100. BCL was the third-largest employer in the nation in terms of its contribution to employment and wages. The corporation employed about 40% of all workers in the mining industry. The impact of the business in Selebi Phikwe was crucial. About one-third of the town's working men were directly employed by it, and it contributed to 40% of the wages paid in Selebi Phikwe.

BCL was a primary client of the Water Utilities Corporation and the Botswana Power Company together with TNMC, BCL accounted for 50% of BPC's electricity sales to the mining industry, making it BPC’s largest single customer. The enterprise was a significant coal consumer and a significant customer of Botswana Railways.

The mining activity at BCL contributed BWP 28.6 million (US$ 4.9 million$_{2006}$[1]) to local businesses and services in the vicinity, not including the payroll to mine employees amounting to BWP 180 million in 2006 (Mguni, 2022). For BCL and TNMC, this equated to about 1.5% of all formal sector employment in 2016. A BWP 68.7 million$_{2016}$ monthly payroll represented around 3% of Botswana's total wage income that year.

BCL has made significant economic contributions to the country during the past few years. BCL's commercial endeavours sustain the nation's economy. According to the BCL 2008 Annual Report, the total amount spent on procurement in 2008 was BWP 789 million, 57% of which went toward buying goods and services from Botswana.

BCL contributed BWP 14.5 billion, or an average of 3.5% of Botswana's gross domestic product (GDP), between 1976 and 2005 (Central Statistics Office, 2010). This amount includes wages, profits (in lucrative years), taxes, and spending on local products and services, which had various effects on the country's economy.

Copper-nickel mining contributed 2.4% to the GDP in the first half of 2016. This GDP contribution was eroded because of BCL's closure. In terms of the direct impact, it was estimated that Botswana's GDP growth would lower from a projected 3.5% - 4.0% to 1.0% - 1.5% in 2016 if the mine were closed for a full year (Economist Intelligence, 2016). More recent CSO publications no longer report on copper-nickel mining as a separate line item.

In terms of exports, BCL has contributed to about 9% of all Botswanan exports; this contribution increases to 15.6% when TNMC's output is included that were processed by BCL smelter.

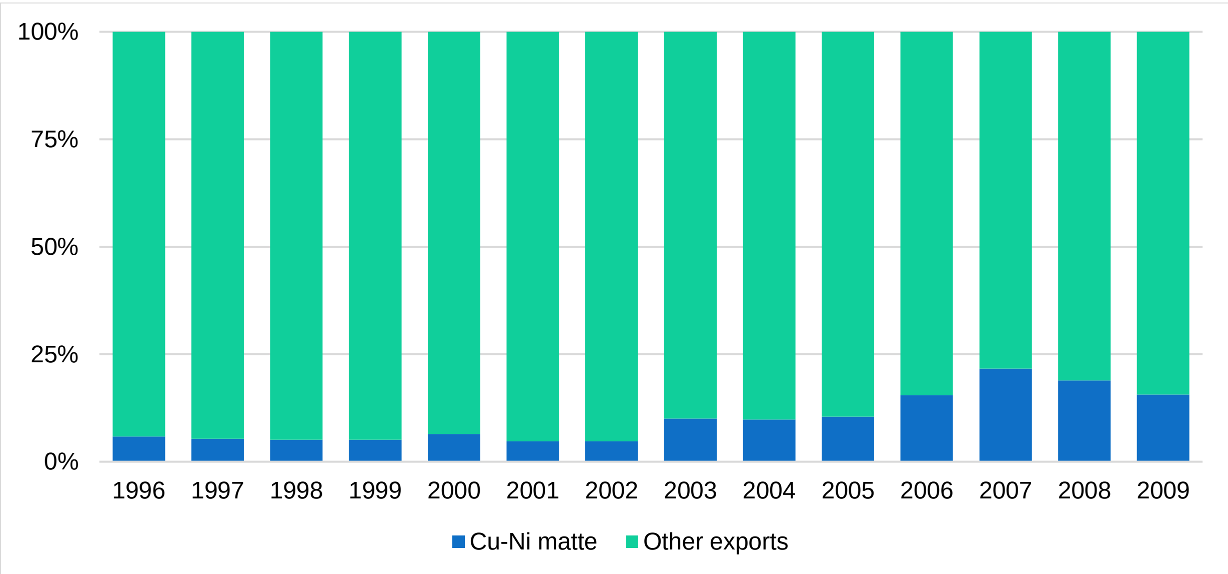


Figure 2-6: Ni-Cu matte contribution to total exports of Botswana (Central Statistics Office, 2010).

[1] At a BWP:US$ exchange rate for 2006 of BWP 5.8303 : US$ 1

The closure of the BCL smelter also had repercussions in South Africa, where the only primary nickel mine, Nkomati (owned 50/50 between African Rainbow Minerals and Norilsk Nickel), was mothballed in 2019. Nkomati is close to the mining town of Machadodorp in South Africa's Mpumalanga province and transported its nickel concentrate for processing to BCL Smelter. In 2015 approximately 7.5 ktpm of 10% Ni, 5% Cu & 0.5% Co containing concentrate was sent to BCL Smelter, approximately 32% of the BCL smelter feed.

2.5.2 Tati Nickel Mining Company

Tati Nickel Mining Company (TNMC) comprised of the Phoenix and Selkirk deposits, which were processed at the Phoenix concentrator plant and concentrate product shipped to BCL smelter at Selebi Phikwe. The Phoenix deposit is located 45 km due East of Francistown in the Northeast District of Botswana, near the border with Zimbabwe, as shown in Figure 2-7.

A timeline of TNMC's significant events is presented in Table 2-5. The Phoenix deposit was discovered in 1963 through mapping and geochemical soil sampling. The exploitation of the deposit commenced in 1995 (Lanham, 2005).

TNMC may have been purchased for a reasonable price, but the business was in terrible shape. Near Francistown, an active open cast mine called Phoenix was nearing the end of its useful economic life.

The Selkirk mine was planned to be reopened by TNMC as an open-cast operation to ensure continuous supply to the Phoenix concentrator, but this required a substantial expenditure. And in both cases, the ore grades were low: in its most recent report, Norilsk said Phoenix had ore grades of 0.22% nickel while 0.18% copper and Selkirk had ore rates of 0.27% Ni & 0.3% Cu. Despite Selkirk mining being commercially marginal, BCL management saw its expansion and reopening as the cornerstone of a rebuilt BCL and essential to providing a consistent concentrate flow to the BCL smelter.

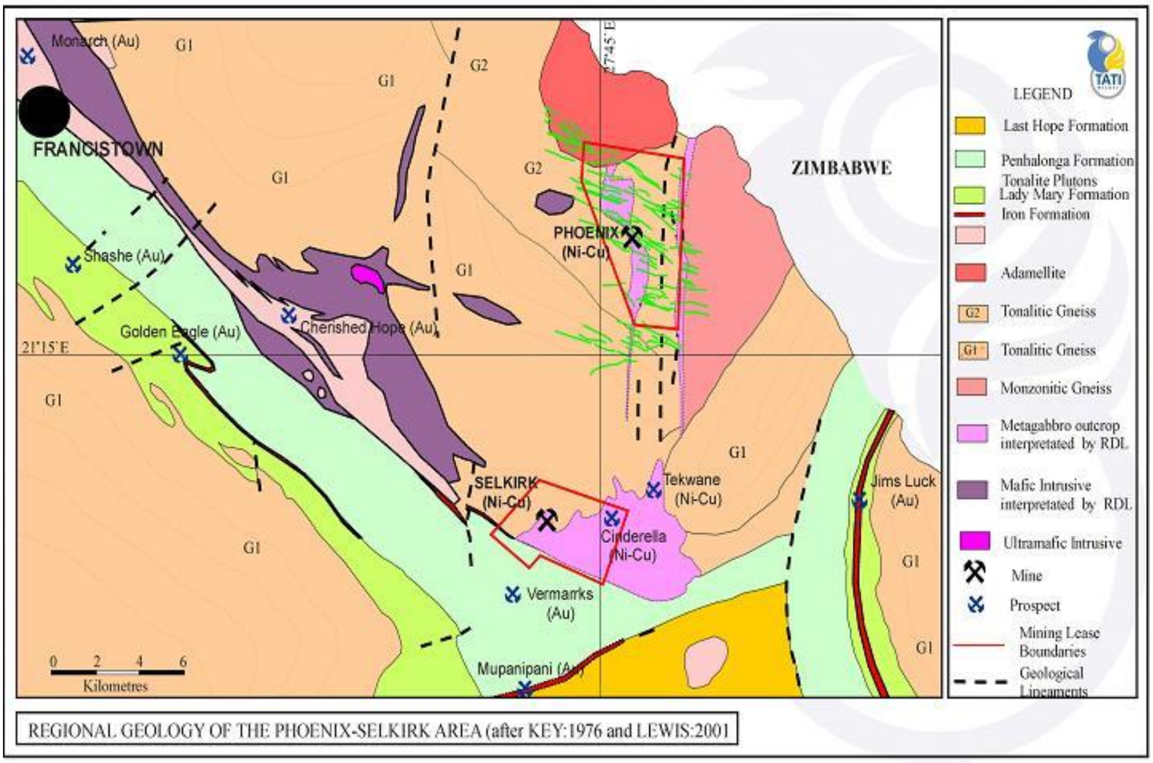


Figure 2-7: TNMC mining assets geography.

Table 2-5: Timeline of Tati Nickel Mining Company (Pty) Ltd.

Year	Comments
	Original ownership: LionOre Int. 41.65% | Anglo American Corporation 43.35% | Botswana government 15%
1963	Phoenix deposit discovered
1989	Selkirk underground mining commences
1995	Phoenix exploitation commences
2002	Selkirk placed on care and maintenance
2002	Tati concentrator commissioned (Murray and Robers) – 3.6 Mtpa
2002	LionOre acquires Anglo-American shares (now owns 85%)
2006	LionOre proposed the purchase of BCL shares – not accepted
2007	Norilsk Nickel acquires LionOre International
2008	DMS section commissioned – 12 Mtpa ROM capacity
2015	BCL Limited acquired 85% of TNMC from Norilsk Nickel
2016	BCL assets placed in liquidation
2022	Selkirk deposit sold to Premium Nickel Resources

2.5.3 Activox Hydromet Technology Development

TNMC, while owned by LionOre International, developed a custom hydrometallurgical process, the Tati Activox® Project (TAP), and installed and operated a pilot plant based on this technology, the Hydrometallurgical Demonstration Plant (HDP), in 2003. This new hydrometallurgical technology was custom-developed and produced pure metal products, as opposed to the Bessemer matte from the BCL smelter. If the Activox plant were built, it would have stopped the supply of any concentrates to BCL, in favour of processing the ores with the Activox plant (Barradas, 2008).

The HDP plant could process 7 tonnes per day of concentrate and produce 270 kg of nickel cathodes and 150 kg of copper cathodes at 99.9%. Cobalt was produced as cobalt carbonate, and PGMs were concentrated in a residue for further refining. Process recoveries were satisfactory at 94.2% for nickel, 81.6% for copper and 89.9% for cobalt.

The success of the demonstration plant led to the design and construction of a full-scale plant capable of processing all of Tati's concentrates. The commercial Activox plant plant would have produced between 20 to 25 kt of payable nickel and 12 to 16 kt of copper annually by Q3 2009. Hatch, a Canadian EPCM, started the design of the full-scale plant in 2006. The Activox capital cost consisted of US$ 482 million, US$ 114 million for an update to the concentrator's dense media separation facility, and US$ 24 million for the infrastructure needed to supply electricity, as reported in 2006. Construction of the Activox plant started in H2 2007.

However, due to a significant increase in project costs from the above-reported numbers, the new owners Norilsk Nickel put off the construction of Activox refinery and related tailings disposal facility by 4 June 2008.

The new refinery was anticipated to boost Botswana's gross GDP by roughly 1%, and increase export revenue of Botswana by 2.5%, have a beneficial ripple impact on the neighbouring Selkirk mine operated by TNMC, and generally help economic diversification once it is fully operational.

The technologies and intellectual property developed remains very commercially valuable for future extraction of the Phoenix and Selkirk deposits, potentially also the Nkomati deposits, where testing was also performed.

2.5.1 Empress Nickel Refinery in Zimbabwe

The Empress Nickel Refinery (ENR), situated in the Eiffel Flats in Kadoma, Zimbabwe and owned by RioZim, a breakaway company of Rio Tinto's historic Zimbabwean involvement, processed Ni-Cu matte from BCL on a toll treatment basis, after its deposit (the Empress nickel mine) was depleted.

The Empress nickel refinery was constructed alongside the Empress nickel mine in 1968 and ran to 1982 when the mine depleted (RioZim, 2022). The refinery was fed with 0.4% Ni ores, producing ~69,500 refined Nickel tonnes over this period. In 1985, Rio Tinto Zimbabwe initiated BCL matte treatment, requiring facility expansion in 1995. The facility produced refined nickel and copper and PGM and cobalt residues for further beneficiation elsewhere.

During 2011 and 2012, ENR operated at ~50% of its installed capacity of 17,000 tonnes of combined metals. During the year ended December 2014, ENR received less than 30% of its annual contracted matte supplies and operated at less than 25% capacity. Base metals produced amounted to 2,915 t. ENR was placed on care and maintenance around the same time BCL was placed under provisional liquidation in 2015-2016, with the exact date unknown.

RioZim has processed reverts into saleable intermediate products to fund their care-and-maintenance program, and talks are being held with Kamativi Tailings Co., which is interested in the conversion of the facility to produce battery-grade lithium products. Potential copper offtake to Empress would no longer be technically possible.

2.6 Copper in Botswana

Mining has long been an essential contributor to the Botswana economy. Still, the sector is currently dominated by coal and diamonds, with a lack of diversification since the closure of the BCL nickel-copper smelting complex. According to Standard and Poor Capital IQ Pro (2022), Morupule colliery and the Orapa diamond mine are Botswana's most significant mining operations based on the in-situ value of resources.

The latest global copper pipeline analysis by Standard and Poor's Capital IQ Pro indicates that a possible supply lag of copper concentrate is on the horizon, as presented in Figure 2-8 (Soares, 2021).

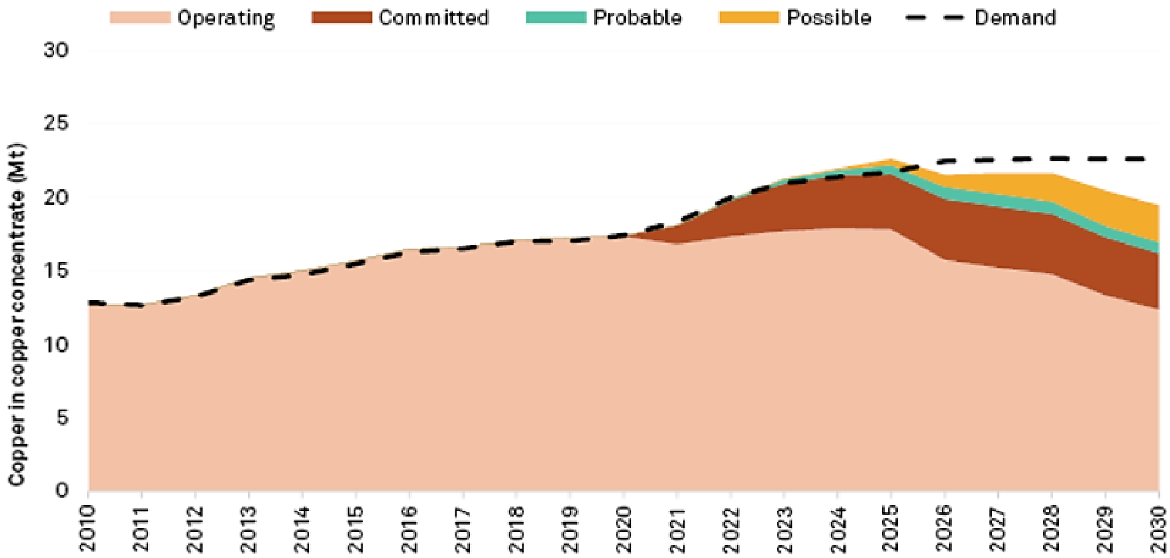


Figure 2-8: Expected 3.15 Mt copper concentrate deficit by 2030 (Soares, 2021).

The Botswanan 2021 annual exploration budget has gradually increased from 2020 lows, reaching US$ 374 million as measured by Standard and Poor Capital IQ Pro (2022) (all commodities). The Botswanan 2021 annual exploration budget represented 0.3% of global mining exploration in 2021 and included the expenditure of 19 companies. 47% of the 2021 annual exploration budget focuses on copper, as shown in Figure 2-9. The rising trend of electrification and the anticipated global shortage of copper may lead to increased copper prices as demand increase and renew interest in Botswana's underexplored copper sources.

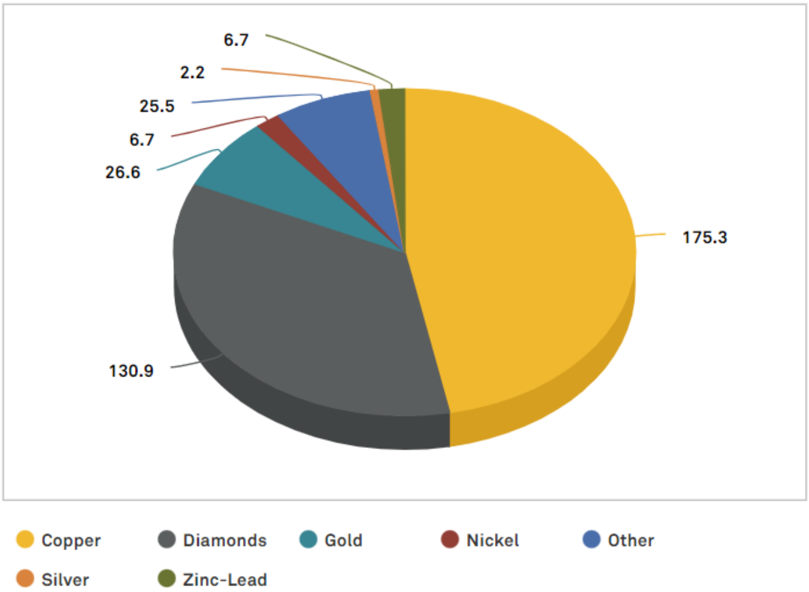


Figure 2-9: Botswana 2021 annual exploration budget by commodity (US$ million).

The Kalahari Copperbelt (KCB), which extends ~1,070 m along strike through Namibia and into the North-West of Botswana, is a prospective zone that offers the opportunity for a large copper production sector to provide diversity and growth for mining in Botswana. The Kalahari Copperbelt, formally named the Northwest Botswana Rift, hosts 18 deposits, presented in Table 2-6 (Zientek, Hammarstrom, & Johnson, 2015).

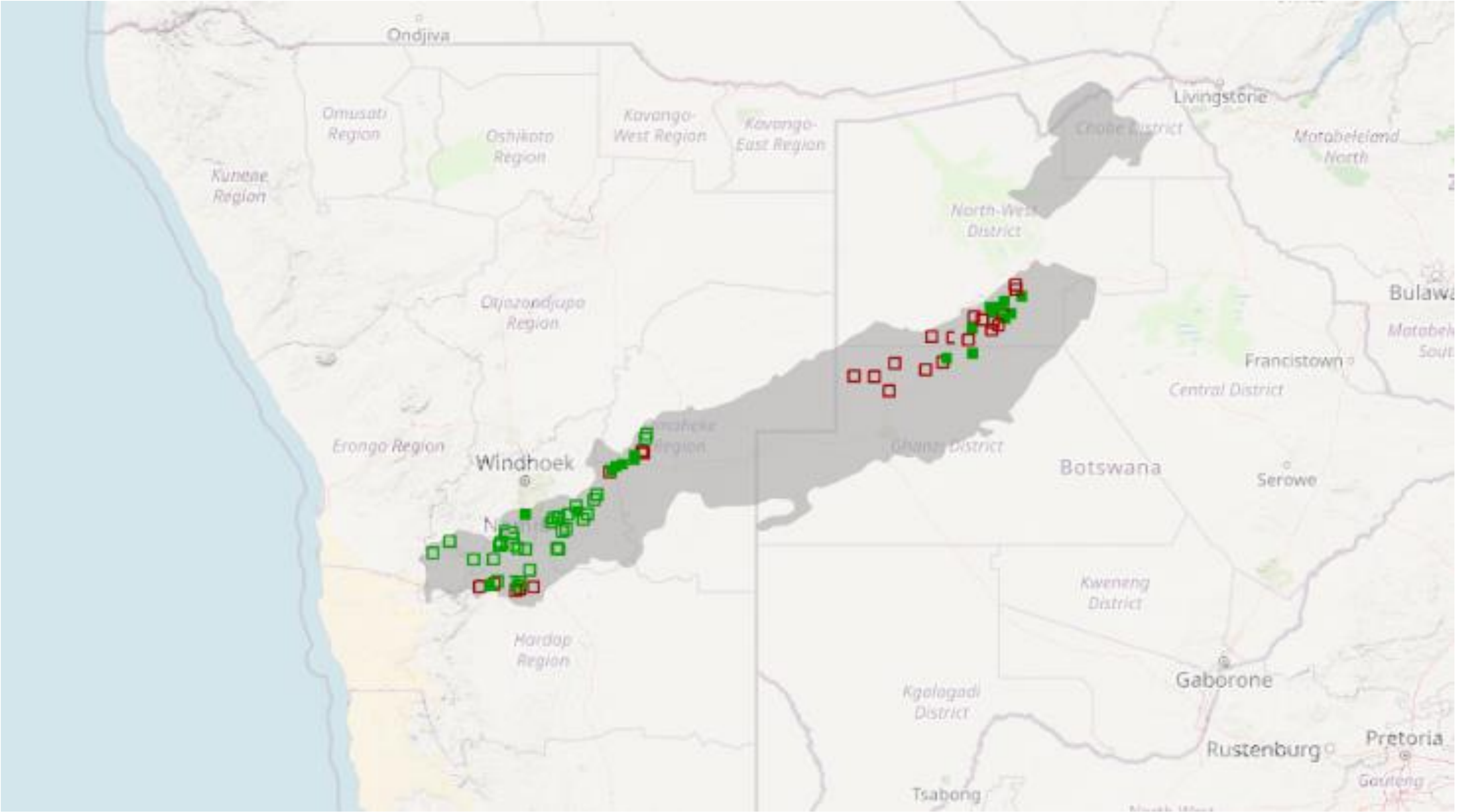


Figure 2-10: The Kalahari Copper Belt after Zientek et al. (2015).

Table 2-6: 18 deposits along the KCB after Zientek et al. (2015).

Name	Latitude	Longitude	Ore minerals	Major commodities	Resources (unmined)	Citation
Reduced-facies deposits						
Banana zone	-21.089	22.738	Cc, Bn,Ccp	Cu, Ag	91.22 Mt @ 1.15% Cu & 14.98 g/t Ag	Discovery Metals (2011b); Pretorius and Park (2011)
Ghanzi project – zone 5	-20.619	23.222	Cc, Bn, Ccp	Cu, Ag	13.4 Mt @ 1.66% Cu & 12.11 g/t Ag	Same as above
Ghanzi project – zone 6	-20.414	23.359	Ccp, Bn, Cc, Cp	Cu, Ag	6.27 Mt @ 1.50% Cu & 6.68 g/t Ag	Same as above
Petra and plutus	-20.543	22.961	Cc, Bn, Ccp	Cu, Ag	67.4 Mt @ 1.4% Cu & 14 g/t Ag	Discovery Metals Ltd. (2010, 2011a & 2011b)
Zeta	-20.605	23.008	Cc, Bn, Ccp	Cu, Ag	35.4 Mt @ 1.4% Cu	Same as above
Ne mango	-20.679	23.150	n/a	Cu, Ag	33.3 Mt @ 1.2% Cu	Discovery Metals Ltd. (2014)
Selene	-20.472	23.141	n/a	Cu, Ag	16.0 Mt @ 1.0% Cu	Same as above
Zeta ne	-20.539	23.092	n/a	Cu, Ag	12.9 Mt @ 1.3% Cu	Same as above
Corner k	-21.146	22.408	n/a	Cu, Ag	9.5 Mt @ 0.91% Cu	MOD Resources Ltd. (2012)
Dorbabis (koperberg)	-22.940	17.749	Cc, native Cu	Cu	1.74 Mt @ 0.97% Cu	Kalahari Minerals plc (2008)
Klein aub	-23.800	16.633	Ccp, Bn, Cc, Cp	Cu, Ag	6 Mt @ 1.5% Cu	Ruxton (1986), Borg and Maiden (1987), Andritzky (1998), Cox et al (2003)
Sandstone-copper deposits						
Christiadore	-22.417	18.232	n/a	Cu	1.2 Mt @ 2.3% Cu	Andritzky (1998), Kalahari Minerals plc (2006), Extract Resources (2008), Kalahari Minerals plc (2008)
Gemsbockvley	-22.464	18.177	n/a	Cu	0.4 Mt @ 1.8% Cu	Same as above
Malachite pan	-22.285	18.465	n/a	Cu	3.0 Mt @ 2.1% Cu	Same as above
Okasewa	-22.390	18.316	n/a	Cu	6.0 Mt @ 1.8% Cu	Same as above
Oamites	-22.974	17.089	Ccp, Bn, Cc	Cu, Ag	6.1 Mt @ 1.33% Cu & 12.3 g/t Ag	Lee and Glenister (1976), Maiden et al (1984), Andritzky (1998), Cox et al (2003)
Ophion	-20.796	22.733	n/a	Cu	14.0 Mt @ 1.0% Cu	Discovery Metals Limited. (2011b)
Witvlei (pos)	-22.339	18.462	Cc, Bn, Ccp, Cv, Dg	Cu, Ag	2.8 Mt @ 1.5% Cu	Anhaeusser and Button (1973), Maiden et al (1984), Andritzky (1998), Cox et al (2003), Extract Resources (2008), Kalahari Minerals plc (2008), Cullen Resources (2011a)

Despite good quality orebodies with good grades, the disadvantage of protracted and expensive logistic routes has softened project financial returns and hampered the development of mines on the KCB. Notwithstanding this, two near-term producers have moved towards commercial production, Khoemacau and Sandfire.

Based on the current development of the Kalahari Copper Belt and other Botswanan copper resources, which is elaborated following this Section, the current state of value extracted from copper resources ends with copper-bearing concentrates exported to offshore markets. When considering the growing demand for copper, as it is used in technologies critical to net zero greenhouse gas emission targets, the demand for copper is expected to increase significantly. Electric vehicles (requiring four times more copper than conventional vehicles) and renewable energy systems such as wind and solar photovoltaic installations require up to 12 times more copper when compared to traditional energy generation (International Copper Association, 2021).

2.6.1 Khoemacau

Khoemacau Copper Mining (Pty) Ltd is 88.1% owned by Cupric Canyon Capital LLC, with the balance of shares held by Resource Capital Fund VII L.P. Their Boseto operation is close to the town of Toteng in the Ngamiland province. The earliest information on the mining lease areas now held by Khoemacau date back to 1996, when Gencore and BHP performed a mineral resource estimate of the Ghanzi project, which drilled the NE fold, Zeta, and Banana zone plots. A solvent extraction/ electrowinning (SX/EW) processing facility of 30 ktpa capacity was considered in the past (Standard and Poor, 2022).

Khoemacau declared mineral reserves of 30.4 Mt ore and mineral resources of 92.4 Mt at their Zone 5 near-term exploitable orebody, as outlined in Table 2-7. This mineral resource of 92.4 Mt is a considerable upgrade, when it is compared to predecessor Discovery Metals' 2011 declaration of 13.4 Mt in Table 2-6.

Table 2-7: Khoemacau Mineral Resources.

Zone 5 Ore Reserves	**Ore (million tonnes)**	**Copper grade (%)**	**Silver grade (g/t)**
Proved	11.0	2.17%	19.7
Probable	19.4	1.95%	19.3
Total	**30.4**	**2.03%**	**19.5**
Zone 5 Mineral Resources	**Ore (million tonnes)**	**Copper grade (%)**	**Silver grade (g/t)**
Measured	16.5	2.40%	22.1
Indicated	26.2	2.20%	21.1
Inferred	49.6	2.10%	22.6
Total	**92.4**	**2.20%**	**22.1**
Total Mineral Resources	**Ore (million tonnes)**	**Copper grade (%)**	**Silver grade (g/t)**
Reserves	37.4	2.03%	19.7
Measured & Indicated	43.0	2.30%	21.3
Inferred	299.1	1.52%	19.8
Total	**379.5**	**1.66%**	**20.0**

The mine will be exploited by underground means with three portals planned to be developed. This results in three separate mining portals, each producing run of mine (ROM) ore of 1.0 – 1.5 Mtpa with the sub-level open stoping mining method.

The mined ore will be trucked approximately 35 kilometres to the Boseto processing facility, which is refurbished and enhanced to process 3.65 Mtpa ROM. Processing will be conventional sulphide flotation via three-stage crushing, ball milling and flotation, producing a high-quality copper concentrate grading of approximately 40%. At the stated production volumes, this will equate to ~150 000 tonnes per annum of concentrate for a minimum period of 8.3 years, based on the stated JORC-compliant mineral reserve.

Longer-term expansion plans are also described with the intention of increasing ROM throughput to 5.8 Mtpa, resulting in the production of approximately 290 ktpa of 40% copper concentrate. The increased throughput is evaluated as a potential expansion scenario. The Zone 5 life of mine derives to 15 years and will exploit 82% of the reported reserves. Assuming all Zone 5 Mine Resources can be exploited, an additional 3 years of mine life exists at the steady state processing rate of 5.85 Mtpa ROM ore. Should Khoemacau's total declared Mineral Resources are exploited at the same processing rate, then only 20% of Khoemacau's Mineral Resources are currently planned for exploitation, which is equivalent to an additional 52 years' life of mine. Khoemacau's total potential life of mine is therefore 67 years, noting that valuation of inferred resources is not possible via the Income Approach.

2.6.2 Sandfire Resources

Sandfire Resources acquired the Motheo T3 and other Tshukudu resources previously held by MOD resources. Sandfire Resources' T3 Project is also located in the KCB and at an advanced stage of development. Similar to the Khoemacau Project, the project is in the late stage of development and has a declared JORC-compliant Mineral Reserve of 34.4 Mt for the T3 project, as detailed in Table 2-8.

Table 2-8: Sandfire Resources Mineral Resources.

T3 Ore Reserves	**Ore (million tonnes)**	**Copper Grade (%)**	**Silver Grade (g/t)**
Proved	-	-	-
Probable	34.4	1.0%	13.2
Total	**34.4**	**1.00%**	**13.2**
Total Mineral Resources	**Ore (million tonnes)**	**Copper Grade (%)**	**Silver Grade (g/t)**
Reserves	39.9	1.13%	20.0
Measured & Indicated	24.9	1.21%	21.8
Inferred	10.5	0.87%	15.9
Total	**75.3**	**1.12%**	**20.0**

The mine will be exploited by an open pit mining operation ramping up to a capacity of 3.0 Mtpa ROM for just over 11 years. Mining of the T3 open pit started in April 2022, with the first production expected in June 2023.

ROM will be processed on-site at the dedicated concentrator to produce around 100 ktpa of a 30% copper concentrate. The ore mineralogy is predominantly chalcopyrite, bornite and chalcocite.

A further orebody has been identified, A4, and is currently being developed from an exploration perspective. The expanded case relies on a 5.2 Mtpa Motheo expansion feasibility study, due for completion in quarter 3 of 2022. Considering the Total Mineral Resource declared, 68% of the resource will be exploited in their current operating plans. The life of mine can be extended by 4.6 more years, should the rest of the Mineral Resource be exploitable, totalling a possible life of mine of ~16 years.

2.6.3 Other resources in Botswana

While the Kalahari copper belt is considered the copper resource with the largest potential significance for this study, other base metal regions in Botswana include:

- BCL and the immediate vicinity of the now-defunct Selebi Phikwe mines. While some mining rights were sold to prospector Si6, and two shafts sold to Premium Nickel Resources, the remainder is still under liquidation. The BCL orebodies are predominantly nickel based, of which the processing method would be incompatible to a primary copper beneficiation strategy.
- Limpopo Mobile Belt, North-East of Selebi Phikwe, is also under liquidation, as explained above.
- Matsitama Schist Belt (Northeast and West of Francistown). One potentially near-term producing asset on the Matsitama Schist belt, Mowana, is currently under administration.

Leboam Holdings (Pty) Ltd.'s Mowana copper mining operation in Botswana is currently under liquidation. The property houses a concentrator plant, commissioned in 2008, with a 1.2 Mtpa processing capacity and expansion studies to increase the throughput to 2.6 Mtpa were historically under consideration. The mine was most recently reopened in 2017 by Cradle Arc PLC, with a working capital facility from Fujax Minerals & Energy limited, only to be closed towards the end of 2018 due to shareholder disagreements (The Projects Magazine, 2021).

A near-term production profile scenario plans the return of the mine to operation. The near-term production profile generates a 25-year life of mine, processing 1.25 Mtpa. Considering the declared Mineral Resources of Mowana in Table 2-9, an additional 39 years are potentially possible at the above stated production rate, as the plan exploits only 35% of the mineral resources at a low processing rate.

Table 2-9: Mowana Mineral Resources.

Total Mineral Resources	**Ore (million tonnes)**	**Copper Grade (%)**	**Silver Grade (g/t)**
Reserves	31.8	1.17	0
Measured & Indicated	22.9	1.18%	0
Inferred	20.3	1.08%	0
Total	**75.0**	**1.15%**	**0**

To the author's knowledge, no other primary copper near-term opportunities exist on the Matsitama Schist Belt. Further consideration of other potential sources is unpacked in Section 3.2.

2.7 New copper processing facility prospects in Botswana

Fichani and Masialeti (2019) performed an independent discounted cash flow (DCF) evaluation for a copper processing facility in Botswana. From a technology-scoping view, a pyrometallurgical smelting flowsheet using a top-submerged arc furnace was selected, and assumptions from the recently constructed Kansanshi copper smelter in Zambia were used to estimate capex, opex and metallurgical recoveries. Fichani and Masialeti (2019) sourced ore from Khoemacau, Mowana and Sandfire Resources' developments. They predicted a peak copper concentrate feed from these sources at 388,000 tonnes per annum, graded at 38% copper and 278 g/t of silver. The combined production profile resulted in peak production from the facility of 151 kt of copper from in-country sources. The facility in their study was sized and costed at 485,000 tonnes of concentrate per annum, but required substantial copper imports to fill this modelled capacity. The resulting DCF model resulted in poor economies without concentrate imports, as presented in Table 2-10. A negative NPV signals that investment should not be pursued.

Table 2-10: Model results extract from Fichani and Masialeti (2019).

Valuation year	Annual copper production	Discount rate	NPV	IRR	Payback period
2019	Peak of 151 kt copper	8%	(US$ 48.5 million)	6.5%	12 years

Fichani and Masialeti (2019)'s work can be improved accordingly:

- The significant quantities of silver in the source orebodies in Botswana warrant the inclusion of silver separation and refining from the copper concentrate.
- It is argued that the manufacturing tax regime should be used as a baseline, as beneficiation is distinctly different to mining.
- While the technology selection applied by Fichani and Masialeti (2019) is suitable, the capital and operating cost estimates could be significantly improved by using a fundamental cost approach per unit operation and per operating cost line item, as opposed to applying costs from a previous installation with no insight on the cost components or differences in metallurgical characteristics.
- Independent labour estimates could be performed, and staffing rates applicable to Botswana could be applied.
- The smelting infrastructure at BCL may be repurposed to smelt copper concentrates and potentially decrease the capital intensity of setting up a new smelting facility.

2.8 Coal bed methane gas in Botswana

Botswana has significant coal deposits, inferred to be more than 200 billion tonnes of coal (Kalahari Energy Botswana, 2022). Coal bed methane (CBM) occurs as a concentrated gas adsorbed in the coal beds, and it is principally composed of methane (CH_4, >95%) (Zou, 2017). The CBM gas can be extracted from underground coal resources that are not economically accessible through open pit mining by drilling wells into the coal seam. CBM is cleaner than conventional natural gas as it i) does not contain H_2S, has ii) low quantities of heavy hydrocarbons and iii) contains low quantities of condensate (Zou, 2017). Overall, CBM and natural gas are similar in that they are both sources of methane, but they were formed and are extracted using different methods.

The top submerged lance furnace technology employed by the smelting facility can directly utilise natural gas as its fuel source (Matusewicz & Reuter, 2008). Direct utilisation of natural gas substantially increases the furnace's thermal efficiency, which is the primary operating metric for a high-temperature, operating smelting furnace. The thermal efficiency of CBM in a power plant ranges between 30-35%, whereas direct use can increase the thermal efficiency to as high as 90% (Pramod, et al., 2020). This thermal energy benefit signals the potential benefits of its use in heating applications.

CBM development in Botswana is still in the early stages, and there are currently no commercial CBM production projects in the country. However, there have been several studies and exploration activities aimed at evaluating the feasibility and potential of CBM as an energy source in Botswana. These efforts have included drilling test wells and conducting geophysical surveys to assess the distribution and quality of the CBM resource. While different companies are engaged in CBM exploration, efforts are concentrated in the region to the West of Serowe, spanning to the South of Orapa.

It is important to note that the development of CBM in Botswana, like any energy resource, will involve a range of environmental, social, and economic considerations. It will be important to carefully assess and address these considerations in order to ensure the sustainable and responsible development of CBM in the country.

2.9 Economic challenges: the Resource curse and Dutch disease

Many resource-abundant countries suffered from low growth throughout the 1980s and early 1990s, a phenomenon termed the resource curse by Auty (1993). The natural resource curse, also known as the resource curse or the paradox of plenty, is a phenomenon in which countries that are rich in natural resources such as oil, minerals, and timber tend to have slower economic growth and are more prone to conflict and corruption than countries with fewer natural resources. The resource curse presupposes that a mineral discovery or resource boom do not correlate to sustainable economic growth in the host country.

There are several theories about why the natural resource curse occurs. One theory is that countries with abundant natural resources may rely too heavily on these resources for economic growth and development, leading to a lack of diversification and innovation in other sectors of the economy. This can make the economy vulnerable to external shocks, such as changes in commodity prices or shifts in global demand.

Another theory is that natural resource wealth can lead to rent-seeking behaviour, in which individuals or groups seek to capture a share of the resource wealth for themselves rather than investing it back into the economy. This can result in corruption, mismanagement, and a lack of transparency in resource management.

Additionally, the natural resource curse can be exacerbated by a lack of strong institutions and good governance. In some cases, resource wealth can be used to entrench authoritarian regimes or fuel conflict, rather than being used to improve the lives of ordinary citizens.

Overall, the natural resource curse is a complex and multifaceted issue that is influenced by a range of economic, political, and social factors.

The phases of the resource curse are outlined: A rapid increase in export of the booming commodity leads to a surge in foreign exchange, which appreciates the real exchange rate. It is observed in public company reports that producer country currencies correlate with increasing related commodity prices (Glencore AG, 2021). While the foreign exchange rate surges, the non-mining sectors become relatively less competitive in the export market and may slump when invoiced in local currency (Sarraf & Jiwanji, 2001).

Reasons behind unsustainable economic activity include bad policy-making and the failure of the host country to promote a competitive manufacturing sector, often termed the Dutch disease. Dutch disease and the resource curse are two economic phenomena that are often associated with the exploitation of natural resources. Both phenomena can have negative impacts on a country's economy and development, but they operate in slightly different ways.

Dutch disease refers to the negative economic consequences that can occur when a country experiences a sudden influx of foreign currency, often as a result of the exploitation of natural resources such as oil, minerals, or timber. The term "Dutch disease" was coined in the 1970s to describe the economic decline that occurred in the Netherlands after the discovery of natural gas deposits, but it has since been used to describe similar situations in other countries.

Botswana is generally considered to be a relatively low corruption country, with a strong track record of good governance and transparency. According to the Corruption Perceptions Index published by Transparency International, Botswana is ranked as the 35th least corrupt country out of 180 countries in 2021, and it has consistently ranked in the top 40 countries on the Corruption Perceptions Index in recent years (Transparency International, 2022).

The Corruption Perceptions Index measures perceived levels of public sector corruption in countries around the world, based on expert assessments and opinion surveys. A higher score on the Corruption Perceptions Index indicates a lower level of perceived corruption.

For Southern African context, the established mining and processing sector on the Congo Copper Belt, spanning over Zambia and the Democratic Republic of the Congo (Kinshasa) (DRC) is of worthwhile consideration. As reference: Zambia is a country that has been impacted by the natural resource curse. The country is rich in natural resources such as copper, cobalt, and zinc, and these resources have played a significant role in its economic development. However, the exploitation of these resources has also been accompanied by a range of negative economic, political, and social consequences.

Zambia's economy is heavily reliant on the mining sector, which is subject to fluctuations in commodity prices and global demand. This reliance exposes the economy to external shocks and may contribute to economic instability during depressed commodity cycles.

ZCCM-IH is a state-owned company in Zambia that was established in 1982 to manage the country's mineral assets. It is involved in a range of activities related to the mining and exploration of minerals, including copper, cobalt, and zinc.

There have been allegations of corruption and mismanagement within ZCCM in the past. In the 1990s, the company faced criticism for its role in the sale of state-owned mines, which was seen by some as a controversial and opaque process that was prone to corruption. There have also been more recent allegations of corruption and mismanagement within the company, including allegations of financial mismanagement and poor governance.

In the height of BCL’s operation, Ni-Cu matte exports totalled ~15% of total Botswana exports (Central Statistics Office, 2010). While it is unlikely that copper exports from the new copper beneficiation facility will dominate in Botswana to the extent that it dominates in Zambia (~74% of exports in 2020) or the Democratic Republic of Congo (~66% of exports in 2020), proper management and cognisance of the resource curse is needed.

The windfall from the new mineral royalty revenues is a new income stream that the Botswana government can reallocate to other industries. The relative proximity of the Kalahari Copper Belt to the Okavango Delta tourist attraction would mean that infrastructure development in the surrounding area would benefit both industries.

It is argued later in this work that the beneficiation of copper is a suitable candidate to invest the royalty cashflows.

2.10 Efforts to diversify the Selebi Phikwe region

A further investigation of the events surrounding BCL and the Selebi Phikwe region is explored, as it relates to the potential of a resource curse.

A group of African, Caribbean and Pacific countries signed the Lome Convention in 1975. The Lome Convention aided the signed countries in developing mining and agricultural sectors and to achieve tariff benefits from European markets. A funding instrument was established called the System for the Stabilization of Export Earnings from Mining Products (Sysmin), so that funds from European Development Funds (EDFs) could support the development process in Lome Convention signee countries.

The Botswanan government received access to the EDF8 (8 ACP BT 13) finance stream in 2002 to address two related issues: expanding the BCL Limited mining operation in Selebi Phikwe and creating a diversification plan to lessen the region's reliance on the mining industry (Modkwa, 2009).

An On-Lending Agreement was used to make money available for each Sysmin intervention. A Re-Employment Account (REA) held by the Bank of Botswana is where the fixed-rate interest and capital are to be repaid. Per a cooperative agreement between the government of Botswana and the European Commission, the money placed in the REA was utilised to stimulate economic diversification in the Selebi Phikwe Region. Additionally, funds from the National Development Plan (NPD) designated in the 2008 planning process were also used for the project's scope-conforming diversification of the local and regional economies.

The Selebi Phikwe Economic Diversification Unit (SPEDU) was setup with its headquarters in Selebi Phikwe. The SPEDU's mission was to promote and oversee Selebi Phikwe's diversification. In July 2007, all SPEDU’s recommendations were approved by the Botswanan government. Four short-term Technical Missions with a focus on tourism, agricultural development, the construction of the Letsibogo Dam close to Selebi Phikwe, and a regional socio-economic audit have been commissioned by SPEDU.

2.11 Special economic zones

Special Economic Zones (SEZ) are geographically isolated areas inside a nation with more lenient legal and economic rules to promote foreign investment in export-oriented industries and services (Wang, 2013). According to the World Bank (2008), 3,000 SEZs in 135 countries account for more than 68 million direct jobs, and more than US$ 500 billion in value is contributed to direct commerce. As of 2008, 114 SEZs were registered in Sub-Saharan Africa and employed 1,040 million people or 0.20% of the national employment in the region.

When increasing an investment's competitiveness and efficiency, the standard SEZ policy package includes liberal foreign currency policies, import and export duty exemptions, streamlined customs, administrative regulations and procedures, and income tax benefits.

Wang (2013) empirically quantified the effects of SEZ establishment in China on economic development and concluded that SEZ establishment led to an increase in Foreign Direct Investment (FDI) in the applicable regions in the following years. As shown in Figure 2-11, a continued upward trend in FDI per capita ensued, up to 6.9% from the baseline after six years. Over an average post-implementation period of 13.45 years, the study further reports exports increased by 1.1% percentage points, Total Factor Productivity (TFP) growth increased by 1.6%, average worker wages increased by 8%, and Consumer Price Inflation (CPI) increased by 5%. Wang (2013)’s work indicates that the SEZ framework helped develop and industrialise the samples investigated.

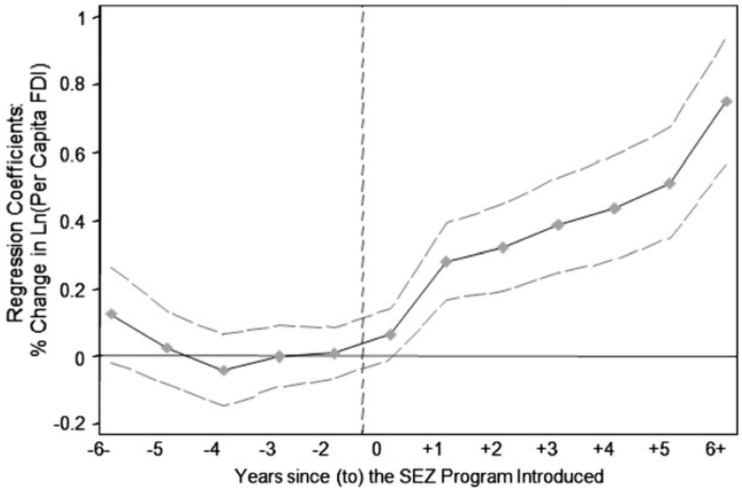


Figure 2-11: Foreign direct investment per capita from the inception of SEZ establishment (Wang, 2013).

The government of Botswana established the Special Economic Zone Authority (SEZA) in 2015; subsequently, eight SEZs were established throughout Botswana (SEZA Botswana, 2022), as shown in Figure 2-12. Of primary interest for this project are the following:

- Francistown – Mixed use
- Selebi Phikwe – Mixed use

Other SEZs include:

- Sir Seretse Khama International Airport - Mixed use
- Tuli block – Agropolis
- Lobatse – Meat and leather
- Fairgrounds – International finance and technology
- Pandamatenga – Agropolis
- Greater Palapye – Energy

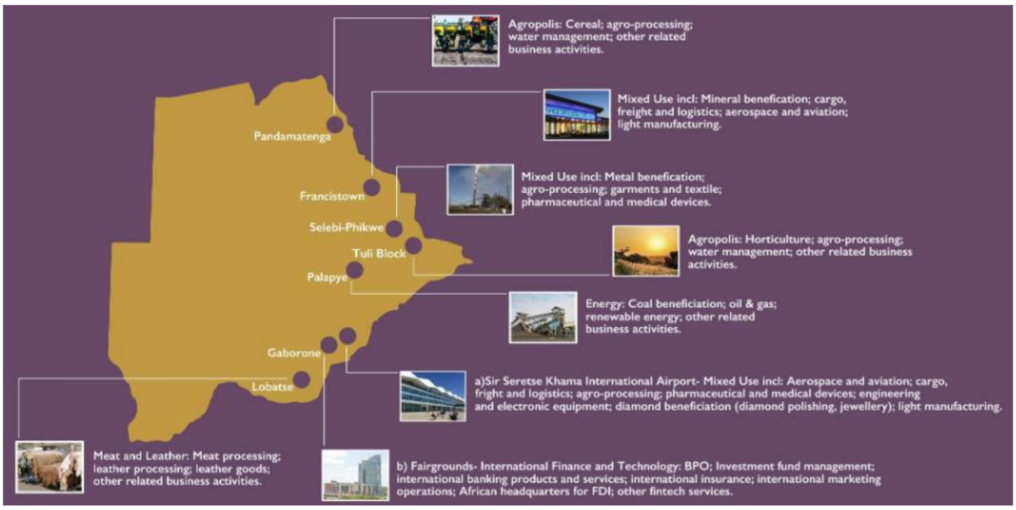


Figure 2-12: Special Economic Zones in Botswana.

It is inferred that SPEDU and the Selebi Phikwe SEZ is the same entity.

2.12 Botswana beneficiation legislation

The African Union's Africa Mining Vision publication in 2009 states that action is required to promote local beneficiation and value addition of minerals. It is envisioned that beneficiation can produce feedstock to drive local industrialisation (African Union, 2009).

The legal mining framework in Botswana is governed by the Mines and Minerals Act of 1999, chapter 66:01. While policy development for in-country beneficiation was debated in 2013, members of parliament argued that i) beneficiation legislation would hinder foreign direct investment (Oluyeju & Tshiamo, 2018).

Oluyeju and Tshiamo (2018) ii) argue that the enactment of beneficiation legislation's opportunities outweighs the costs, based on learnings reviewing Indonesian and South African policy effects. It is argued that beneficiation does not seek to infringe on foreign investment, unlike alternative policies such as nationalisation or expropriation. The enactment of beneficiation legislation would however deter foreign investment if a suitable down-stream processing facility is not available. Local, on-site beneficiation is essential because no waste, which may contain potentially saleable by-products, is lost over the value chain. To date, beneficiation legislation is not enacted in Botswana.

2.13 Copper smelting competition in Southern Africa

Logistically and due to high operating costs, Zambian copper smelters are not viable off-take locations from Botswanan copper mines. Zambian copper smelters export their products to other ports in Southern African and are situated too far from the KCB, especially considering the sensitivity to logistics exhibited in the modelling phase of this project within Botswana alone.

The most significant potential competition would be the Namibian Custom Smelter (NCB), owned by Dundee Precious Metals Tsumeb (DPMT), located close to the town of Tsumeb in Namibia. It can treat 240 ktpa of copper concentrates, explicitly designed to treat high arsenic and lead-bearing concentrates (Dundee Precious Metals, 2022). 240 ktpa of copper concentrate smelting capacity translates into 40-50 ktpa of blister copper (>96% Cu) (Jones, 2015). Concentrate transport from the Kalahari copper belt to Tsumeb may be technically viable, due to its distance from mines and to the port at Walvis Bay. Available rail infrastructure from Tsumeb to Walvis Bay would lower logistical costs. As of mid-2022, NCM's production guidance for the next three years is stable, between 210-240 ktpa concentrate, and to optimise smelter costs is cited as their imperative.

The Palabora smelter, owned by Palabora Mining Company (Pty) Ltd, situated in the Limpopo province of South Africa, is a second contender for copper concentrate offtake. Palabora smelter has a nameplate capacity of 160 ktpa of copper (Jones, 2015).

The recently closed BCL smelting complex in proximity to Selebi Phikwe treated Ni-Cu bearing ores to produce a Bessemer matte containing 30 ktpa of copper (Jones, 2015). Significant upgrades are required for the facility to comply with modern SO_2 abatement legislation, a rebuild of their furnace would be required due to the uncontrolled stoppage when liquidation was announced and to modify the facility to process primary copper ores.

2.14 Mineral asset management

The conventional mineral strategy over the life of the resource is portrayed in Hotelling’s (1931) work, and the definitions thereof are subsequently outlined. Firstly, it is acknowledged that the mineral resource is exhaustible and that the resource's life depends on the extraction rate. The extraction technology is assumed to remain constant.

Hotelling (1931) developed the r percent rule, which states that for the efficient exploitation of a non-renewable and non-augmentable resource, the percentage change in net price per unit of time should equal the discount rate to maximise the present value of the resource capital over the extraction period. This rule can be expressed by the equilibrium situation representing the optimal solution:

$$\frac{P'(t)}{P(t)} = r$$

When P(t) is the unit profit at time t, compared to an anticipated future unit profit, P’(t), and r the discount rate (derived from the weighted cost of capital), or interest rate.

The resource should be consumed so that the rate of growth of the value of the extracted resource should equal the desired discount rate δ. The economic mine life is resultantly a decision variable. The derived optimal extraction strategy must encompass the entire resource.

Camus (2002) further developed the notion that a mineral resource should be considered capital, which leads to no mining optimisation being completed without considering the total mineral resource. During the life of mine planning, the cash flow *C* derived from exploiting a portion *r* of the total mineral resource *R* (with value *V*). It follows that the marginal cost of extraction and the extraction rate is directly linked to the product price, as expressed in Figure 2-13.

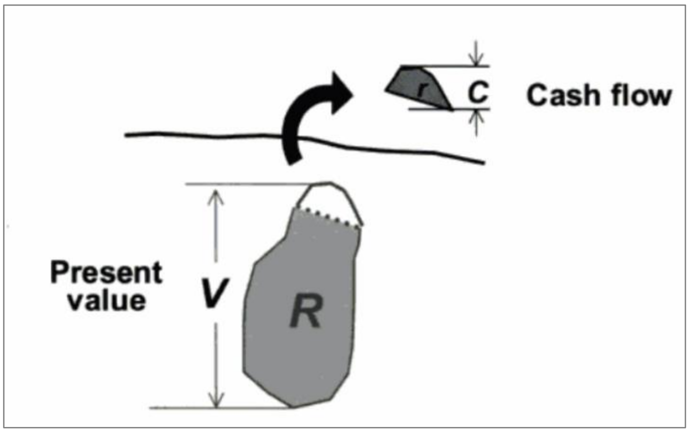


Figure 2-13: Mineral resource extraction and the derivation of present value (Camus, 2002).

For a given cost structure, the given cash flow from the operation depends on the adopted strategy. Strategy in this context may be factors such as the extraction rate and the level of mining selectivity, and Figure 2-14 conceptually depicts how cost structure decisions impact the resulting profitability of an example operation. In general, a higher extraction rate or scale would allow favourable project economics.

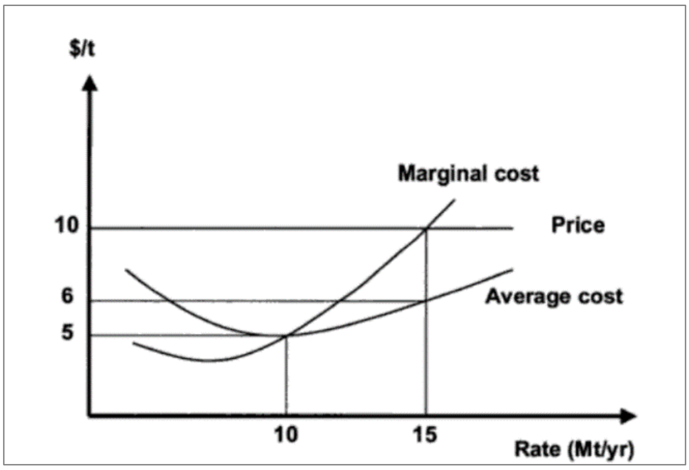


Figure 2-14: Cost structure for a coal mining operation (Camus, 2002).

Both price and time-cost fluctuations may induce changes in extraction policies and resulting project values, termed perfect competition. This possibility to respond to variations in either economic or technical conditions adds value to investment projects. This factor is not explicitly considered in the standard decision-making process, as traditional discounted cash flow models are not intended to measure these opportunities (Slade, 2001). This concept is called option theory, and its application in mining investment revolves around the economic assumptions made at a particular time of interest.

Variables affecting consistency include (Camus, 2002):

- Geological features of the mineral reserve.
- Market conditions and costs.
- Size of the mine and the associated processing infrastructure.

This result is consistent with market forces, wherein a price increase becomes a call for more production in the commodity cycle. During a price decrease, the demand for production decreases and the premature ramp-down and closure of a mining asset may be forced. The aim to extract all the value from the asset is therefore curbed if mining is performed selectively. The classic value chain of the mining industry is portrayed in Figure 2-15 (Macfarlane, 2020).

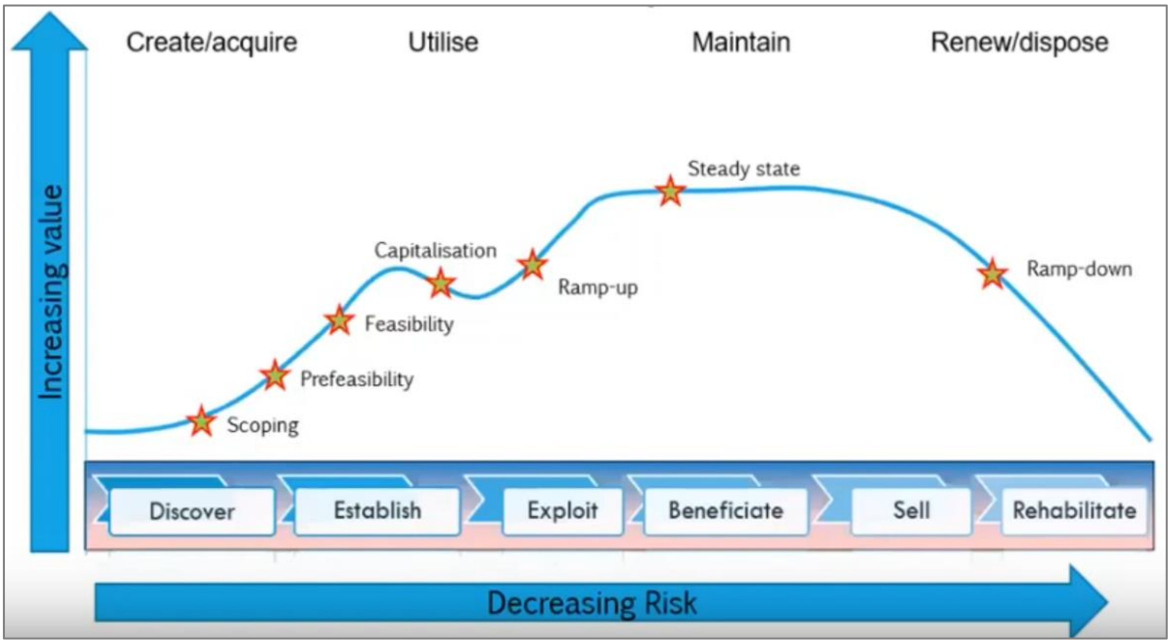


Figure 2-15: The mining value chain (Macfarlane, 2020).

3. Methodology: model development

A techno-economic discounted cash flow model was built for a Greenfields processing facility to primarily exploit the Kalahari Copper Belt. The review of near-term production targets indicated that copper concentrates to be produced from the KCB would contain economically significant quantities of silver. The project therefore targets a copper and silver processing facility capable of producing an LME-grade copper cathode and a silver doré as saleable products.

The facility utilises a pyrometallurgical flowsheet that separates and refines the silver downstream of copper smelting. While several technologies can be selected and traded off, this work employs a conventional copper smelter flowsheet, and provides a further conceptual view should a hydrometallurgical circuit be pursued as a processing alternative. The results presented are post-tax, post-royalties, with ungeared cash flows.

The critical evaluation metrics that were used as part of the evaluation included (Ross, et al., 2013):

- NPV (Net present value),
- IRR (Internal rate of return),
- Payback period (undiscounted from first expenditure date),

A project's computed net present value represents the excess of market value over the cost at a defined discount rate. Because the generated cash flows consist of a significant capital expenditure followed by revenue generation, the conventional internal rate of return is sufficient and favoured over modified variants. While positive NPVs may be generated, the expected payback period of mining-related projects can be long with arduous commodity pricing adversely impacting the longevity. The financier needs to consider their appetite for delayed returns.

The amount of Measured and Indicated Resources included in each copper miner’s life of mine needs to be considered and while the facility will have an extended life of 20 to 40 years, it would be prudent for the NPV to be positive when a shortened period is considered of 15 years, as well as the payback period being less than 15 years, with 15 years being the mean period where inferred resources may be included in the copper miners’ production profiles.

A further refinement is to ensure that the capital efficiency of the project, the NPV over investment capital ratio is a multiple larger than a factor of 1. This is important because beneficiation is a capital-intensive industry that requires substantial up-front investment.

3.1 Basis of assumptions

Table 3-1 summarises the employed valuation metrics.

Table 3-1: Basis of assumptions.

Factor	Assumption
Method of analysis	Discounted cash flow.
Cash flow terms	Real (base year: 2022).
Currency	United States Dollar (US$), with local costs escalated from Botswanan Pula (BWP).
Base evaluation date	1 Jan 2021
Cash flow frequency	Annual
Discount rate	7.7% (US$, Real, post-tax), based on a Botswana-based WACC.
Life of operation	22.5 years operation (+2.5 years construction and +1 year of project development (out of thesis scope)).
Processing technology	Pyrometallurgical and Hydrometallurgical for copper with down-stream silver refining included (technology specific to copper options).
Facility size	Copper concentrate feed rates of • 300 ktpa (Baseline), • 450 ktpa (Blue Sky) and • 300 ktpa with expansion to 450 ktpa after five years.
Business cases	• Toll treatment with off-take logistics handling. • Toll treatment without off-take logistics handling. • Concentrate purchase (outside thesis scope).
Facility location	• Orapa • Francistown • Selebi Phikwe • Serowe • Mmashoro • Jwaneng • Maun • Dukwe Logistical routes from i) source concentrator to processing facility and ii) processing facility to port were calculated based on the selected location, as well as the cost of coal bed methane provision to the location, if the option was considered in valuation. External development capital estimates can be toggled for each location to be included in the valuation.
Port location	Either Walvis Bay or Durban could be selected as copper and silver export ports, with applicable freight and insurance rates applied. No in-country consumption and the resulting manufacturing is assumed in this phase. • Walvis Bay (Namibia) • Durban (South Africa) • Shortest route (dynamic selection based on above facility location)
Market rates	• Copper, Silver, Country CPI: USA, BWA and currency exchange forecasts were obtained from S&P Global Capital IQ Pro.

Factor	Assumption
	• Sulphuric acid sales prices largely depend on local market conditions. Applicable market rates of July 2022 were used. • BPC electricity tariffs were supplied by the Chamber of Mines Botswana. • Natural gas rates per location were costed, based on pipeline lengths and engineering estimates to construct on-site power generation. • Treatment and other charges were inferred from market bulletins published on S&P Global's Capital IQ Pro platform. Treatment charges of US$ 75 per tonne were set.
Gross revenue sources (Toll treatment)	• Free copper and silver, recovered above the concentrate purchase payability. • Applicable minimum deductions for copper and silver. • Treatment and refining charges for copper and silver. • Applicable penalty credits for deleterious impurities. • A logistics premium applicable if offtake logistics is managed by the facility.
Selling expenses	Logistic rates were obtained from trucking and rail operators in Botswana and shipping and freight costs were derived from benchmarks.
Project capital	Capital estimates were developed in line with the process flow methodologies applied in the mass balance. Equipment sizing and cost estimation were performed from internal costing benchmarks. Time correction for historic pricing was done with the Chemical Engineering Plant Cost Index (CEPCI) and the 6/10^{ths} rule was applied to perform capacity escalation to match the desired plant. Contingency of 15% was applied to the capital estimate.
Sustaining capital	The sustaining capital was estimated as a fraction of total project capital at 0.8% as inferred from benchmarked operating cost accounts.
Operating costs	The direct and indirect operating costs were derived from first principles and were organised in five sections: • Labour • Power • Reagents • Logistics (as applicable) • Maintenance and Consumables
Labour	Patterson-grade labour estimates were performed, informed by benchmarking.
Power	The total power requirement for each process route and facility size was determined from equipment sizing calculations per process unit. Emphasis was placed on using direct coal bed methane as energy source as a distinguishable scenario from electricity usage. Two scenarios are selectable on the dashboard: 1) Electricity and coal. 2) Direct coal bed methane application with the balance of electricity generated via a CBM power island.

Factor	Assumption
Reagents	Reagent requirements were sized from equipment scale. Pricing was informed from market rates available.
Logistics	Information from the location study was used to map travelling routes along highways with BWP/t.km rates. Additionally, the option to include the available rail infrastructure was included.
Maintenance and consumables	Maintenance and consumable spend was sourced from existing operating plants' cost accounts.
Royalties	Royalties on gross revenue derived from copper (3%) and silver (5%) are paid by the copper producers and would typically fall out of scope for a Processing plant. Royalty incentives, as a means to fund the Processing plant, have been factored in as a cash flow stream to the Processing business.
Import duty	The import duty of mining equipment and spares could be zero rated upon negotiations with government. Processing equipment is not specified. A scenario is built where the project capital can be zero rated to indicate this potential impact.
Tax	The Botswana tax year runs from 1 July to 30 June. The functional currency for tax calculation is the Botswanan Pula (BWP). No export duties are applied to goods exported from Botswana. With annual cash flows modelled, calendar and tax years are not distinguishable. The manufacturing tax rate of Botswana was applied as the baseline(15%, comprising 5% manufacturing tax and 10% additional company tax), with the option to evaluate SEZ tax. The company is allowed a deduction of 100% of the mining capital expenditure incurred during a tax year with a 5 year carry forward of losses towards computation of the assessable income per tax year. This carry forward increased to 10 years when SEZ tax was applied.

Additional metrics that were modelled includes:

External Capital (as used in the text) is defined as the additional water infrastructure and housing development requirements that would apply at different locations considered for the facility. The likely housing and infrastructure costs in less developed regions were provisioned. These additional costs can be toggled to be included or excluded based on the evaluation criteria.

The toggles Transport Premium and Transport Costs need to be used in tandem: If the transport premium applies, the transport cost needs to be factored into the model, and vice versa.

The product logistics approach: either just trucking or a hybrid option that considers existing rail and optimises for per-location low costs only applies if Transport Costs are included in the model.

Botswana charges mineral royalties amounting to 3% for base metals, including copper, and 5% for precious metals, including silver (Matshediso, 2005). An additional tax incentive was theorised and calculated: 1% of payable mineral royalties from the contained copper and silver, paid by the copper producer to the government, could be diverted as a paid cash flow of the processing facility. This results in an effective royalty of 2% on copper and 4% on silver, with the 1% excess diverted from mine to processing facility.

3.2 Production inputs: copper concentrate

The production profiles were inferred from publicly available study reports of Khoemacau, Sandfire and Mowana (Khoemacau Copper Mining, 2021) (Sandfire Resources, 2019). This information and public statements from stakeholders were used to generate the i) Baseline production profile. Further consideration of Southern African sources, such as the inclusion of Orion Minerals' Prieska and O'kiep resources (South Africa), Trigon Metals' Kombat copper mine (Namibia) and expansion plans of the Botswanan producers, were used to generate the ii) Blue Sky production profile. The Baseline production profile includes the most likely production ramp-up scenario in Botswana. In contrast, the Blue Sky scenario includes speculative, distant mines that are not yet operational and still require financing.

The combination of production sources in the Baseline scenario indicated that this scenario would deliver 300 ktpa of copper-bearing concentrate, whereas the Blue Sky scenario would increase the copper-bearing concentrate to 450 ktpa throughput. A third scenario assumes that the baseline production scenario is built, with an additional capex allowance to increase production to 450 ktpa scenario once producers reach the required scale, which is inferred from production profiles to be five years.

Eight copper concentrate streams are available, as described in Table 3-2 and provided in Table 3-3.

Table 3-2: Producer information.

Producer	Type	Location	Data source
Khoemacau Baseline	Baseline	Kalahari copper belt (KCB)	Baseline conditions sourced from the company website. https://www.khoemacau.com/project-development-exploration/overview and Standard and Poor Capital IQ Pro.
Khoemacau Expansion	Blue Sky	KCB	Inferred from company strategy on website. Assumed similar grades to published information for the expansion projects.
Sandfire Baseline	Baseline	KCB	Project feasibility study information was supplemented by further internal details such as locked cycle tests.
Sandfire Expansion	Blue Sky	KCB	Internal discussions regarding future expansion plans were used to model the upside capacity target for Sandfire. Baseline information, such as grades and recovery, was superimposed.
Mowana	Baseline	Matshitama Schist Belt (MSB)	The internal production profile, done by Wardell Armstrong and SENET, was provided by the liquidator and used to model production. It is noted that Mowana is in care and maintenance.

Producer	Type	Location	Data source
BCL & Tati	Exclude	Limpopo Mobile Belt & Selebi Phikwe	BCL and TNMC’s resources required flowsheet consideration to be included in a primary copper circuit. They were excluded due to Cu to Ni's low proportional economic value in these feedstocks.
Orion Minerals: Prieska	Blue Sky	Northern Cape, South Africa	The Bankable Feasibility of this South African prospective Cu-Zn producer was used as a baseline in this study (Cu stream only). While the concentrate would, in theory, be compatible with the employed processing technology
Orion Minerals: Okiep Copper Company	Blue Sky	Northern Cape, South Africa	The restated concept study was communicated on the ASX and performed by Fraser McGill.
Kombat	Blue Sky	Otjozondjupa Region Namibia	Information published on the company website—low production volume from the small producers and logistical challenges.

Table 3-3: Producer production profiles.

	UoM	LOA	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
1. CONCENTRATE PRODUCERS																		
Khoemacau baseline																		
Concentrate tonnage	kilotonne	2 393	-	83	165	165	165	165	165	165	165	165	165	165	165	165	165	165
Contained Cu	kilotonne	1 008	-	35	70	70	70	70	70	70	70	70	70	70	70	70	70	70
Contained Ag	kg	897 188	-	30 938	61 875	61 875	61 875	61 875	61 875	61 875	61 875	61 875	61 875	61 875	61 875	61 875	61 875	61 875
Sandfire baseline																		
Concentrate tonnage	kilotonne	1 100	-	-	-	118	112	104	122	122	105	108	97	90	52	43	27	-
Contained Cu	kilotonne	332	-	-	-	31	32	30	38	40	32	33	32	28	14	13	9	-
Contained Ag	kg	456 986	-	-	-	26 188	35 761	34 233	47 382	64 091	50 853	49 205	51 503	45 324	16 683	19 562	16 200	-
Mowana																		
Concentrate tonnage	kilotonne	1 337	-	-	41	57	57	55	56	57	57	58	55	55	59	56	54	58
Contained Cu	kilotonne	337	-	-	13	17	20	16	13	14	15	16	13	16	14	12	15	13
Contained Ag	kg	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Khoemacau expansion																		
Concentrate tonnage	kilotonne	995	-	-	-	-	-	-	99	99	99	99	99	99	99	99	99	99
Contained Cu	kilotonne	419	-	-	-	-	-	-	42	42	42	42	42	42	42	42	42	42
Contained Ag	kg	372 945	-	-	-	-	-	-	37 295	37 295	37 295	37 295	37 295	37 295	37 295	37 295	37 295	37 295
Sandfire expansion																		
Concentrate tonnage	kilotonne	563	-	-	-	-	-	-	-	50	73	73	73	73	73	73	73	-
Contained Cu	kilotonne	157	-	-	-	-	-	-	-	14	20	20	20	20	20	20	20	-
Contained Ag	kg	196 310	-	-	-	-	-	-	-	17 424	25 555	25 555	25 555	25 555	25 555	25 555	25 555	-
Orion Prieska																		
Concentrate tonnage	kilotonne	1 125	-	-	-	8	98	114	117	114	122	117	100	94	100	81	58	1
Contained Cu	kilotonne	226	-	-	-	1	18	23	23	23	24	23	20	19	20	16	14	0
Contained Ag	kg	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Kombat																		
Concentrate tonnage	kilotonne	449	-	-	-	18	44	55	51	71	106	106	-	-	-	-	-	-
Contained Cu	kilotonne	122	-	-	-	4	11	14	13	20	30	30	-	-	-	-	-	-
Contained Ag	kg	66 437	-	-	-	6 006	6 459	12 287	6 169	9 031	13 242	13 242	-	-	-	-	-	-
Orion O'kiep																		
Concentrate tonnage	kilotonne	387	-	-	-	-	16	31	34	34	31	30	46	30	32	28	40	34
Contained Cu	kilotonne	102	-	-	-	-	3	8	9	9	8	8	14	8	8	7	12	9
Contained Ag	kg	15 292	-	-	-	-	553	1 162	1 351	1 340	1 180	1 149	2 041	1 146	1 235	1 031	1 708	1 396

3.2.1 Concentrate composition

The minerals in ore would be concentrated and not undergo chemically altering reactions. Two copper minerals must be distinguished for process design: oxide and sulphide ores. Both ore types can be readily smelted together. Oxide ores and their associated copper minerals occur close to the surface, have been weathered, and can be readily leached with acids. Sulphide ores are typically hypogene and need to be accessed with underground shafts. Sulphide ores require modification before leaching.

The approximate mineral composition of the Kalahari Copper Belt ores is presented in Figure 3-1 below. The copper in the ore is predominantly in the form of sulphide minerals such as Bornite, Chalcocite, and Malachite, whereas the upper seams contain appreciable oxide minerals such as Chrysocolla.

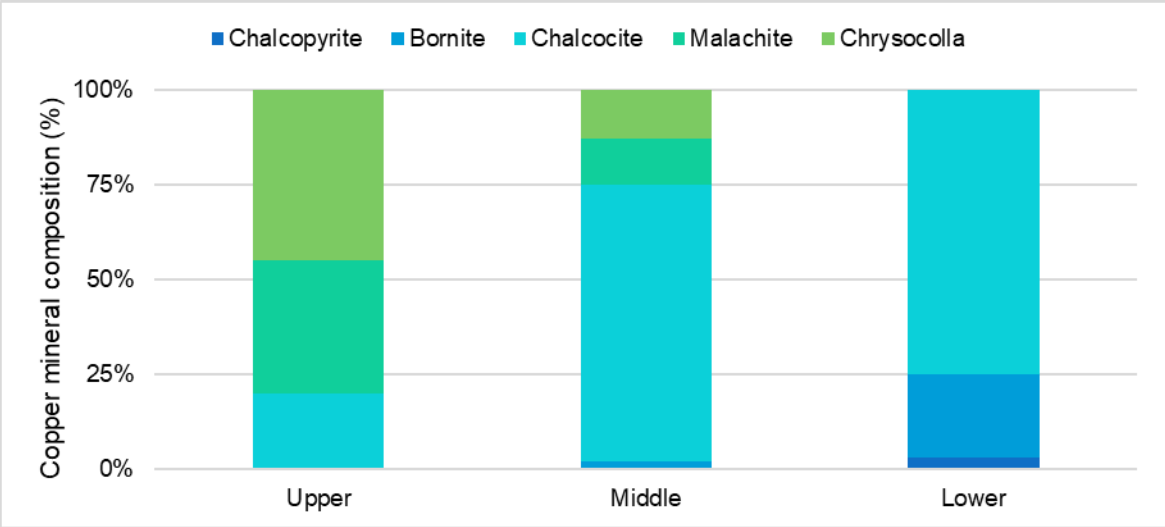


Figure 3-1: Kalahari Copper Belt mineral composition (Valenta & Mulcahy, 2016).

A technical overview of the process flow designs is provided below. Two design philosophies can be used to process the identified Cu-Ag concentrates: the conventional pyrometallurgical process route or a novel hydrometallurgical process route tailored to the Kalahari Copper Belt's geography.

As presented in Table 3-4, copper concentrates are to be processed. While it may be possible to heap leach ore if a hydrometallurgical process is designed directly, the copper miners have already committed to producing concentrates and the hydrometallurgical process design are tailored to align with the copper miners' existing business models.

Table 3-4: LOM average concentrate grades.

Life of mine average production	Baseline	Blue Sky
Concentrate [ktpa]	300	450
% Oxides	33%	31%
Cu [%]	35%	29%
Ag grade [g/t]	280	185

In both the Baseline and Blue Sky production profiles, significant quantities of silver by-products warrant the inclusion of a silver refining circuit that can produce silver doré. The silver doré of high 90% - 98% Ag purity would be refined further off-site.

3.3 Facility size

The concentrate supply from all the producers scoped in this study is visualised in Figure 3-2. Figure 3-3 isolates the concentrate supply from the only operating Kalahari Copperbelt producers, and Figure 3-4 presents the Blue-Sky concentrate profile options.

The combined concentrates from Khoemacau, Sandfire and Mowana yield enough concentrate only for a 300 ktpa facility. Considering a two-year construction period and a ramp-up period with reduced production in the first year, the earliest viable year for total production is 2024.

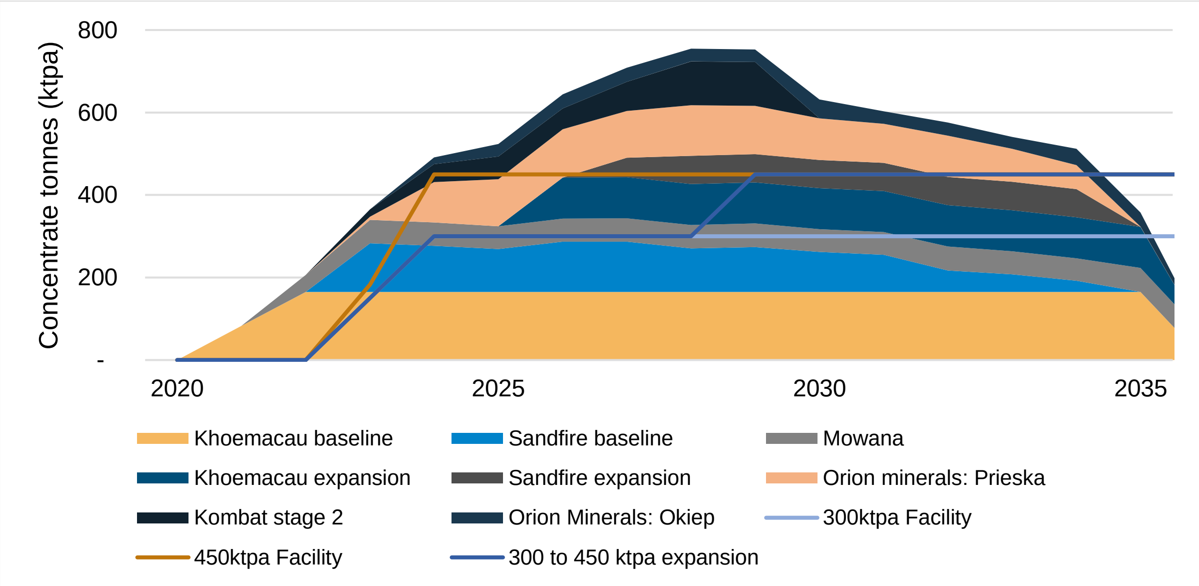


Figure 3-2: Copper concentrate available from all Southern African sources.

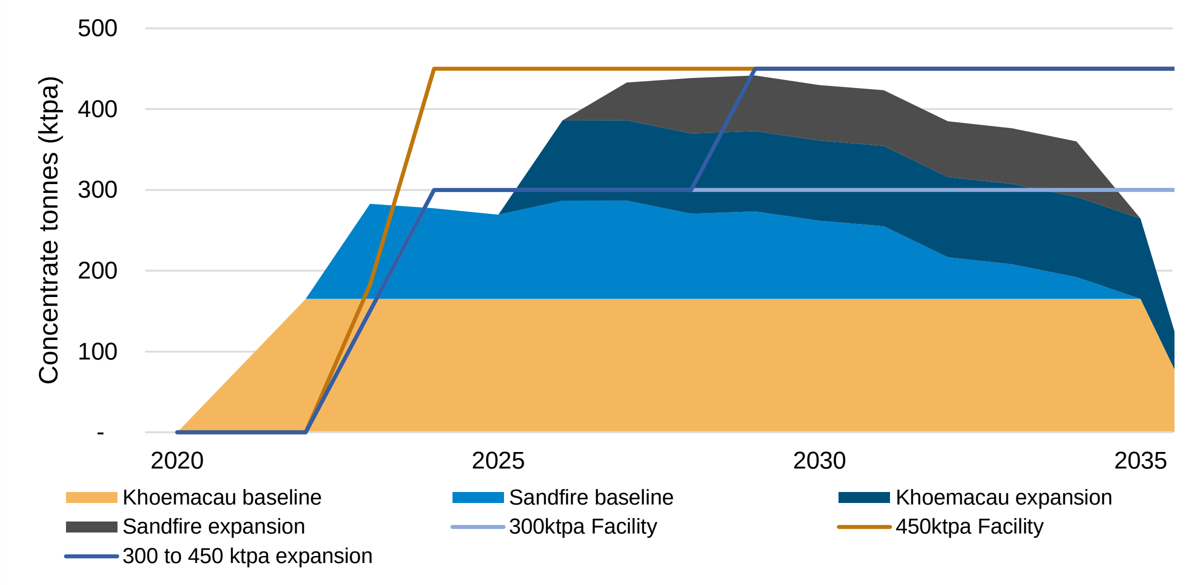


Figure 3-3: Concentrate supply from the Kalahari copper belt only.

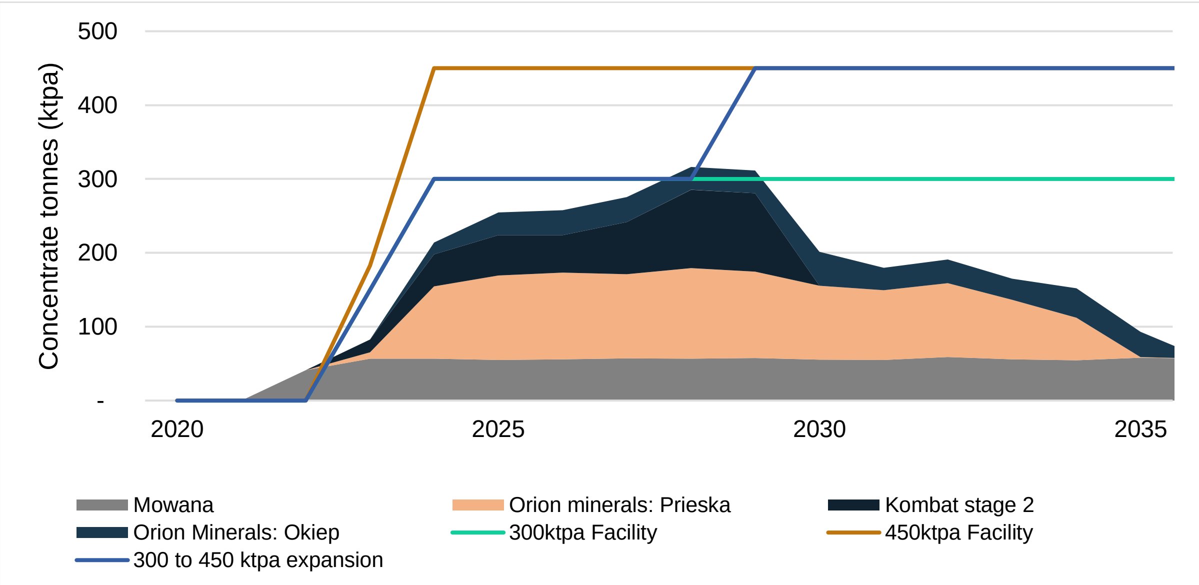


Figure 3-4: Concentrate supply from un-financed projects or neighbouring countries.

3.4 Process design

3.4.1 Pyrometallurgical route

ROM ore is crushed and milled to micron size (~100 µm) prior to sulphide flotation to produce an upgraded copper concentrate of ~20-30% Cu grade. Copper concentrates from different mines are blended before adding to a top-submerged lance (TSL) furnace. The concentrated blend in production profiles would contain enough sulphide ore to produce a matte phase.

Pyrometallurgical smelting entails the dissolution of all minerals at high temperatures; for copper, this will typically be around 1180°C.

Among the pyrometallurgical technologies available, Top Submerged Lance (TSL) Smelters have gained significant traction at Zambian and Democratic Republic of the Congo copper-cobalt operations. The moist concentrate is fed from the top while oxygen-enriched air is blown through a vertical lance into the molten material bath of the furnace. Like flash smelting, the energy from the exothermic reactions inside the furnace contributes significantly towards the total energy requirements for the furnace. The TSL furnace was selected based on its proved industrial applications elsewhere and its advantages over flash furnaces. Some advantages include (Davenport, et al., 2011):

- Higher recovery rates: TSL furnaces typically have higher recovery rates for copper and other metals, meaning that more of the metal in the concentrate is recovered as refined metal.
- Greater process control: TSL furnaces allow for more precise control over the smelting process, which can result in a more consistent and high-quality product.
- Lower energy consumption: TSL furnaces tend to be more energy efficient than flash furnaces, which can result in lower operating costs. The concentrate is fed to a flash or top-submerged lance (TSL) furnace to produce a sulphide matte. This matte is converted to remove sulphur and iron and produce blister copper. Blister copper is fire refined to produce anodes and subjected to electrorefining to produce LME-grade copper (Dworzanowski, 2013).

The copper-rich matte from the TSL furnace would be intermittently or continuously tapped into a settling furnace designed to be heated by natural gas. The settling furnace provides residence time to allow the settling of the matte phase and acts as a recovery vessel for copper and metal losses to the converter slag. The loss of copper to slag phases is predominantly due to materials handling and physical entrainment of matte in the slag phase. Copper may, however, also partially oxidise and dissolve into the slag phase during Peirce Smith converting. The reductive conditions inside the settling furnace allow effective matte recovery.

The furnace matte still has residual sulphur and iron, and both species are removed by adding silica as a fluxing agent and blowing air through the molten mixture to produce a Fayalite slag phase and release SO2 in the off gas. Conventional batch converting via Peirce Smith converters or continuous converting can be applied. Peirce Smith converters are horizontal, cylindrical, refractory-lined vessels with a tuyere line for oxygen blowing and a tilting mechanism to turn in and out of operation during the batch process cycle.

The blister copper product from the Peirce Smith converter is rich in copper at ~98% Cu. To prepare the blister copper product for electrorefining, fire refining/anode casting must be undertaken to remove impurities. Residual sulphur and oxygen form bubbles on the copper surface, giving blister copper its name. Fire refining is a batch operation where a two-step process of i) air-oxidation removal of sulphur, followed by ii) hydrocarbon-reduction of oxygen, is conducted. Anode fire refining is done in smaller Peirce Smith type crucibles. Finally, the anode product undergoes electrorefining, dissolving the impure copper anodes and selectively electroplating pure copper from the electrolyte solution.

Fire refining and electrorefining separate the base metals and precious metals. The anode slimes and discarded electrolytic solutions contain dissolved silver and possibly other precious metals that are contained in the feedstock. The anode slime stream is the primary feedstock to the silver refinery.

The silver process consists of a pressure-leaching autoclave to dissolve silver from the anode slimes by leaching with hydrochloric acid at an elevated temperature of approximately 140°C and 6 bar pressure.

The crude silver will then undergo impurity removal via a deselenising roaster. The deselenising roaster will remove Se, Te, Bi, As, Pb and other impurities. The produced off-gas will route to the sulphuric acid plant for environmental compliance.

The Dore furnace is used to flux the unrefined silver stream and to sparge oxygen to remove oxidisable impurities from the silver stream by producing a slag phase containing the residual impurities. Silver refining can then be undertaken with electrorefining to produce pure saleable silver.

SO_2 abatement (air quality compliance) done via the wet sulphuric acid process (WSA) utilises a catalyst bed to convert SO_2 to concentrated, saleable H_2SO_4 with no other effluent streams produced.

An accompanying process block flow diagram is presented in Figure 3-5.

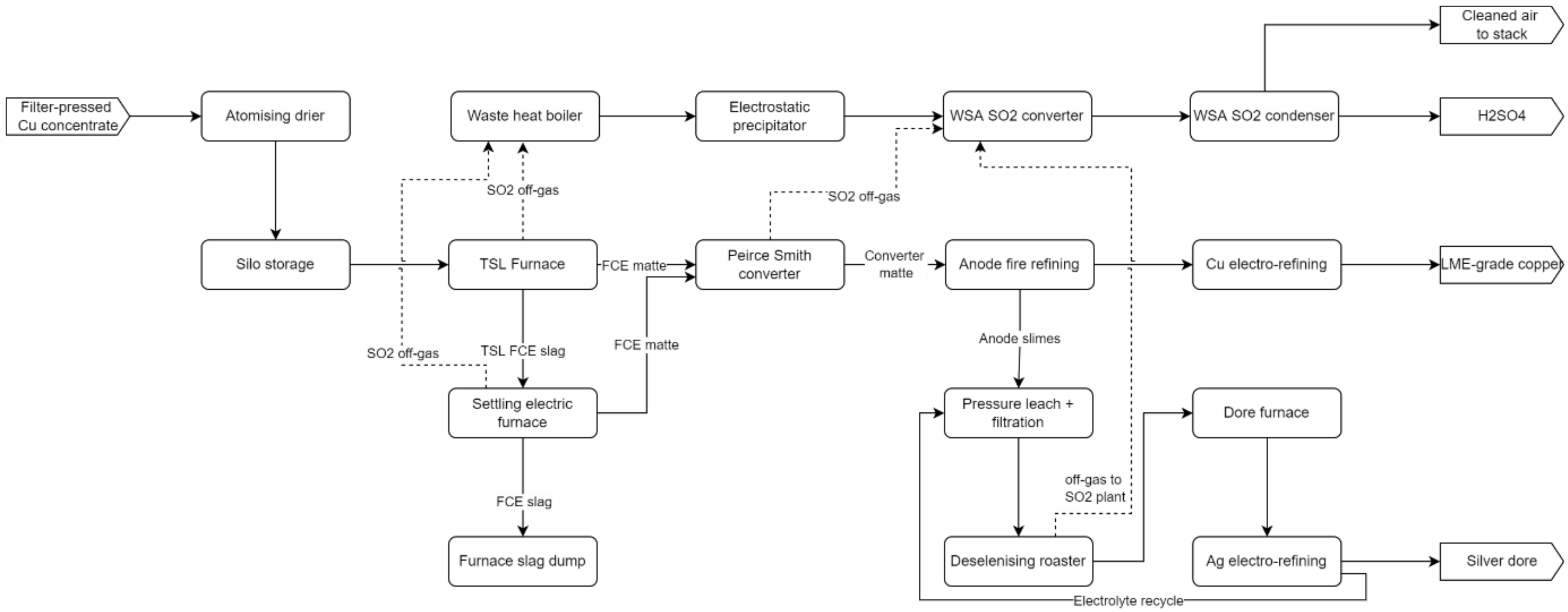


Figure 3-5: Pyrometallurgical process route block flow diagram.

The capacities of existing copper smelters in Southern Africa are provided in Figure 3-6, with a 300 ktpa New Botswana facility superimposed (Jones, 2015). At 450 ktpa capacity, the new Botswana facility would be of a similar scale to Mopani Copper Mines' Nkama Smelter in Zambia.

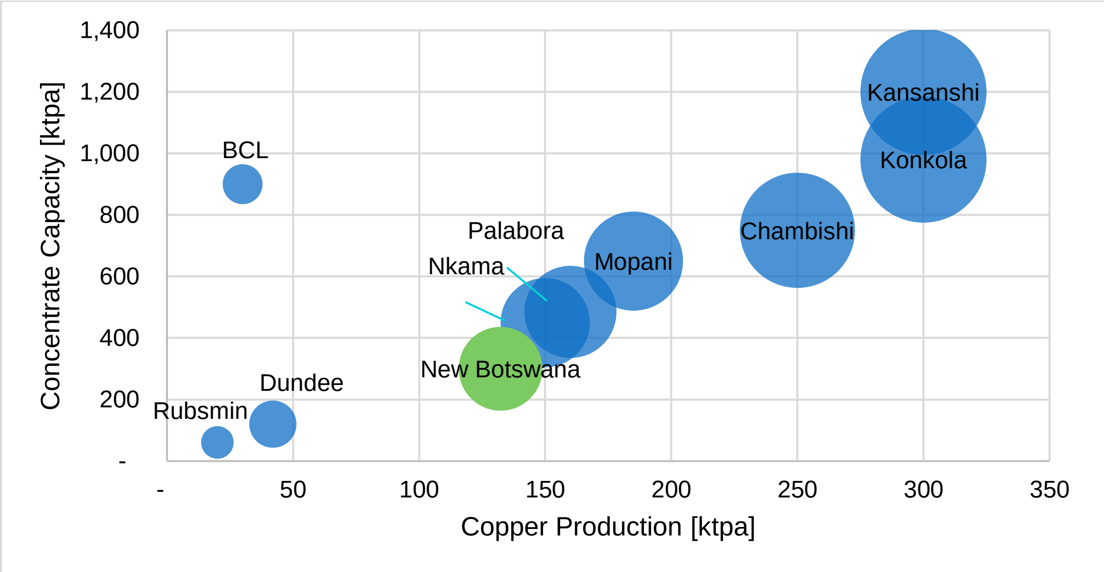


Figure 3-6: Southern African copper processing facility capacities (Jones, 2015).

3.4.2 Hydrometallurgical route

A hydrometallurgical recovery route for predominantly sulphide ores is not typically executed on this scale. However, many attractive features of hydrometallurgical facilities make it worthwhile to consider.

Of primary concern when evaluating hydrometallurgical options are the anticipated consumption of the primary lixiviant, commonly sulphuric acid, and neutralising agent reagents (limestone and quick lime), as these reagents make up the two most extensive operating cost parameters. While the lixiviant liberates the target metal from the host mineral, it will also leach other minerals of no economic importance, such as dolomites and other Ca and Mg-bearing minerals present.

The target minerals would determine whether the ore is amenable to leaching. Sulphide minerals, typically associated with underground sources, would need to undergo additional steps to allow leaching. The copper-bearing minerals present in the Kalahari Copper Belt primarily include Chalcopyrite (~$CuFeS_2$), Bornite (~Cu_5FeS_4), Chalcocite (~Cu_2S), Malachite (~$Cu_2CO_3(OH)_2$) and Chrysocolla (~$Cu_2H_2Si_2O_5(OH)_4$) (Valenta & Mulcahy, Development of a geometallurgical model for a copper concentrator, 2016).

The concentrates would be sorted according to their origin, oxide or sulphide concentrates. The sulphide concentrate will undergo sulphating roasting at 700°C, followed by calcine quenching to dissolve the copper into the leach solution. Sulphating roasting was selected over total pressure oxidative leaching in autoclaves because the copper producers already employ flotation or dense medium separation to reduce logistical costs by upgrading the ore feedstock. Many industrially applied references of sulphating roasting operate in Southern Africa, similar to operation at Kamoto Copper Company's Luilu refinery situated in the Democratic Republic of the Congo. The oxide material can now be blended with the calcine quench for elevated temperature (80°C) sulphuric leaching in agitated vessels.

The fast-leaching copper in the solution will be separated from the residue via thickening, and the slow-leaching copper will continue to leach in counter-current decanters. The leached solutions (high grade and low grade) will then undergo solvent extraction (loading and stripping) with a copper-selective organic solvent such as Lix 84-I to yield an impurity-free aqueous solution for copper electrowinning.

The leached residue from the sulphuric acid leach process undergoes a carbon-in-leach process to leach silver from the residue and ultimately form cyanide complexes in the solution. The silver cyanide will then be adsorbed onto activated carbon. The silver-loaded activated carbon will undergo elution to strip the silver in the solution from the carbon. The silver-bearing solution can undergo a few refining methods, with electrowinning added to the chosen process route, which operates similarly to copper electrowinning described above.

The proposed flowsheet described above is depicted in Figure 3-7.

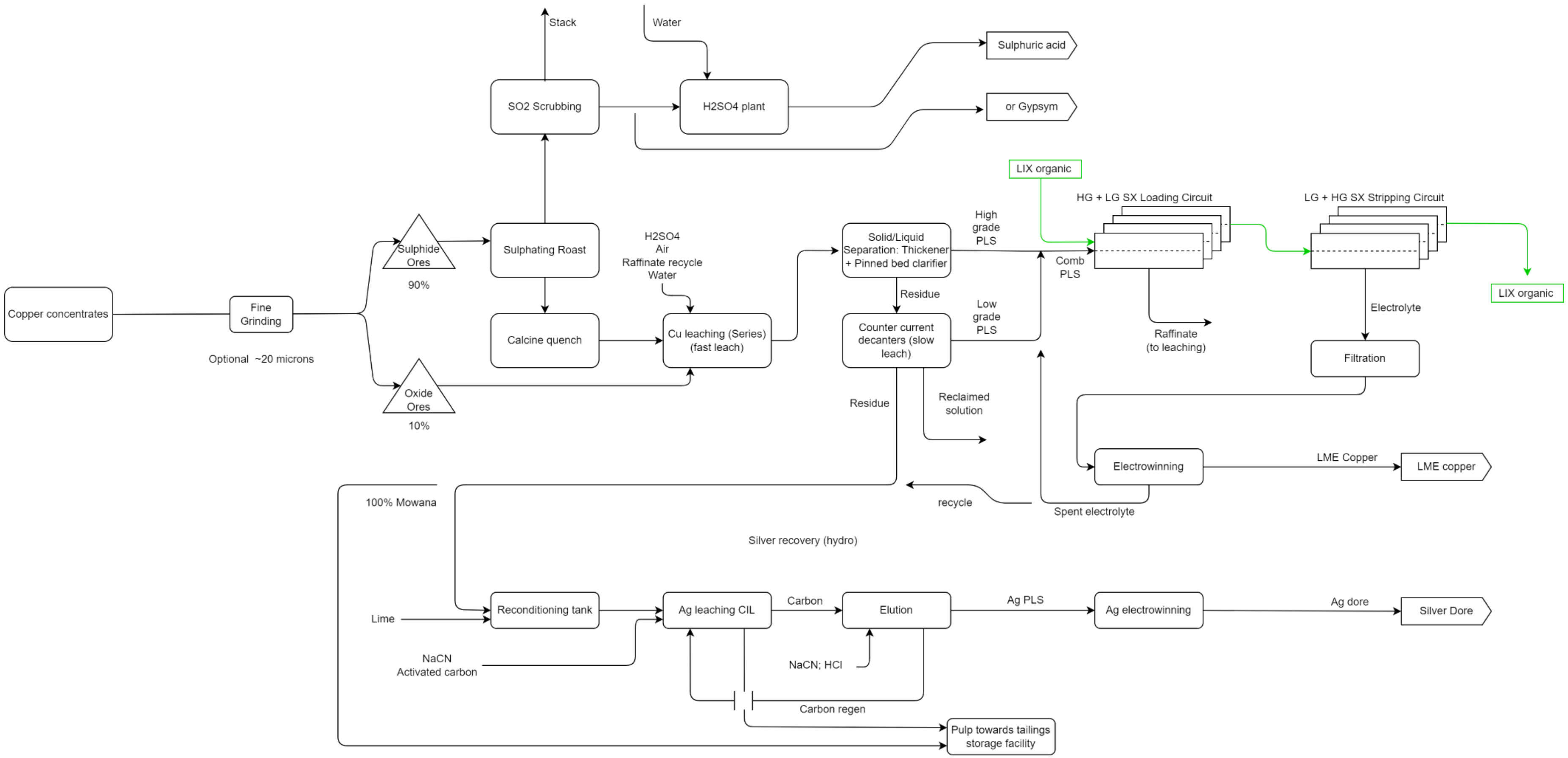


Figure 3-7: Proposed hydrometallurgical circuit.

In summary, an options weighting of the two processing routes are presented in Table 3-5.

Table 3-5: Summary of pyrometallurgical and hydrometallurgical process options.

Pyrometallurgy	**Hydrometallurgy**
Robust process - flexibility to switch between oxide and sulphide ores readily.	Requires separate treatment of sulphide ores to extract metals.
High capex, requires a minimum size of 400 ktpa concentrate.	Favourable for operations less than 30 ktpa Cu.
Ag separation in anode slimes produce a high grade and a small plant footprint is requirement for the ag refinery.	Larger Ag recovery circuit required to treat all residues from the Cu leach circuit.
Typically, a small silver/precious metal recovery circuit is sufficient. It can be decommissioned if ore feedstock does not contain silver anymore.	A large Carbon-in-leach facility would be required with lower recoveries than the pyrometallurgical setup
Air quality compliance requires an SO2 gas abatement plant.	Environmentally easier to manage and better for the environment. However, acid mine drainage of tailings requires special tailings storage facility linings.
Natural gas can be directly employed in many smelting unit operations.	Requires more power in the form of electricity for process operations, except for the sulphating roaster which can be run with natural gas.
Energy released by oxidising sulphur is utilised to smelt the ore.	Gives the opportunity for suppliers to open their mass pulls, increasing copper recovery on concentrators and compensating for the typical lower metal recoveries of the hydromet circuit.
	Silver Extraction potentially lower due to the precipitation of silver in Argentojarosite, an undesired side-reaction.

3.4.2.1 Glycine leaching

Novel hydrometallurgical processing routes may also be considered to process the unique concentrates from the KCB and surrounds. The current industry interest centres around the Glycine leach process. It involves leaching the ore with a solution of glycine (an amino acid). The glycine solution is highly selective, meaning that it only dissolves certain metals, such as copper, while leaving normally acid-consuming gangue minerals, such as dolomites, behind. This makes it possible to recover copper from ores that contain other metals that would be difficult to separate using other methods. This technology is pioneered and patented by Mining and Process Solutions, which would require their involvement to test their technology on the KCB ores (Mining and Process Solutions, 2022).

3.5 Location options

Eight viable towns and their surrounding areas were identified and scoped for the construction of the new copper processing facility, as illustrated in Figure 3-8

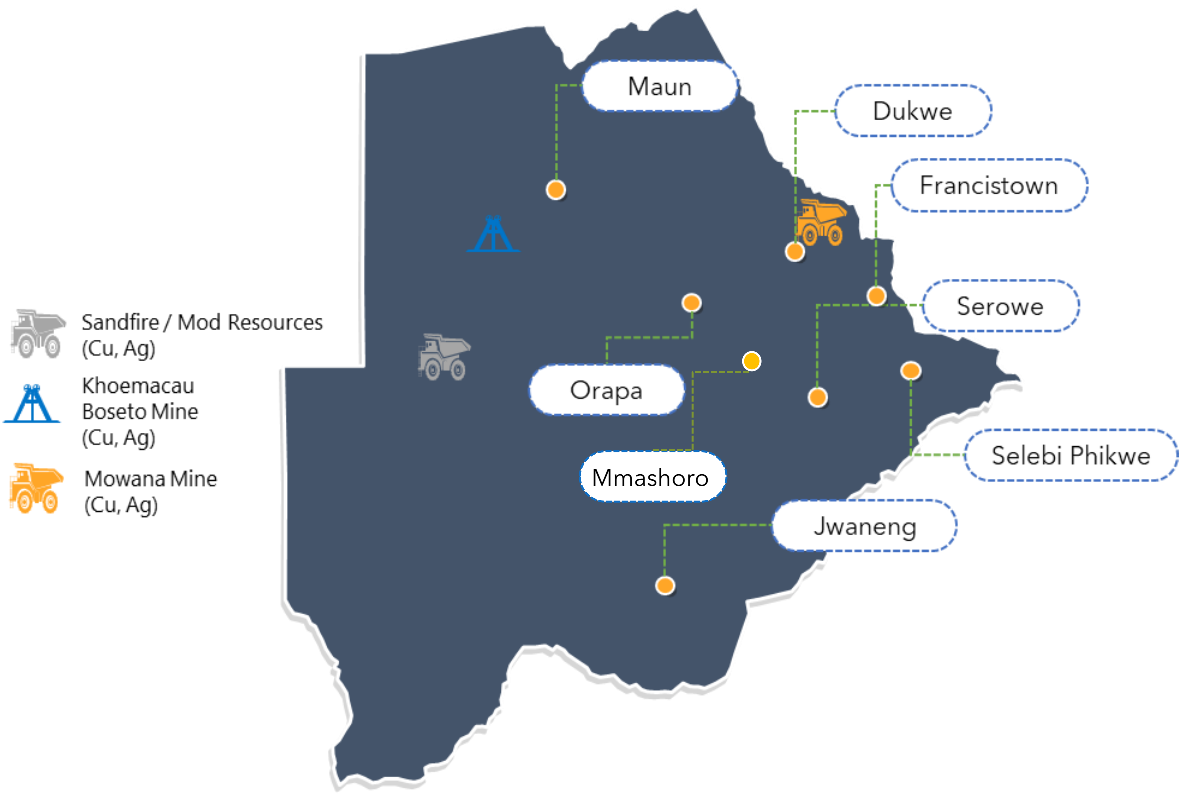


Figure 3-8: Viable locations for the new copper processing facility.

The following were considered when assessing each of the proposed location:

- Logistics costs of transporting concentrate from the three baseline producers to the new processing facility.
- Logistics costs of transporting the refined products to either the Durban or Walvis Bay ports.
- Logistics costs of transporting coal (from South Africa), limestone (from Botswana) and other specialist reagents required in each process from South Africa.
- CBM gas supply costs to location
- The water supply infrastructure and housing costs, which were collectively termed the external developmental capital costs.
- The existing rail infrastructure routes that were included during scenario development is presented in Figure 3-9.

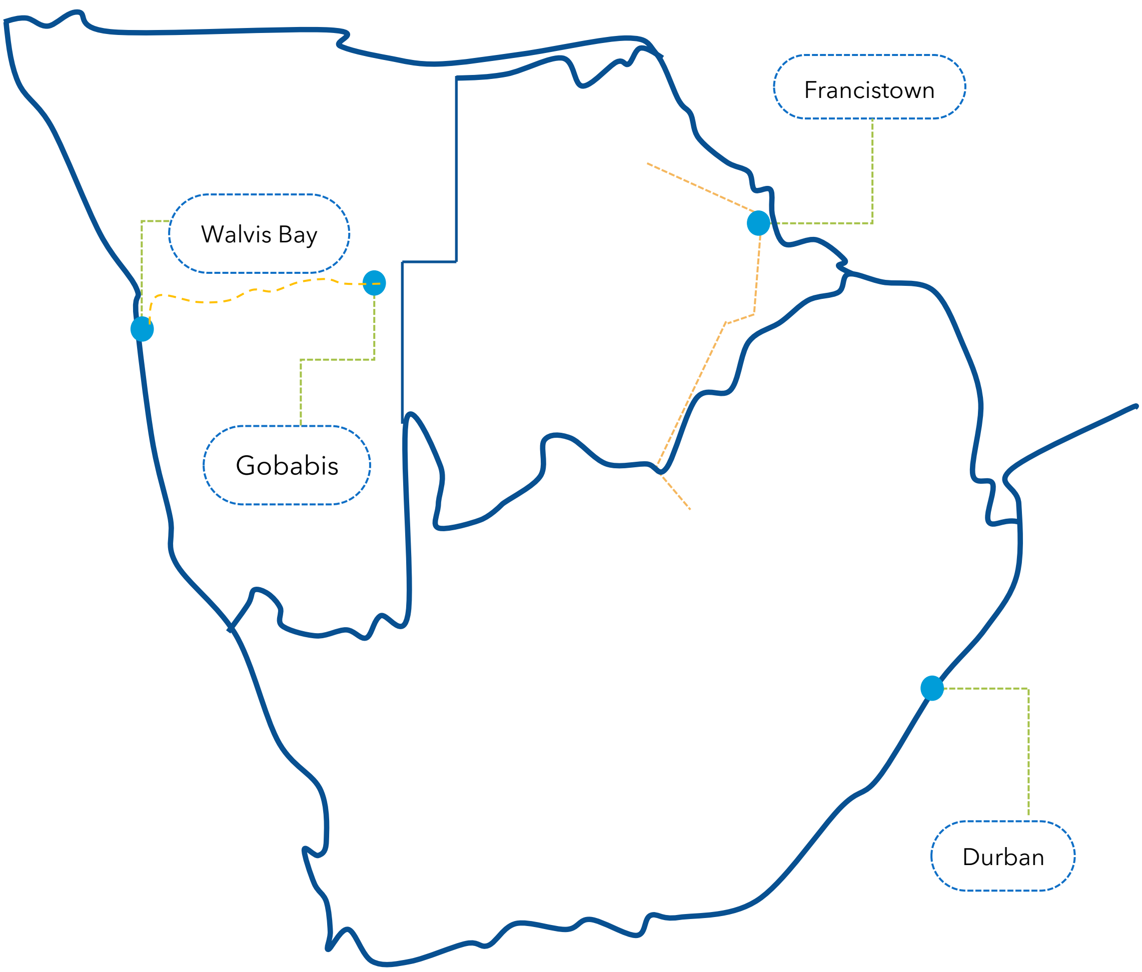


Figure 3-9: Available rail infrastructure modelled in study.

3.6 WACC calculation

The weighted average cost of capital calculation applicable to the study was performed as outlined in Figure 3-10. The shown discount rates are not deterministic, and scenario analysis could alter the effective tax rate and the weighting between equity and debt.

Figure 3-10: Weighted average cost of capital calculation.

Factor	Rate	Comments
Risk-free rate (R_f)	6.66%	Botswana-denominated government bond 10Y. http://www.worldGovernmentbonds.com/country/botswana/
Market risk premium	5.43%	http://pages.stern.nyu.edu/~adamodar/New_Home_Page/datafile/ctryprem.html
Asset beta (β)	1.00	SFR = 1.21, Yahoo Finance, 29 May 2022
Cost of equity (ke)	**12.09%**	**Calculated**
Cost of debt	5.76%	Botswana's current prime lending rate. https://www.bsb.bw/news&resources/news/article.php?id=77#:~:text=Following%20the%20adjustment%20of%20the,effective%2029th%20April%202022.
Margin	25	the premium for credit risk (from RMB)
The pre-tax cost of debt	6.01%	Calculated

Factor	Rate	Comments
Marginal tax rate	15.00%	Botswana's manufacturing tax rate of 15% as a proxy
Post-tax cost of debt (kd)	**5.11%**	**Calculated**
E% =	100%	Percentage of financing that is equity
D% =	0%	Percentage of financing that is debt
WACC (nominal)	12.09%	Calculated
Less country inflation	7.24%	Long-term country inflation rate. https://www.worlddata.info/africa/botswana/inflation-rates.php#:~:text=The%20inflation%20rate%20for%20consumer,the%20price%20increase%20was%205%2C285.19%20%25.
WACC (real)	4.52%	Calculated
Add: Country risk premium (real)	1.19%	http://pages.stern.nyu.edu/~adamodar/New_Home_Page/datafile/ctryprem.html
Add: Commodity risk premium (real)	0.25%	MDCB factor for Copper
Add: Project risk premium (real)	2.00%	MDCB factor for Greenfield projects
Risk-adjusted discount rate (nominal)	**15.28%**	**Calculated**
Risk-adjusted discount rate (real)	**7.71%**	**Calculated**

3.7 Labour compliment

The necessary labour compliment was developed using a Patterson hierarchy structure. The Total Cost to Company remuneration is comprehensive in that it caters to special travel arrangements (if needed) for upper management and provides adequate, higher range compensation to local employees. The developed labour complement is provided in Table 3-6. The scale-up to a 450 ktpa facility will allow more local employment with the same upper management level and a limited increase in D levels. A scale-up to 450 ktpa benefits local economic empowerment significantly and leverages economies of scale to increase profitability.

This operation will require key engineering professionals on the E and D bands. It would be most beneficial to source local employees as far as reasonably possible. Employees from the closed BCL smelter operation would be able to meet the skills requirements, subject to training and operational readiness assessments.

Table 3-6: Proposed labour compliment.

Patterson grade	Job level description	Cost to company [individual, US$/annum]	300 ktpa labour quantity	300 ktpa labour cost [US$/annum]	450 ktpa labour quantity	450 ktpa labour cost [US$/annum]
E_U	General manager	202,504	1	202,504	1	202,504
E_L	Department managers	101,785	3	305,355	3	305,355
D_U	Mid-level managers (engineering, finance, HR, safety)	75,000	9	675,000	10	750,000
D_L	Engineers	40,714 – 53,571	3	147,856	4	201,427
C_U	Foremen, junior engineers and senior artisans	37,500 – 82,500	31	1,291,924	40	1,723,708
C_L	Technicians, artisans and SHEQ personnel	18,214 – 34,178	163	4,726,099	197	5,710,295
B_L	Operators, general workers & security	17,142	244	4,182,648	305	5,228,310
Total			**454**	**11,531,386**	**560**	**14,121,599**

The labour cost presented above accounts for the operational staff that will be employed on a full-time basis at the facility during steady-state operation. It does not include temporary service providers or engineering, procurement, and construction management firm (EPCM) employees to construct the facility, which is provisioned for in Capex. It also does not consider any employment of other related services to the smelting operation that would typically be contracted and expensed as Opex.

Income from individual taxpayers is taxable in Botswana if the source is within Botswana, and depending on resident status, different brackets apply (PWC, 2022).

A non-resident is taxable on earned income in accordance with the personal income tax rates but pays to withhold tax (WHT) only at the rate of 15% for interest, commercial royalties, and management and consultancy fees, 10% applies to dividends, and 10% applies to entertainment fees, where such income is of Botswanan origin. Table 3-7 summarises resident income tax (2022) and Table 3-8 summarises non-resident income tax.

Table 3-7: Resident individual tax (PWC, 2022).

Taxable income (BWP)		Tax on column 1 (BWP)	Tax on excess
Over	Not over		
0	48,000	0	0%
48,000	84,000	0	5%
84,000	120,000	1,800	12.5%
120,000	156,000	6,300	18.75%
156,000		13,050	25%

Table 3-8: Non-resident income tax (PWC, 2022).

Taxable income (BWP)		Tax on column 1 (BWP)	Tax on excess
Over	Not over		
0	84,000	0	5%
84,000	120,000	4,200	12.5%
120,000	156,000	8,700	18.75%
156,000		15,450	25%

3.8 Operating costs

The basis of operating costs for the processing facility was an engineering study. Table 3-9 presents a breakdown of operating cost assumptions applied in the model.

Table 3-9: Operating cost assumptions.

Description	Unit of measure	Rate (rounded)
Power		
Coal bed methane cost (location dependent)	US$/kWh	0.05
Coal/ anthracite	US$/kWh	0.08
BPC electricity cost	US$/kWh	0.08
Diesel	US$/t Cu	22.5
Heavy fuel oil	US$/t Cu	30.6
Reagent costs		
Flux (Limestone)	US$/t	123.3
Silica	US$/t	34.3
Slaked Lime ($Ca(OH_2)$)	US$/t	149.8
Hydrochloric acid	US$/t	180.0
Water	US$/t	0.85
Smelter maintenance and consumables		
Refractories	US$/t Cu	8.4
Stores & spares	US$/t Cu	10.5
Operations & maintenance	US$/t Cu	10.6
Repairs & maintenance	US$/t Cu	20.1
Equipment & vehicle hire	US$/t Cu	8.8

Description	Unit of measure	Rate (rounded)
Waste handling	US$/t Cu	7.9
Other consumables (Casings, Paste, etc.)	US$/t Cu	7.5
Silver refinery maintenance and consumables		
Operating consumables	US$/t Ag	12.8
Stores & spares	US$/t Ag	5.7
Operations & maintenance	US$/t Ag	3.5
Repairs & maintenance	US$/t Ag	17.9
Equipment & vehicle hire	US$/t Ag	11.2
Labour		
Shared	US$ '000 pa	22,530
Smelter	US$ '000 pa	213,610
Silver refinery	US$ '000 pa	79,050
Overheads		
Admin and duty	US$/t Cu	15.4

The above operating cost factors translate into a USc 20.68/lb Cu cost, which is benchmarked to other Southern African operations in Figure 3-11. The proposed operating cost figures align well with mid-tier operations' operating costs.

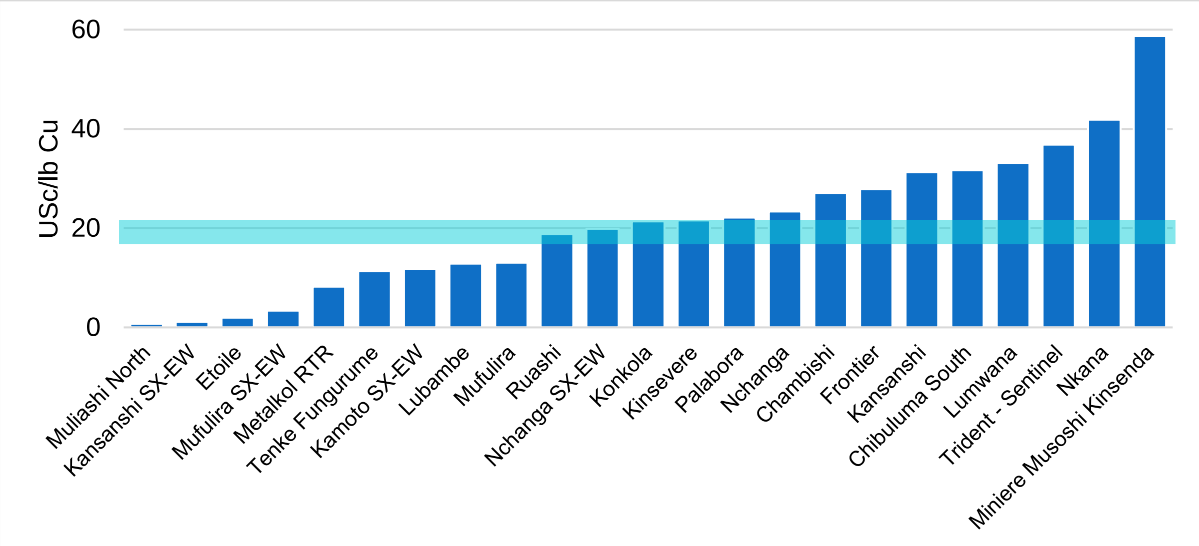


Figure 3-11: Benchmark TC/RC costs in USc/lb Cu.

3.9 Capital cost estimate

The capital cost estimate is summarised in Table 3-10, and a benchmark against comparable Southern African facilities is presented in Figure 3-12.

Table 3-10: Capital cost estimate - 300 ktpa copper pyrometallurgical facility.

Description	Unit of measure	Rate
Copper process	US$ '000	265,098
Silver refinery	US$ '000	10,103
Shared process	US$ '000	15,464
Infrastructure, utilities and ancillaries	US$ '000	29,416
Project delivery management	US$ '000	56,973
15% - Contingency	US$ '000	56,558
TOTAL	US$ '000	433,612

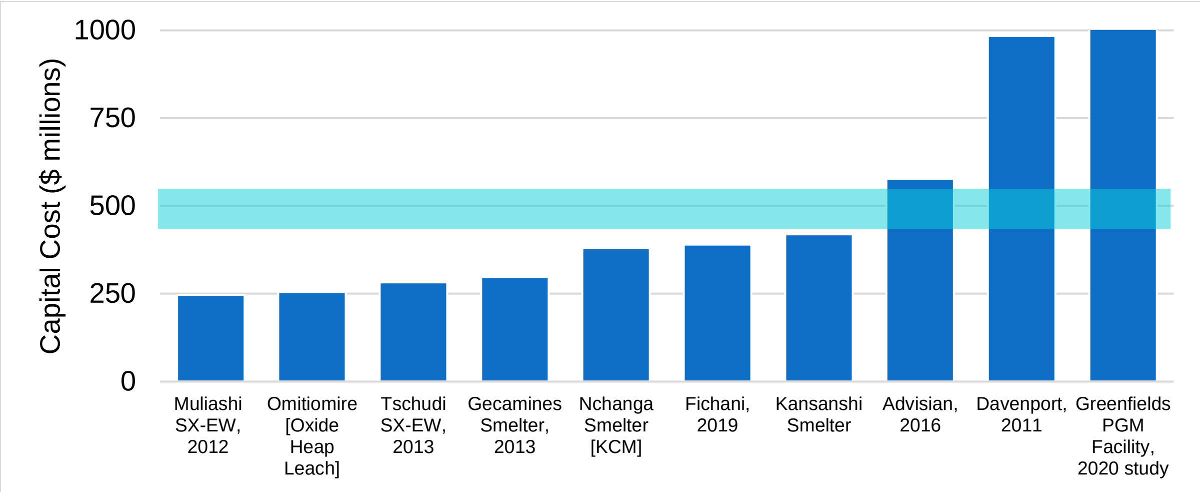


Figure 3-12: Capital cost benchmarking with recent or equivalent facilities (scaled to 300 ktpa equivalent).

3.10 Model dashboard

With the inputs of the model defined, a Microsoft Excel discounted financial model was developed, for which the dashboard is shown in Figure 3-13. Valuation results per selection is presented on the left tab, the radio buttons in the middle tab allows user input and selection of options, and graphs visualise the selected outcomes on the right tab. The valuation results section also allow the user to individually alter the sensitivities of input variables in % changes.

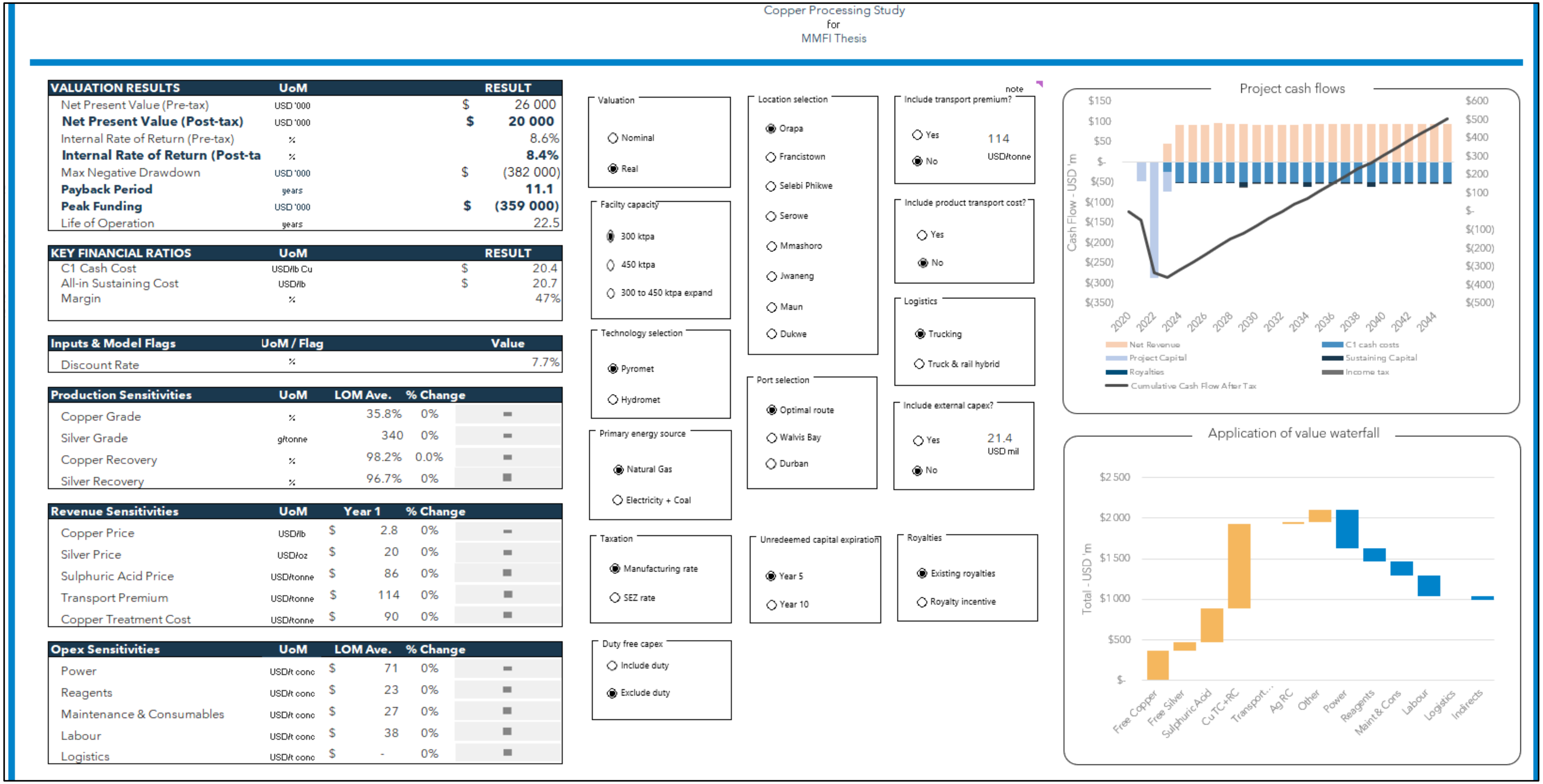


Figure 3-13: Model dashboard preview

3.11 External development capital requirements

The locations considered may be in rural or underdeveloped regions of Botswana, or water-scarce regions, necessitating additional capital to provide housing for employees and a water pipeline with a pumping station, as set out in Table 3-11. The hydrometallurgical circuit requires proportionally more water than the pyrometallurgical process, with proportionally more costs allocated. Selebi Phikwe and Francistown are considered well-developed and no additional housing costs were required at these regions.

Table 3-11: External development capital requirements.

Location	Housing cost	Pyro: water supply pipeline & pump station	Hydro: water supply pipeline & pump station
	[US$ '000]	[US$ '000]	[US$ '000]
Orapa	8,243	21,434	27,338
Francistown	-	2,246	2,864
Selebi Phikwe	-	2,300	2,933
Serowe	8,243	13,148	16,769
Mmashoro	27,429	11,917	15,199
Jwaneng	16,485	13,219	16,860
Maun	13,715	48,981	62,471
Dukwe	21,957	13,579	17,319

4. Valuation results

4.1 Baseline 300 ktpa facility

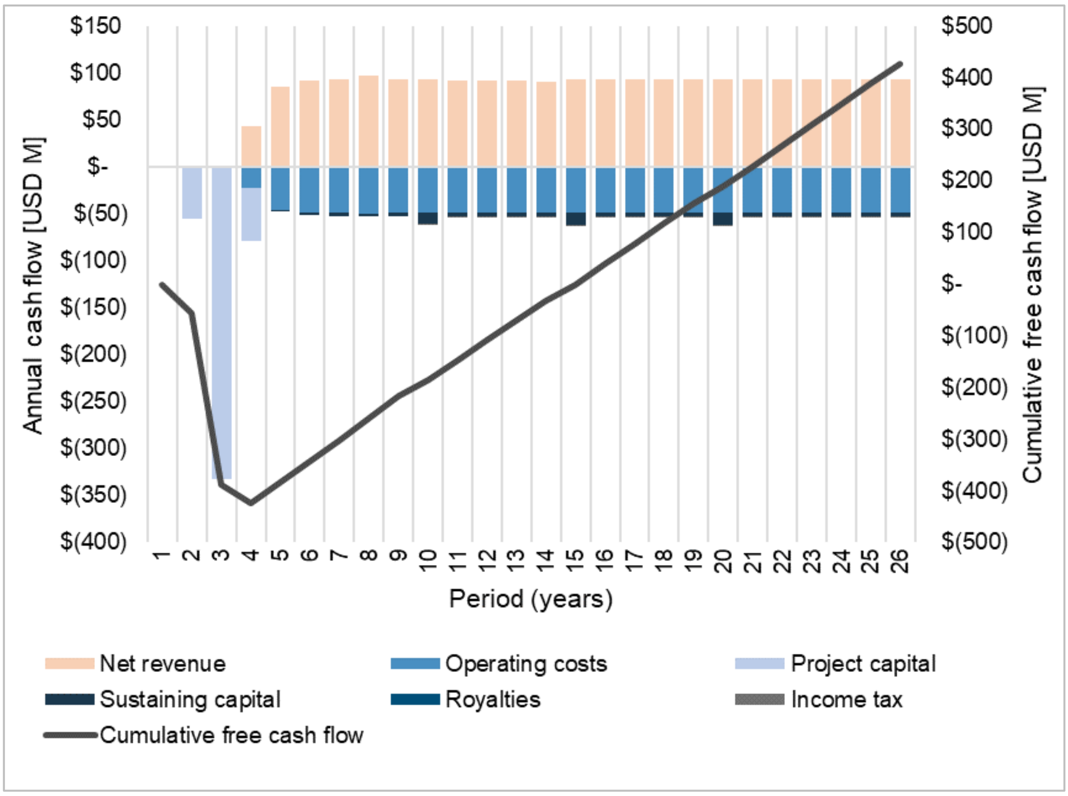
The Valuation results for the base case production profile identified is presented in this section. Due to the high number of options that can be selected by the model's end-user, a guide of selected options is presented underneath results shown, for example:

Other options selected: Real | 7.7% discount | Pyro | Natural Gas | Optimal Location | Shortest Distance | With External Capex | Baseline Tax

The scenarios developed were taken to deliver cash flow projections for the 300 ktpa Pyrometallurgical facility in Figure 4-1 at Orapa. This option assumes that electricity from BPC is supplied, that off-take logistics are not managed and that the optimal off-take port is selected to export products to markets abroad. The external development capital required at Orapa is included, amounting to US$ 21 M.

An operating cost margin of 46% is generated, realising a steady state annual free cash flow (FCF) of US$ 40 M[2]. Despite this, the facility generates a negative post-tax net present value$_{7.7\%}$ (NPV$_{discount_rate}$) of US$ (42 M) over 25-year facility life, with an IRR of 6.4% and a payback period of 13 years. The max negative drawdown, equal to the investment capital required, is US$ (443 M). Correspondingly, the revenue contributions and operating costs, undiscounted over the life of operation, is presented in Figure 4-2. The full cash flow for this scenario is presented in the Appendix.

[2] The steady state free cash flow is measured in all scenarios between 2025-2029.



Other options selected: Real | 7.7% discount | Pyro | Electricity + Coal | Orapa | Shortest Off-take Distance | With External Capex | Baseline Tax | No transport management

Figure 4-1: Cash Flow Analysis for the 300 ktpa Pyro Facility scenario at Orapa

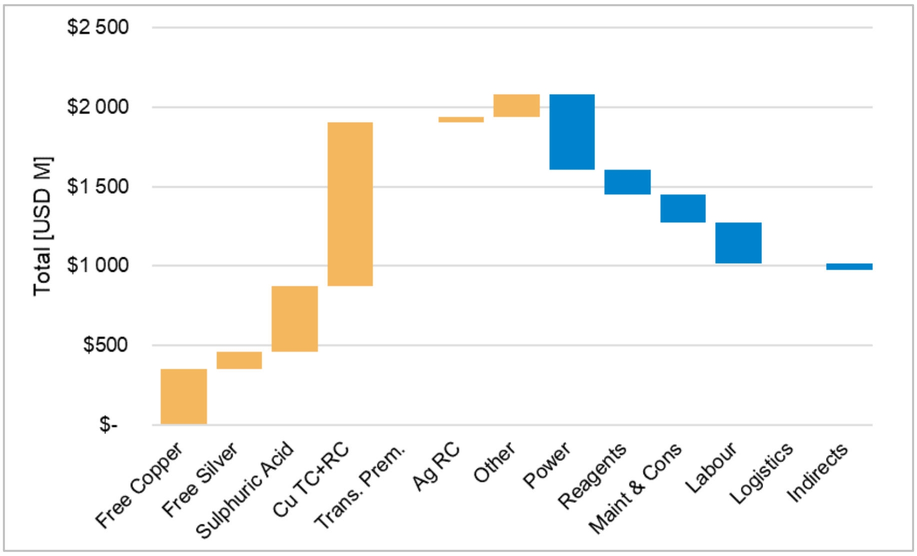
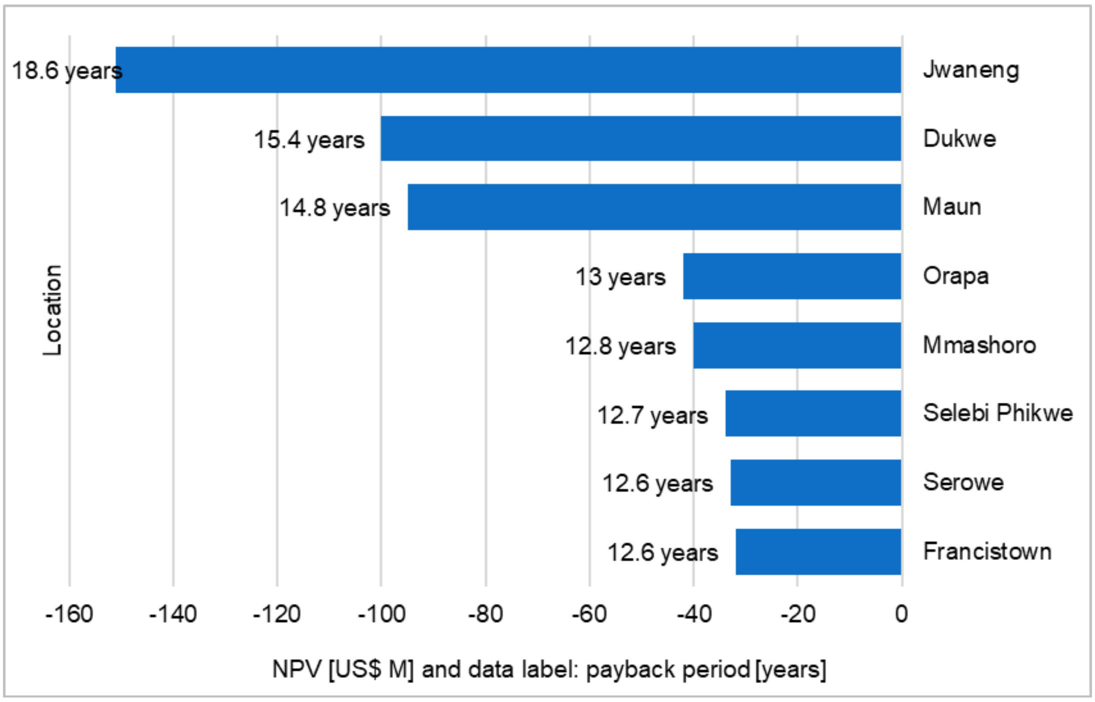


Figure 4-2: Revenue and operating costs undiscounted over life of mine for the 300 ktpa Pyro Facility at Orapa

No location, when considered with the same criteria above, yields a positive investment case, as evidenced in Figure 4-3. Locations, Francistown, Serowe, Selebi Phikwe and Mmashoro yielded marginally better investment cases with less negative NPVs and lower payback periods. Best option Francistown yielded an $NPV_{7.7\%}$ of US$ (32 M), with a payback period of 12 years and 7 months.

It was expected that Maun, being the closest in vicinity to the host mines would yield the optimal investment case, but considering the high external development capital required at Maun being an additional US$ (49 M), the location did not suit the investment.



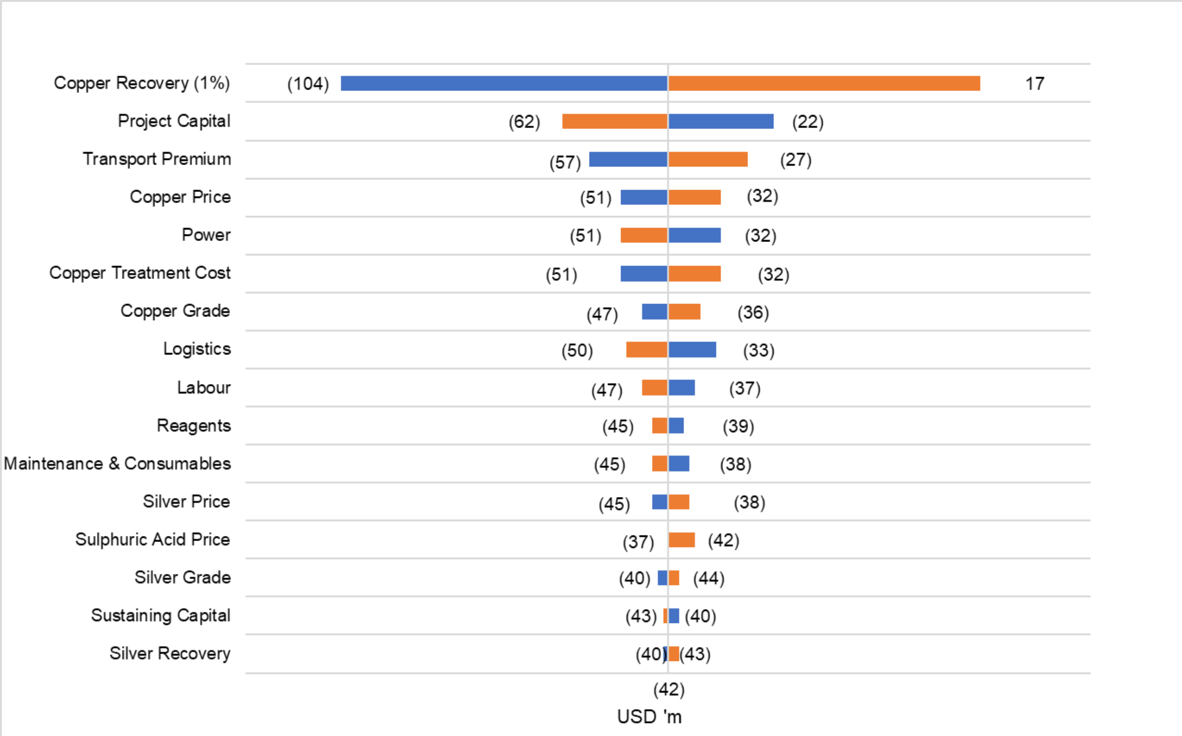
Other options selected: Real | 7.7% discount | Pyro | Electricity + Coal | Shortest Off-take Distance | Trucking | Without External Capex | Baseline Tax | No transport management

Figure 4-3: Location evaluation for the baseline scenario.

The 300 ktpa facility, for which concentrate supply is highly probable, is not financially viable and cannot be pursued without optimisation.

4.2 Sensitivity analysis

A sensitivity analysis was performed to understand the key project drivers towards a positive investment scenario. The NPV tornado diagram, based on the baseline conditions for the pyrometallurgical circuit at Orapa, is presented in Figure 4-4. 5% sensitivity increments were applied to the input variables in isolation, with a notable exception being that copper recovery was adjusted in 1% increments. The metallurgical copper recovery has by far the largest effect on the profitability of the project, followed by the expended project capital and the negotiated transport premium (to be elaborated further). Factors inside the control of the facility, such as the metallurgical copper recovery has a more pronounced effect on the net present value than the applied copper price. Silver and sulphuric acid prices and recoveries did not have significant effects on profitability, signalling a primary focus on copper should be prioritised in feasibility study designs. Diligent project capital expenditure within budget, accurate capital estimates and the transport premium are controllable factors.



Other options selected: Real | 300 ktpa | Pyro | Natural Gas | Shortest distance | With External Capex | Baseline Tax

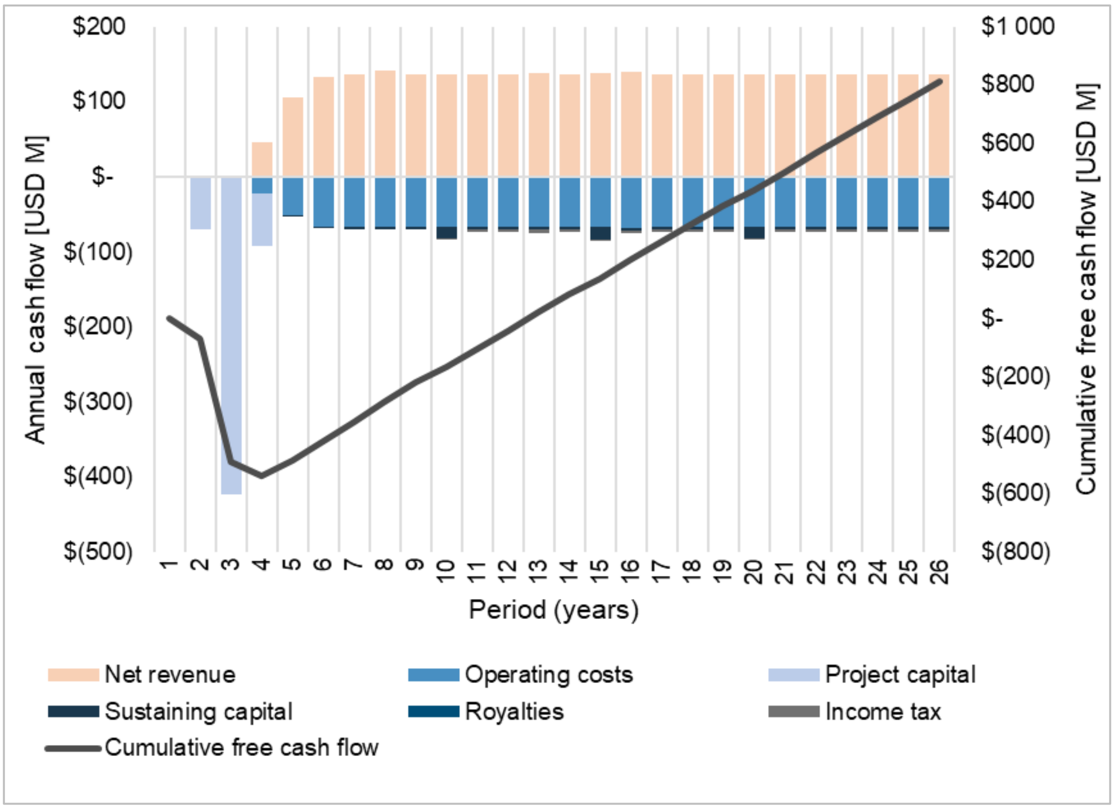
Figure 4-4: Tornado sensitivity analysis of the post-tax NPV (Real) for a 300 ktpa facility at Orapa with baseline parameters. Blue = decrease, orange = increase.

4.3 Blue Sky 450 ktpa facility

As evidenced from past work elaborated in Section 2.7 that a larger economy of scale would likely be needed to meet the investment criteria. Figure 4-5 presents the facility at a 450 ktpa scale, assuming the same baseline assumptions, but the feed composition now incorporates the Blue Sky feed composition, as presented in Section 3.2.1.

An operating cost margin of 51% is generated, realising a steady state annual free cashflow (FCF) of US$ 64 M. The 450 ktpa facility generates a positive post-tax $NPV_{7.7\%}$ of US$ 48 M over 25 year facility life, with an IRR of 8.8% and a payback period of 10.8 years. However, the max negative drawdown, equal to the investment capital required, increases to US$ (563 M).

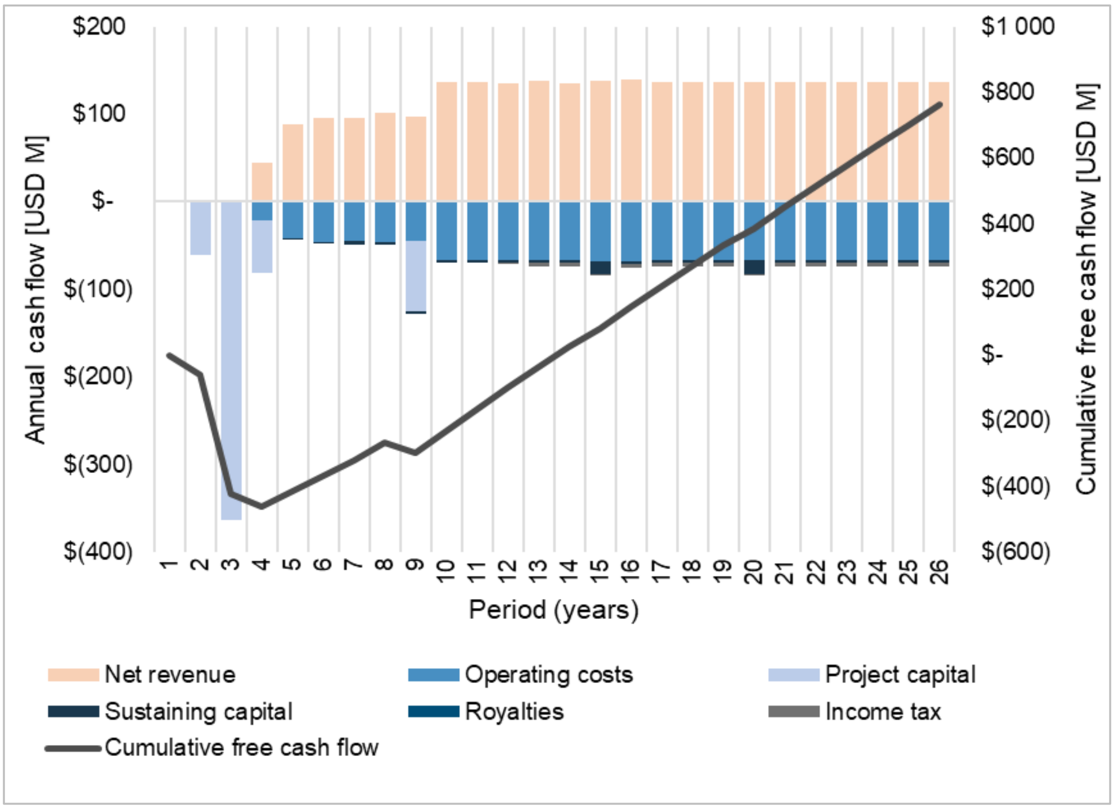
When a reduced timeline of 15 years is evaluated, to prevent the consideration of inferred resources, the $NPV_{7.7\%}$ lowers to US$ (88 M) with a corresponding IRR of 4.5% being lower than the discount rate of 7.7%.



Other options selected: Real | 7.7% discount | Pyro | Electricity + Coal | Orapa | Shortest Off-take Distance | Trucking | With External Capex | Baseline Tax | No transport management

Figure 4-5: Cash Flow Analysis for the 450 ktpa Pyro Facility scenario at Orapa

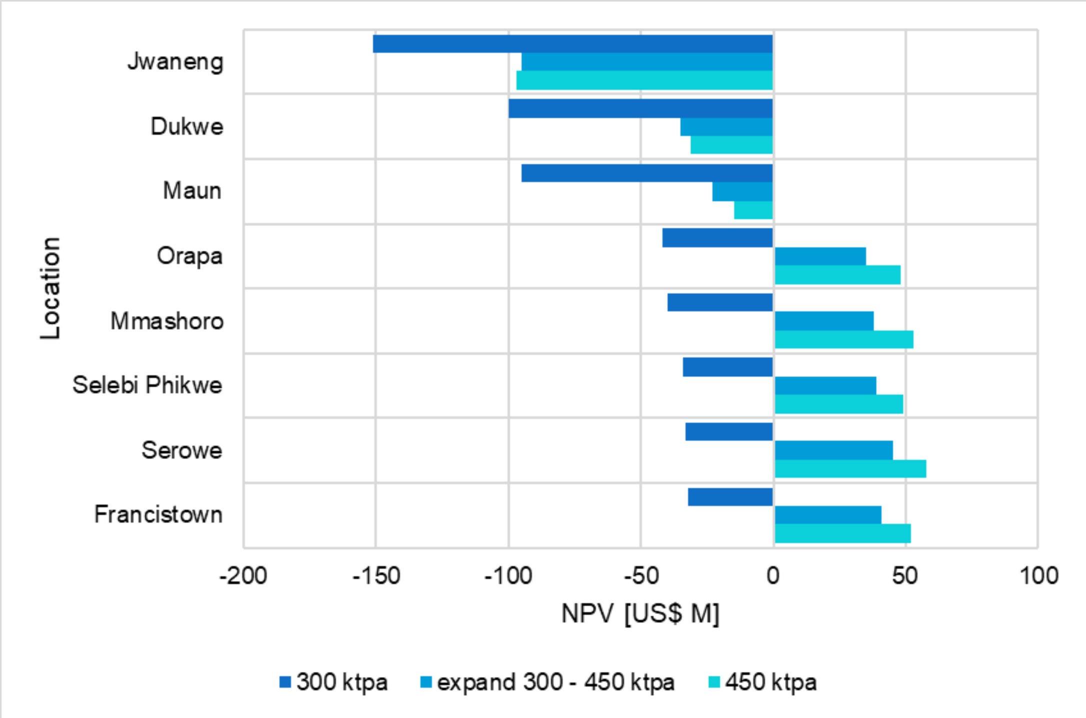
It is noted that concentrate supply of 450 ktpa is not possible in the short term and that building a 450 ktpa facility exposes the facility to concentrate supply risk. A more realistic approach would be to design a 300 ktpa facility that has the capability to expand to 450 ktpa after 5 years of operation. This facility could stimulate the market and potentially attract more miners to the KCB or Botswanan region. While 5 years is not enough to break-even, it would generate early cash flows and reduce the max negative draw-down. Figure 4-6 presents the cash flow analysis for the 300 ktpa expand to 450 ktpa scenario. An operating cost margin of 52% is generated. The 450 ktpa facility generates a positive post-tax $NPV_{7.7\%}$ of US$ 35 M over 25 year facility life, with an IRR of 8.6% and a payback period of 11.6 years. The 10 month payback penalty translates into a max negative drawdown reduction from US$ (563 $M)_{450ktpa}$ to US$ (461 $M)_{expand}$.



Other options selected: Real | 7.7% discount | Pyro | Electricity + Coal | Orapa | Shortest Off-take Distance | Trucking | With External Capex | Baseline Tax | No transport management

Figure 4-6: Cash Flow Analysis for the 300 ktpa expand to 450 ktpa Pyro Facility scenario at Orapa

Figure 4-7 presents the economies of scale evaluation at the investigated locations, indicating that with all else being similar, that the same locations prove more probable when the facility's scale is increased.



Other options selected: Real | 7.7% discount | Pyro | Electricity + Coal | Shortest Off-take Distance | Trucking | Without External Capex | Baseline Tax | No transport management

Figure 4-7: Economies of scale and location NPV evaluation.

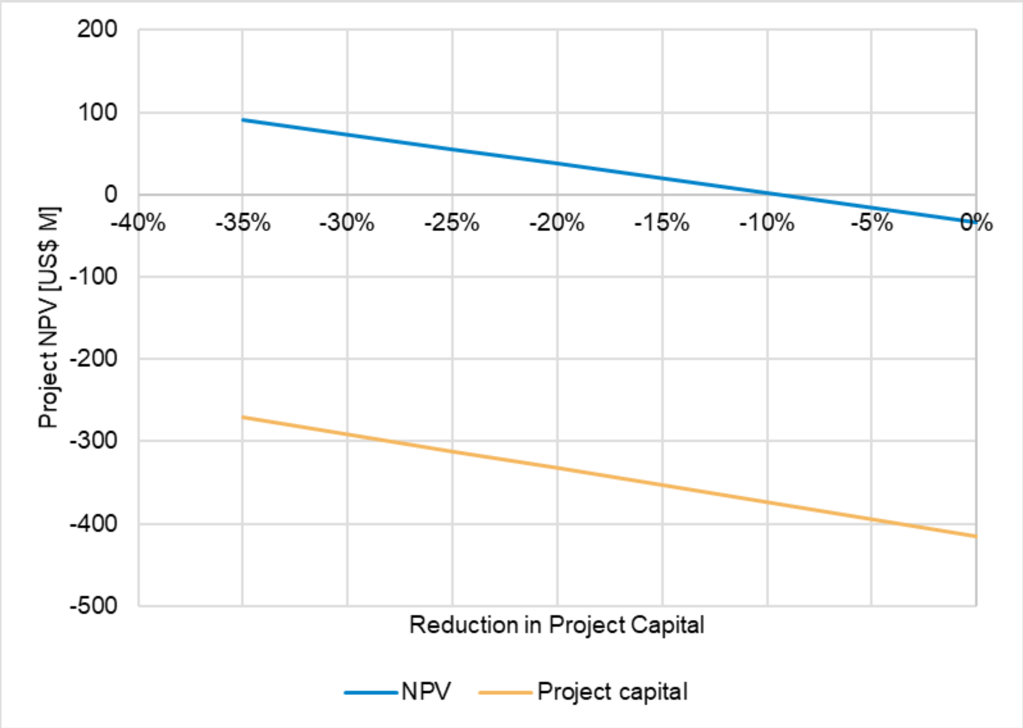
While the capacity expansion after five years scenario yields a lower NPV than the 450 ktpa facility at seven of the eight locations, the concentrate supply risk is mitigated. Should expansion however not commence, the facility would still be loss-making at all locations. This stresses that concentrate supply needs to be the primary negotiation to enable the new facility.

4.3.1 Selebi Phikwe BCL smelter reutilisation

The potential utilisation of infrastructure and services already available at the moth balled BCL smelter warrants further investigation. A separate scenario was developed to quantify by how much the initial capital cost for the new copper smelter needs to be reduced to enable the retrofitting of the BCL smelter.

Figure 4-8 presents the effect a reduction in project capital will have on the NPV of the project. The facility and its equipment would need to be purchased, but if the net project capital requirement turns out to be 15% less than what the model currently estimates at Selebi Phikwe, then BCL will generate a positive NPV. This translates into a capital reduction of US$ 63 M required. When considering an at-risk purchase of the BCL asset between US$ 18 M – US$ 33 M, a project capital reduction between US$ 81 M – US$ 99 M would be required to construct the 300 ktpa Pyro Facility at Selebi Phikwe.

It is worth noting that BCL facility purchase would also attract extensive environmental liability management to correct the sins of the past, which is not factored into the above evaluation.



Other options selected: Real | 300 ktpa | Pyro | Electricity + coal| Shortest Off-take Distance | Selebi Phikwe | With External Capex | Baseline Tax

Figure 4-8: Project capital sensitivity at Selebi Phikwe.

The BCL smelter needs considerable work, and this analysis is not an endorsement, pending serious engineering investigations. The existing flash furnace will be demolished and replaced with a TSL furnace, the aisle will be reconfigured to add the additional process modules needed towards primary copper refining and a new sulphur abatement plant would be required. Many existing BCL unit processes would be moth-balled, such as the NIRO/spray dryers, current waste heat boiler and electrostatic precipitators. The value would be generated from the surrounding infrastructure such as rail networks, workshops, metallurgical labs, etc.

The downside of repurposing BCL smelter is that the implicit cost to extract the remaining Ni-Cu resources and reserves of BCL would increase, as no down-stream off-take would be possible any longer. It is therefore not recommended to repurpose BCL smelter towards copper concentrate smelting. The new smelter is on a smaller scale and will only employ about a tenth of the employees previously employed by BCL – signalling that the KCB cannot revive Selebi Phikwe back to its glory days.

While Ni-Cu smelting cannot be done in a primary copper smelter, Cu concentrates can be added to Ni-Cu ores to enrich their Bessemer matte product. The downside of this approach is that copper is not refined to LME grade, but rather to an upgraded intermediate (the Bessemer matte), which needs down-stream refining.

Therefore if 900 ktpa capacity BCL smelter can manage to resume operations and start-up, it can add smelt the copper ores. Studies that evaluated this opportunity, linked to the liquidation procedure, concluded that the copper concentrate volumes were insufficient.

4.4 Energy source: utilisation potential of CBM

The direct utilisation of coal bed methane (CBM) in the pyrometallurgical process would increase the thermal efficiency of the process and reduce the total power requirements. Furthermore, an on-site CBM power plant would secure energy in remote areas of Botswana and de-risk the project. Botswana's power mix is primarily composed of electricity generated from coal and natural gas. According to data from the International Renewable Energy Agency (IRENA), in 2018, coal accounted for around 77% of Botswana's total electricity generation, while natural gas accounted for about 23% (International Renewable Energy Agency, 2022). There is also a small amount of electricity generated from renewable sources, such as solar and biomass.

The project scenarios are built with either CBM or electricity as the primary energy source at the respective locations, provided in Table 4-1. Each location’s proximity to identified CBM reserves impacts the length of a CBM pipeline, and resultantly the project capital required at the location. The remaining electricity requirements are generated via an integrated CBM power station, for which the capital cost is also included per location.

The electricity energy scenario assumes that electricity is readily available from the grid and applies the general Botswana Power Corporation (BPC) grid electricity tariff, without further deliberation.

The Pyro facility gains a lot of synergy from the CBM energy source which results in a more favourable NPV for the project should a Pyrometallurgical facility be powered by CBM. While no 300 ktpa Pyro facility becomes NPV positive, a tangible benefit of US$ 8 M (on average) is achieved for the 300 ktpa and respectively a larger, US$ 10 M benefit (on average) is achieved for the 300-450ktpa expand facility.

Table 4-1: Energy source comparison per location in NPV (Pyro).

Location **Option** [US$ M]	**Jwaneng**	**Dukwe**	**Maun**	**Orapa**	**Mmashoro**	**Selebi Phikwe**	**Serowe**	**Francistown**
300 ktpa Electricity	(151)	(100)	(95)	(42)	(40)	(34)	(33)	**(32)**
300 ktpa CBM	(141)	(92)	(87)	(34)	(33)	(27)	**(25)**	**(25)**
CBM benefit	**10**	8	8	8	7	7	8	7
300-450 ktpa expand Electricity	(95)	(35)	(23)	35	38	39	**45**	41
300-450 ktpa expand CBM	(84)	(25)	(14)	45	48	49	**54**	51
CBM benefit	**11**	10	9	10	10	10	9	10

Other options selected: Real | Pyro | Shortest Off-take Distance | Electricity + Coal | With External Capex | Baseline Tax

The Hydro facility process is more heavily reliant on electricity as energy source. Only minor process equipment and steam generation can be directly achieved via CBM. The overall lower power requirements for a hydro facility makes the CBM synergy less attractive with a hydro facility.

The direct utilisation of CBM proposed does not consider the electricity grid requirements of Botswana. Botswana generates the bulk of its electricity from the Morupule coal power plant and the Orapa diesel power plants, and are net importers or electricity from surrounding countries, including South Africa. The power requirements of the new copper facility might strain the national grid and when the power issues of South Africa are considered, it may regardless be needed to expend capital on new power generation in Botswana.

4.5 Logistics optimisation

The logistical benefits of in-country beneficiation are quantified, followed by additional optimisation potential should rail networks be utilised to transport finished products to port.

In order to sufficiently evaluate the logistical benefits, the core model was expanded to include both the transport costs from the mine to the new facility, as well as the product logistical costs from the facility to the closest port. As waste is removed at the processing facility, the volumes transported to port are only about 25-30% of the copper concentrate weights miners would've conventionally exported. Additional to road logistics, freight costs of the respective miners would decrease. Up to this level in the Results Section, only product logistics were modelled.

Typically, the miner would be responsible for their concentrate transport costs to either i) ports for export or ii) to the new facility. To allow the benefit of a shortened logistical route, the model includes full transport costs and charges the miner a Transport Premium. The modelled Transport Premium is zero-sum, neither the miner nor the processing facility benefits unduly. The total cost of miners' logistics and freight is replaced by the Transport premium and the processing facility increases its scope to handle all logistics from mine gate. There is no negative impact to the host mines' NPV projects or cash flow. Depending on exact commercial agreements agreed upon, it can be argued that host mines would be able to mine cheaper with an in-country off-taker and in fact, their off-take logistics would decrease substantially.

The baseline assumes that only trucking is applied for product transport, however, if the existing rail infrastructure can be utilised, as observed from data in

Table 4-2. Note that the baseline values per location increases due to inclusion of the logistical benefit to the new processing facility. A portion of this revenue is realisable as the shortened logistical routes will also benefit the in-country miner.

The overall synergy of in-country beneficiation towards logistics is clear. Many of the locations that were not viable on a 300 ktpa scale has become financially attractive. Of all locations, Maun, being the closest to most of the mines, delivers the most attractive location from a financial valuation perspective, despite the high external developmental capital requirements.

The incorporation of rail networks for off-take logistics indicates further financial attractiveness. This is, of course, predicated on the assumption that all rail infrastructure is available and suitable for the duty required.

Table 4-2: Logistic valuation summary expressed in NPV.

Location Option [US$ M]	**Jwaneng**	**Dukwe**	**Maun**	**Orapa**	**Mmashoro**	**Selebi Phikwe**	**Serowe**	**Francistown**
300 ktpa Baseline	(151)	(100)	(95)	(42)	(40)	(34)	(33)	**(32)**
300 ktpa Trucking*	(45)	(6)	**88**	57	47	26	45	48
In-country logistics benefit	106	94	**183**	99	87	60	78	80
300 ktpa Rail + Truck balance*	2	60	**125**	83	105	82	102	113
Rail benefit	47	66	**213**	140	152	108	147	161
300-450 ktpa expand Baseline	(95)	(35)	(23)	35	38	39	**45**	41
300-450 ktpa expand Trucking*	44	94	**217**	170	158	124	151	152
In-country logistics benefit	139	129	**240**	135	120	85	106	111
300-450 ktpa expand Rail + Truck balance*	101	174	**262**	201	228	191	219	230
Rail benefit	145	268	**479**	371	386	315	370	382

Other options selected: Real | Pyro | Electricity + Coal | Shortest distance to port | With External Capex | Baseline Tax | * - transport premium applied.

An upside opportunity that was not evaluated include if products were sold in Botswana or South Africa, which would shorten logistical routes further at most locations, and it warrants further investigation in future work. Copper intermediaries such as Copalcor or Thos Begbie in South Africa may be attractive buyers of copper. Palabora Mining Company also produces their own copper semi-finished goods, but with limited information on these markets, these options need to be investigated further.

4.6 Technology evaluation

The Pyrometallurgical facility is more expensive to construct, employs more people and requires more power to operate, but it benefits from the extensive usage of coal bed methane resources, and it achieves higher and more reliable recoveries than the Hydro facility. The pyro process is also well understood and well proven, whereas a custom, new hydrometallurgical flow sheet will be required to process the ore mix. The developmental and piloting phase for a hydro facility would take longer than a run-of-the-mill pyro process.

Table 4-3 presents a summary of NPVs generated when either Pyro or Hydro plants are built at locations. While viable cases for both Pyro and Hydro can be built, the financial upside of Hydro is more appealing. The upside of the Hydro process does not quantify the underlying risks associated with the technology – metallurgical recoveries may not be achieved, and the development timeframe is not quantified. A smaller scale hydro facility can be marginally profitable, without many interventions required when constructed at either Selebi Phikwe or Francistown.

Table 4-3: Technology selection summary, expressed in NPV.

Location **Option** [US$ M]	**Jwaneng**	**Dukwe**	**Maun**	**Orapa**	**Mmashoro**	**Selebi Phikwe**	**Serowe**	**Francistown**
300 ktpa Pyro + CBM	(141)	(92)	(87)	(34)	(33)	(27)	**(25)**	**(25)**
300 ktpa Pyro + electricity	(151)	(100)	(95)	(42)	(40)	(34)	(33)	**(32)**
300 ktpa Hydro + CBM	(72)	(70)	(98)	(59)	(64)	**(33)**	(50)	**(33)**
300 ktpa Hydro + electricity	(30)	(28)	(56)	(17)	(22)	**9**	(8)	**9**
300-450 ktpa expand Pyro + CBM	(84)	(25)	(14)	45	48	49	**54**	51
300-450 ktpa expand Pyro + electricity	(95)	(35)	(23)	35	38	39	**45**	41
300-450 ktpa expand Hydro + CBM	25	28	1	39	35	**65**	49	**65**
300-450 ktpa expand Hydro + electricity	80	83	56	95	90	**121**	104	**121**

Other options selected: Real | Shortest distance to port | With External Capex | Baseline Tax | Logistics excluded

4.7 External developmental capital

As stated in Section 3, the target locations scoped were mostly underdeveloped and required additional capital to provide housing and water requirements. The Botswanan government may opt to assist with the underlying development of the associated location. Table 4-4 resents the impact on NPV per location should the external development capital be excluded from the smelter scope.

Table 4-4: Effect of external developmental capital on NPV.

Location Option [US$ M]	Jwaneng	Dukwe	Maun	Orapa	Mmashoro	Selebi Phikwe	Serowe	Francistown
300 ktpa Pyro + external capex	(151)	(100)	(95)	(42)	(40)	(34)	(33)	(32)
300 ktpa Pyro + without external capex	(125)	(69)	(41)	(16)	(7)	(32)	(14)	(30)
Benefit	26	31	**54**	26	33	2	19	2

Other options selected: Real \| Shortest distance to port \| Baseline Tax \| Logistics excluded

The direct reduction of up-front capital not only benefits the NPV, but also has a pronounced effect on the payback periods, as shown in Table 4-5. Maun's payback period would decrease by a year and six months if the government assists with external capital.

Table 4-5: Effect of external developmental capital on payback period.

Location Option [years & months]	Jwaneng	Dukwe	Maun	Orapa	Mmashoro	Selebi Phikwe	Serowe	Francistown
300 ktpa Pyro + external capex	18 years & 5 months	15 years & 3 months	14 years & 7 months	13 years & 0 months	12 years & 7 months	12 years & 6 months	12 years & 5 months	12 years & 5 months
300 ktpa Pyro + without external capex	17 years & 2 months	14 years & 3 months	13 years & 1 month	12 years & 1 month	11 years & 6 months	12 years & 5 months	12 years	12 years & 4 months
Benefit	1 year & 3 months	1 year & 1 month	**1 year & 6 months**	8 months	1 year & 1 month	1 month	5 months	1 month

4.8 Tax incentive evaluation

Tax incentives will be required to deliver a favourable return and justify the investment. It may be used as levers to attract foreign direct investment. Duty free imports, special economic tax treatment and a novel concept, royalty diversion are discussed.

4.8.1 Duty free imports

If the government opts to waive duties on imported equipment outlined for project capital during project inception, all locations' NPV increases by a substantial US$ 43 M for the 300 ktpa facility size and increases to a US$ 52 M benefit with the 300 to 450 ktpa expand scenario.

4.8.2 Special Economic Zone tax treatment

The government may want to designate a special economic zone, or existing economic zones may be targeted at Francistown or Selebi Phikwe. The high capital outlay generates unredeemed capital losses up to the project payback period is achieved. The special economic zone decreases corporate income tax from 15% to 5% and extends the expiration of unredeemed capital losses by 10 years or longer.

As observed from Table 4-6, Special Economic Zone tax benefits do not present very attractive scenarios with marginal tax benefits when compared to other options listed above. The designation of a Special Economic Zone tax regime or to migrate the project to an existing SEZ would be low on the new facility's priority list.

Table 4-6: Effect of Special Economic Zone tax treatment on NPV.

Location Option [US$ M]	**Jwaneng**	**Dukwe**	**Maun**	**Orapa**	**Mmashoro**	**Selebi Phikwe**	**Serowe**	**Francistown**
300 ktpa Pyro + manuf. tax	(151)	(100)	(95)	(42)	(40)	(34)	(33)	(32)
300 ktpa Pyro + SEZ tax	(151)	(100)	(92)	(37)	(35)	(31)	(28)	(29)
Benefit	-	-	3	**5**	**5**	3	**5**	3
300-450 ktpa expand Pyro + manuf. tax	(95)	(35)	(23)	35	38	39	45	41
300-450 ktpa expand Pyro + SEZ tax	(94)	(30)	(16)	46	50	48	55	50
Benefit	1	5	7	11	**12**	9	10	9

Other options selected: Real | Electricity + Coal | Shortest Off-take Distance | External capex included | No transport management

4.8.3 Royalty diversion

A novel concept is explored to divert 1% of mineral royalties of copper and silver as a cash flow stream to the new copper facility, with its effect shown in Figure 4-7. The miner still pays its royalty, and the government would funnel the royalty into the new facility.

Table 4-7: Royalty diversion impact on project NPV.

Location Option [US$ M]	**Jwaneng**	**Dukwe**	**Maun**	**Orapa**	**Mmashoro**	**Selebi Phikwe**	**Serowe**	**Francistown**
300 ktpa Pyro baseline	(151)	(100)	(95)	(42)	(40)	(34)	(33)	(32)
300 ktpa Pyro with royalty diversion	(65)	(14)	(9)	44	45	52	53	**54**

Location Option [US$ M]	Jwaneng	Dukwe	Maun	Orapa	Mmashoro	Selebi Phikwe	Serowe	Francistown
Benefit	86	86	86	86	85	86	86	86
300-450 ktpa expand Pyro baseline	(95)	(35)	(23)	35	38	39	**45**	41
300-450 ktpa expand Pyro royalty diversion	10	70	82	140	143	144	**150**	147
Benefit	105	105	105	105	105	105	105	106

Other options selected: Real | Electricity + Coal | Shortest Off-take Distance | With External Capex | Baseline Tax | No transport management

This arrangement and its benefit to the facility could be used to negotiate an equity stake in the company, with the approximate value depending on specific scenarios selected. The following equation quantifies the potential equity stake value to the government to compensate its royalty diversion directly to the mine:

$$\%\ Equity\ stake = \frac{\Delta\ NPV\ Benefit\ [USD]}{Project\ capex\ [USD] + NPV}$$

It would roughly translate into a 16% - 21% equity stake value, as shown per location in Table 4-8.

Table 4-8: Government attributable equity stake to compensate for the equity benefit.

Location Option [Equity stake]	Jwaneng	Dukwe	Maun	Orapa	Mmashoro	Selebi Phikwe	Serowe	Francistown
300 ktpa Pyro with royalty diversion	18%	18%	18%	18%	18%	18%	18%	18%
300-450 ktpa expand Pyro royalty diversion	**21%**	18%	18%	16%	16%	16%	16%	16%

4.9 Scenario development

The individual optimisation opportunities presented in isolation are taken further in this Section to develop four scenarios:

1. A pyrometallurgical facility at Orapa
2. A pyrometallurgical facility at Serowe
3. A pyrometallurgical facility at Maun
4. A hydrometallurgical facility at Francistown

Figure 4-9 to Figure 4-12 presents the corresponding value attribution waterfall diagrams for the four scenarios outlined above. The value attribution waterfall calculates the new facility NPV once a change has been enacted in series. The benefits interact with each other, and the order applied from left to right on the graph impacts the resulting incremental NPV calculated. Therefore, NPV values presented would not necessarily correspond to the cases as they are presented in isolation between Sections 4.1 to 4.8. The scenarios developed are the best-case scenarios, obtained through data analysis of the model outputs. The scenarios' full cash flows are presented in the Appendix.

Scenario 1 at Orapa benefits most from i) the royalty diversion incentive (US$ 105 M), ii) a possible expansion to 450 ktpa (US$ 77 M) and iii) the attribution of 50% of the transport premium benefit (US$ 68 M) to generate an all-inclusive $NPV_{7.7\%}$ of US$ 358 M. Scenario 1 generates an IRR of 17.7%, with a payback period of 7.5 years. Conversely, if the life of operation is shortened to 15 years, an NPV of US$ 188 M is generated, with a corresponding IRR of 14.9%.

Scenario 2 at Serowe benefits most from i) the royalty diversion incentive (US$ 106 M), ii) a possible expansion to 450 ktpa (US$ 78 M) and iii) the usage of rail infrastructure (US$ 69 M) to generate an all-inclusive NPV of US$ 385 M. Scenario 2 generates an IRR of 18.0%, also with a payback period of 7 years and 5 months. Conversely, if the life of operation is shortened to 15 years, an NPV of US$ 197 M is generated, with a corresponding IRR of 15.2%.

Scenario 3 at Maun benefits most from i) the 50% transport premium incentive (US$ 120 M), ii) the royalty incentive (US$ 105 M) and iii) a possible capacity expansion to 450 ktpa (US$ 75 M) to generate an all-inclusive NPV of US$ 402 M. Scenario 3 generates an IRR of 19.7%, with a payback period of 7 years and 2 months. Conversely, if the life of operation is shortened to 15 years, an NPV of US$ 256 M is generated, with a corresponding IRR of 17.2%.

Scenario 4 at Francistown benefits most from i) the royalty diversion incentive (US$ 112 M), ii) the royalty incentive (US$ 103 M) and iii) the usage of rail infrastructure (US$ 77 M) to generate an all-inclusive NPV of US$ 422 M. Scenario 4 generates an IRR of 23.1%, with a payback period of 5 years and 5 months. Conversely, if the life of operation is shortened to 15 years, an NPV of US$ 263 M is generated, with a corresponding IRR of 21.1%.

The incremental NPVs are tabulated in Table 4-9 for direct comparison between scenarios. While it is not expected that all options would be technically achieved at each location, a combination of options and priorities for government and the developing entity is clear from the valuation results.

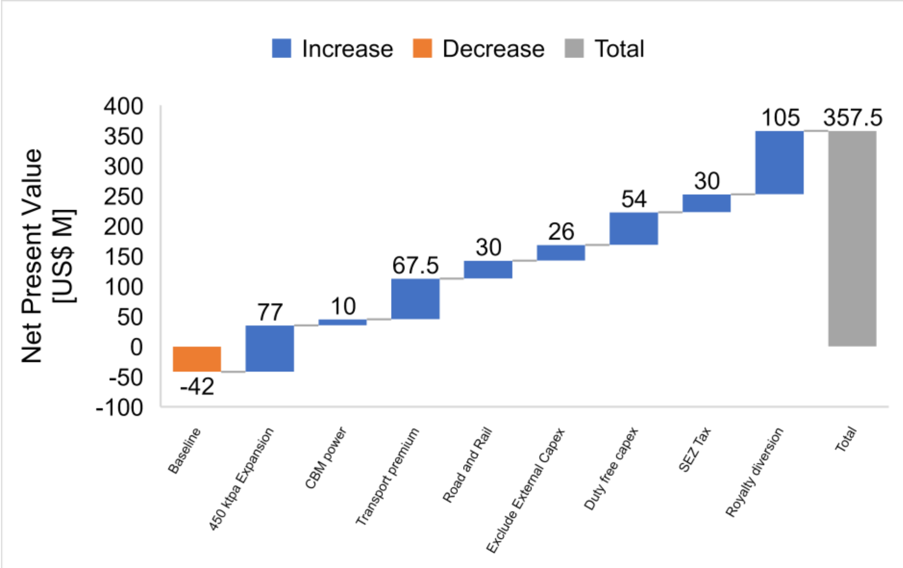


Figure 4-9: Scenario 1: Value attribution waterfall for a 300 ktpa, Pyro facility at Orapa.

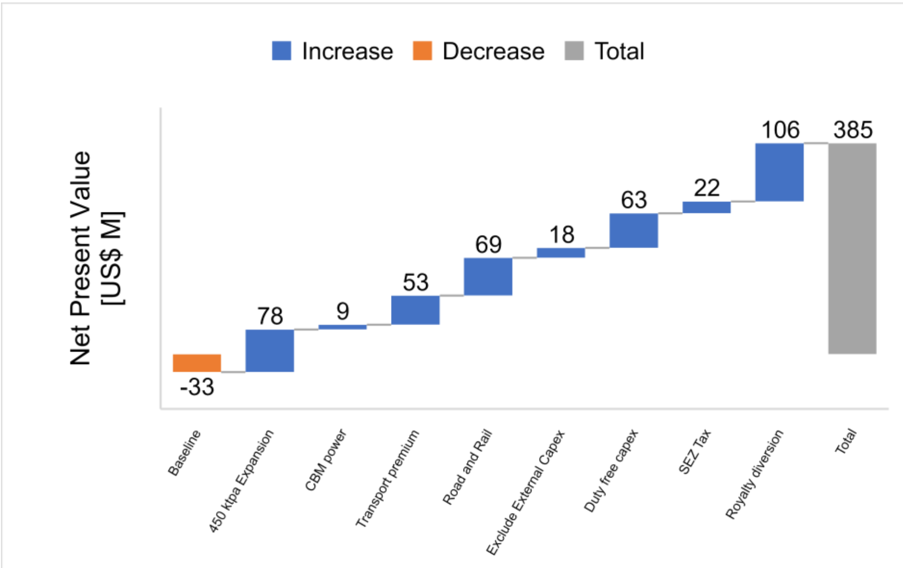


Figure 4-10: Scenario 2: Value attribution waterfall for a 300 ktpa, Pyro facility at Serowe.

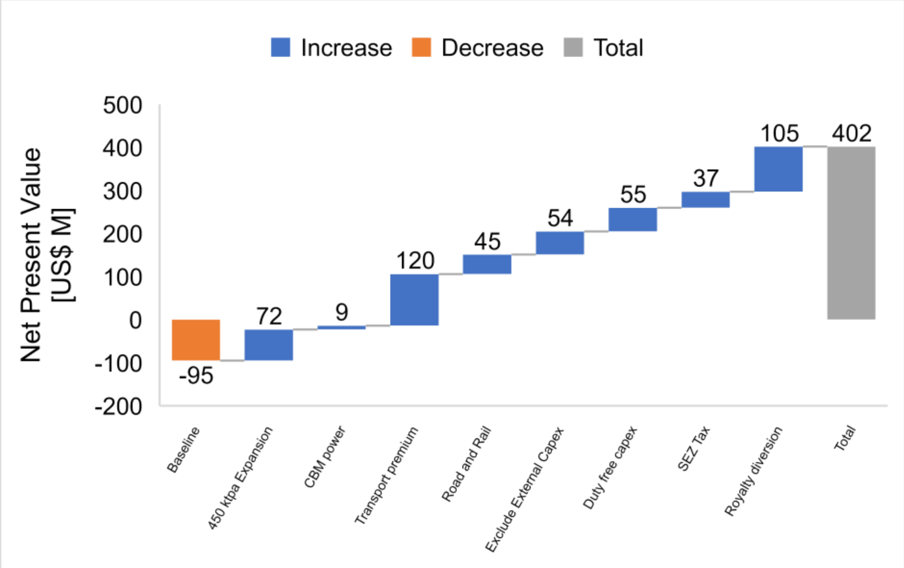


Figure 4-11: Scenario 3: Value attribution waterfall for a 300 ktpa, Pyro facility at Maun.

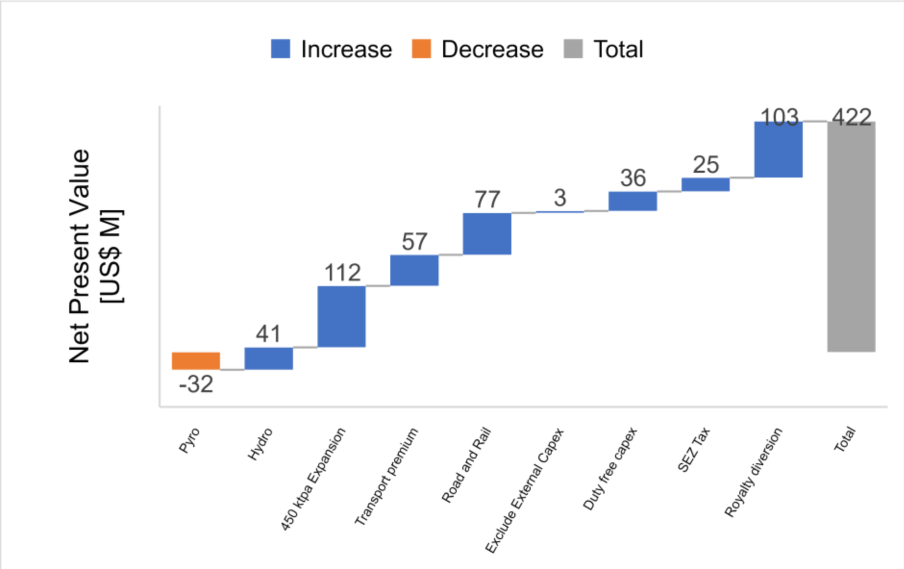


Figure 4-12: Scenario 4: Value attribution waterfall for a 300 ktpa, Hydro facility at Francistown.

Table 4-9: Incremental NPV per option selected.

Option	Orapa Pyro	Serowe Pyro	Maun Pyro	Francistown Hydro
Incremental	[US$ M]	[US$ M]	[US$ M]	[US$ M]
Baseline 300ktpa Pyro	(42)	(33)	(95)	(32)
Hydro	-	-	-	+41
300-450 ktpa expand	+77	+78	+72	+112
CBM power	+10	+9	+9	-

Option	Orapa Pyro	Serowe Pyro	Maun Pyro	Francistown Hydro
50% transport premium	+68	+53	+120	+57
Road and rail	+30	+69	+45	+77
Exclude external capex	+26	+18	+54	+3
Duty free capex	+54	+63	+55	+36
SEZ tax	+30	+22	+37	+25
Royalty diversion	+105	+106	+105	+103
Total NPV	**358**	**385**	**402**	**422**
Capital efficiency	**0.68**	**0.92**	**0.72**	**0.85**

While the NPV approach suggests that Scenario 4 generates the most value, the capital efficiency, considering the NPV over project capital suggests that Scenario 2 should be pursued instead.

4.10 Value as perceived from government

Figure 4-13 presents the undiscounted value added of the operation over its life of 25 years for a 300 ktpa facility that expands to 450 ktpa located at Maun (Scenario 3), totalling US$ 3.6 B. Over and above corporate tax of US$ 161 M, the Botswanan government benefits from dividend withholding tax of US$ 115 M and employees' personal income tax of US$ 52 M. Furthermore, it is estimated that US$ 210 M in operational costs would be locally procured and liable to value added tax amounting to US$ 29 M.

The combined cash flows from this calculation indicate that the value owed to government equals 10.1% of the total project value. According to Standard and Poor's Capital IQ platform (2023), Botswana had a gross domestic product of US$ 18.1 B in 2022. When superimposing Scenario 3's computed NPV of US$ 402 M over the GDP, the Botswana copper processing facility would contribute an additional 2.2% to Botswana's economy when executed. If considered per capita, each citizen of Botswana (with a 2.3 million people population) benefits by US$ 175 per capita. At the date of writing, this translates to ~BWP 2,230 per capita.

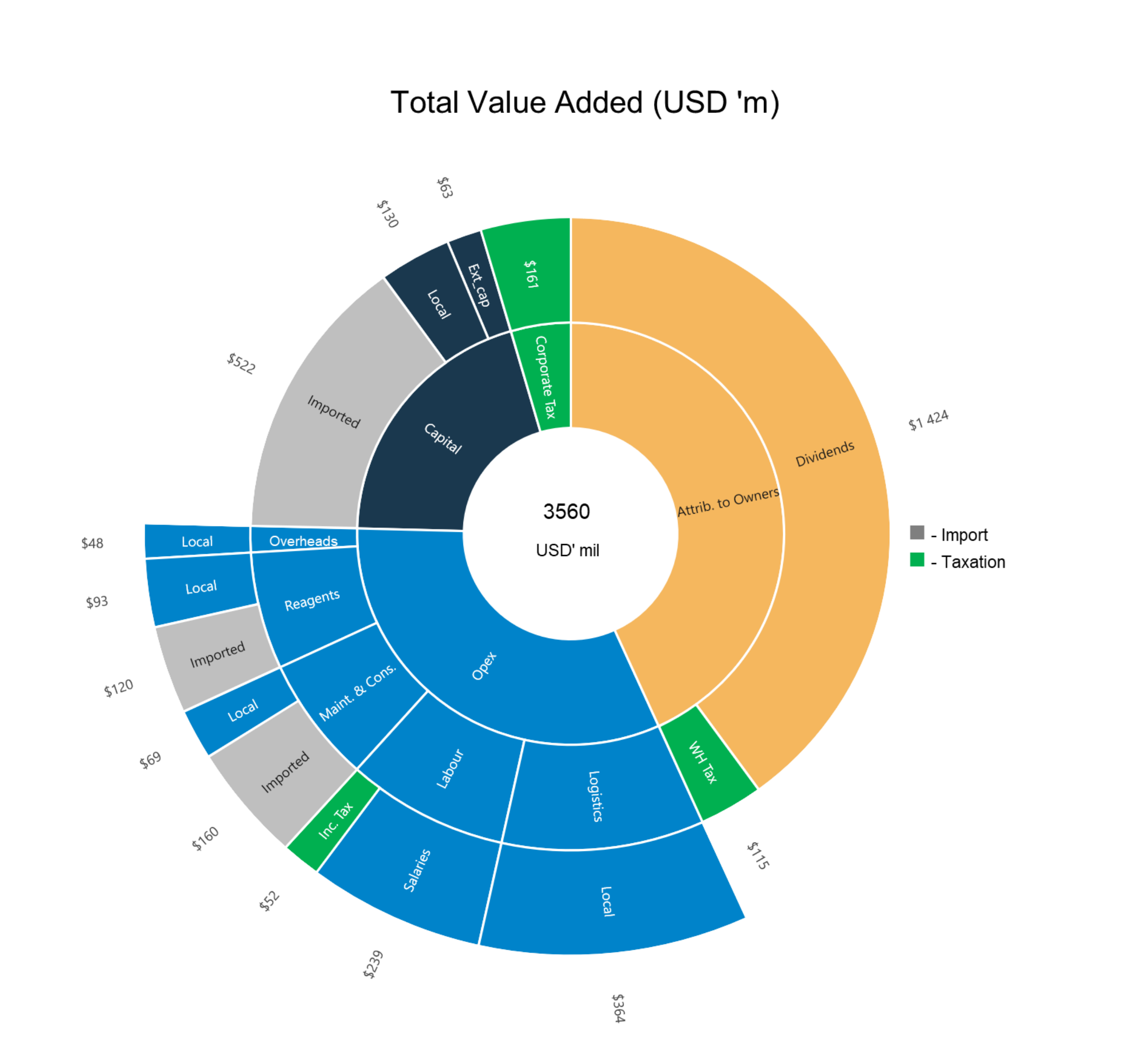


Figure 4-13: Total undiscounted value added over life of operation for Scenario 3 with baseline tax.

4.11 Project finance considerations

The capital budgeting case is presented in preceding sections, consideration now shifts to project finance. The presented WACC assumed a private owner contributed 100% of the equity. Earlier chapters eluded that the royalty incentive could be used to negotiate a government stake of ~15-20% of the business. The other option government needs to consider is that their risk free rate is lower than that of a company, as they are only liable to service their bond notes. As the market risk premium would not apply, the real discount rate may be as low as 3% for the government.

Figure 4-14 presents the sensitivity on the NPV at Scenario 3 with variable discount rates. As to be expected, with increasing applied discount rates, the project NPV erodes correspondingly. Table 4-10 indicates the impact on the discount rate with the inclusion of debt. A combination of the equity:debt structure, and the portion of government equity could optimise the project finance decisions applied.

The selection of an appropriate structure is highly time dependant and were impacted by the interest rate fluctuations during the Covid pandemic, as performed in July 2022.

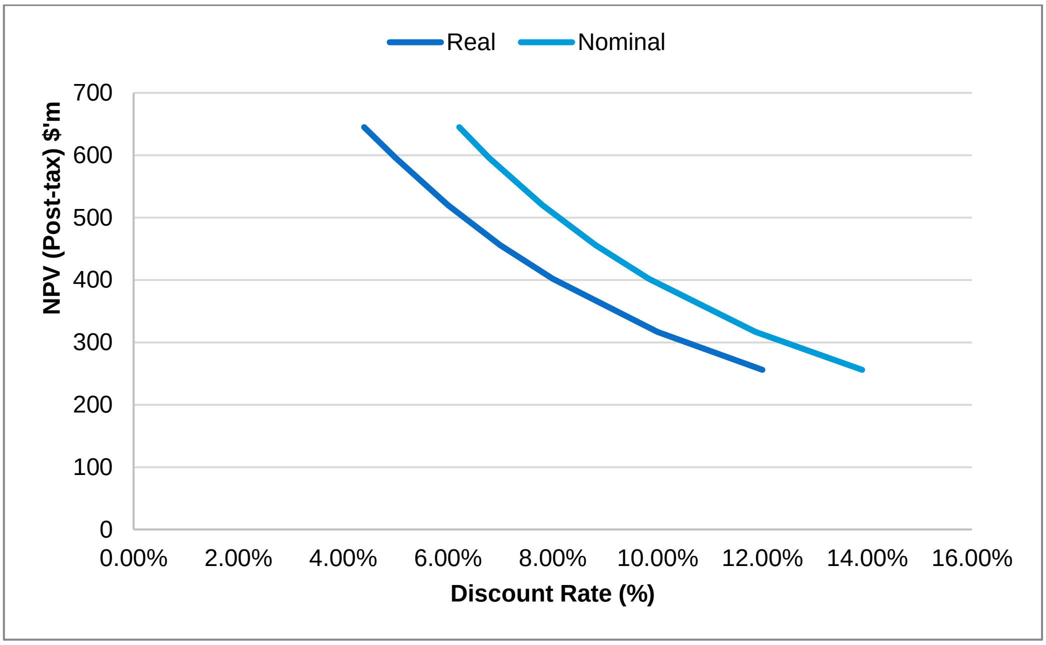


Figure 4-14: Sensitivity of NPV towards the applied discount rate for the optimised 300 ktpa base case.

Table 4-10: Effect of equity weighting on project discount rate.

Option	Discount rate (Real)	Discount rate (Nominal)
35% equity	3.25%	10.49%
50% equity	4.74%	12.09%
75% equity	6.22%	13.68%
100% equity	7.71%	15.28%

5. Conclusion

This study developed financially viable scenarios that enable the down-stream beneficiation or processing of copper concentrates in Botswana from Southern African concentrate sources that are currently destined for export. This facility can possibly contribute around 1% of additional gross domestic product in Botswana.

The best estimate projections of future copper concentrate supply in Botswana can only justify a 300 ktpa Cu-Ag processing facility in the short to medium term. Should miners' future expansion plans realise, the expansion of the facility to a 450 ktpa facility could be viable. The economies of scale for a 450 ktpa facility allow better profitability, yet a good margin can be achieved with a 300 ktpa facility should upside opportunities be realisable. The results of ongoing exploration could firm up additional volumes of ore that could add incremental value to the project and reduce supply volume risk. It is therefore recommended to size the facility at 300 ktpa at inception and to allocate additional capital to allow expansion of the processing facility to 450 ktpa after five years from inception.

In terms of technology selection, the possible conditions that can be realised will determine which technology should be pursued. The Pyrometallurgical process flowsheet is robust and well understood, it employs more people, but requires more energy as either electricity or newly-developed coal bed methane gas, and requires a larger capital outlay. The Pyrometallurgical has many similar applications in Southern Africa, and its progression to higher levels of a lower technical risk. The favourable synergy of the pyrometallurgical facility with coal bed methane gas and the high expected copper recoveries allow for better profitability at a lower risk on the expended capital. The requirement for sulphur dioxide abatement and potential environmental impacts are well understood but would require additional process design and capital to achieve acceptable pollutant emissions within Botswana's air quality act.

The Hydrometallurgical flowsheet has the potential to yield more upside as the application of this technology requires a lower capital outlay and possesses a more modular design than a smelting flowsheet, but requires significant further developmental work from a metallurgical perspective to develop viable, customised flowsheet and prove that metallurgical recoveries and nameplate capacities can be achieved. While the specific proposed hydrometallurgical flowsheet employing sulphating roasting is a viable option, several alternatives might be considered to suit the mineralisation of the Kalahari Copper Belt. An engineering unknown is the level of gangue acid consuming minerals present in specific ore feedstocks, which is not publicly available. New leaching technologies, such as Glycine leaching or the potential synergy with the development of Activox in Botswana should be considered and tested prior to developing a full-scale hydrometallurgical facility. The hydrometallurgical facility would require more water, in some scenarios in water scarce or underdeveloped areas and would require electricity generation from coal bed methane gas, if this synergy is targeted.

Several location options were identified for this facility, and financially viable scenarios were developed for the regions of Orapa, Serowe, Maun and Francistown, depending on the realisable upside potential per location. Project logistics, comprising the concentrate transport from copper mines to the new processing facility and the transport and shipping of purified copper and silver from the processing facility to offshore markets, is the most important factor from a location perspective. Orapa, Serowe, Francistown and Maun ranked proportionately higher within the financial model at the time of valuation. Whilst Maun was the most favourable location from a financial assessment perspective, the close proximity to the environmentally sensitive Okavango Delta, the overall underdevelopment of the region and high anticipated development capital requirements infers that the Maun region requires significant further investigation should it be selected. Dukwe and Jwaneng were the least favourable location options and can safely be discarded from future investigations.

Based on the current assumptions, there are benefits to utilising the existing rail infrastructure in Botswana for the transportation of product to port. A potential synergy could be to repurpose BCL's rail fleet for this facility. The costs associated with the possible refurbishment of the rail network to this purpose has however not been quantified in this study.

The development of the rail infrastructure and providing support for water and housing infrastructure should be prioritised by the Botswana Government. These initiatives provide economic opportunities in Botswana and may stimulate further exploration and development of Botswana's economically significant, but under-explored Kalahari Copper Belt reserves.

Tax incentives from the government are recommended to stimulate foreign direct investment. Viable government incentives such as i) granting special economic zone status, or more relevant ii) to divert 1% of the mineral royalties payable by miners to the government to this new facility in exchange for a proportionate minority equity state. A phasing approach, where this royalty diversion to the facility is limited to the payback period of the new facility, could also be considered.

Four viable scenarios for in-country beneficiation were developed where the $NPV_{7.7\%,real\ 2022}$ of a new copper processing facility could range between US$ 358 – 422 million. Furthermore, the total value generated by the facility, undiscounted over life of operation, was estimated to be US$3.6 billion. 10.1% of the total project value generated would be recovered by the Botswanan government through corporate tax, dividend withholding tax, personal income tax and value added tax. The value added to the Botswanan economy would contribute an additional 2.2% to Botswana's gross domestic product.

The total value generated towards nation building was calculated to be at least three times larger than the profit generated by the facility owners. Copper is a strategically important metal to transition the world away from fossil fuels and is anticipated to reduce the global carbon footprint. Further opportunities such as the manufacturing of intermediate or end-use copper products have not been explored but would be stimulated and be more financially attractive to local investors and entrepreneurs if in-country copper production is achieved. End-use copper product manufacturing may allow Botswana to produce strategically important components to develop Botswana's industry and position it to participate in the fourth industrial revolution and the green energy transition.

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7. Appendix: DCF analysis outputs

7.1 Baseline Orapa Cash Flow

Description	Total (USD '000)	1	2	3	4	5	6	7	8	9	10	11	12	13
Physicals														
Concentrate tonnage (ktpa)		-	-	-	141	277	300	300	300	300	300	300	300	300
Cu metal grade (%)		0%	42%	42%	35%	37%	36%	36%	38%	36%	35%	36%	36%	36%
Ag metal grade (g/t)		-	-	-	311	352	320	364	420	376	370	378	357	262
Sulphur grade (%)		0%	0%	0%	26%	24%	24%	24%	22%	22%	23%	21%	20%	23%
Cash Flow														
Copper Price (US$/t)		6,107	8,996	8,382	7,535	7,885	7,966	8,417	9,414	8,752	8,752	8,752	8,752	8,752
Silver Price (US$/kg)		658	797	689	644	652	654	650	727	727	727	727	727	727
Sulphuric Acid (US$/t)		86	86	347	360	360	360	360	360	360	360	360	360	360
Total Commodity Value														
Copper Sales, Metal Value	**20,742,575**	-	-	-	370,622	788,959	850,328	896,475	1,046,264	932,983	904,125	931,703	937,168	936,101
Silver Sales, Metal Value	**1,601,821**	-	-	-	27,399	61,534	60,723	68,661	88,537	79,233	78,074	79,690	75,347	55,216
Sulhpuric Acid Sales, Value	**417,037**	-	-	-	9,934	18,234	20,171	19,611	18,380	18,342	18,966	16,992	16,454	18,676
Facility Revenue														
Free Metal Recovery Cu	**349,403**	-	-	-	6,243	13,290	14,324	15,101	17,624	15,716	15,230	15,694	15,786	15,768
Free Metal Recovery Ag	**106,477**	-	-	-	1,821	4,090	4,036	4,564	5,885	5,267	5,190	5,297	5,008	3,670
Free Com. Recovery H2SO4	**417,037**	-	-	-	9,934	18,234	20,171	19,611	18,380	18,342	18,966	16,992	16,454	18,676
Transport Premium	**-**	-	-	-	-	-	-	-	-	-	-	-	-	-
Copper Treatment Charge Income	**604,663**	-	-	-	12,723	24,940	27,000	27,000	27,000	27,000	27,000	27,000	27,000	27,000
Copper Refining Charge Income	**429,672**	-	-	-	8,835	17,974	19,174	19,133	19,965	19,148	18,556	19,122	19,234	19,212
Copper Minimum Deduction	**-**	-	-	-	-	-	-	-	-	-	-	-	-	-
Silver Refining Charge Income	**28,807**	-	-	-	548	1,215	1,196	1,359	1,567	1,402	1,382	1,411	1,334	977
Silver Minimum Deduction	**144,247**	-	-	-	2,730	5,421	5,884	5,852	6,545	6,545	6,545	6,545	6,545	6,545
Penalty Credits	**910**	-	-	-	40	40	40	40	40	40	40	40	40	40
Cathode premium	**-**	-	-	-	-	-	-	-	-	-	-	-	-	-
Royalty deferral	**-**	-	-	-	-	-	-	-	-	-	-	-	-	-
Net Revenue	**2,081,216**	**-**	**-**	**-**	**42,874**	**85,203**	**91,824**	**92,659**	**97,006**	**93,461**	**92,909**	**92,101**	**91,401**	**91,890**
Operating Costs														
Power	**(478,107)**	-	-	-	(10,060)	(19,720)	(21,349)	(21,349)	(21,349)	(21,349)	(21,349)	(21,349)	(21,349)	(21,349)
Reagents	**(154,615)**	-	-	-	(3,253)	(6,377)	(6,904)	(6,904)	(6,904)	(6,904)	(6,904)	(6,904)	(6,904)	(6,904)
Maintenance and consumables	**(176,509)**	-	-	-	(3,629)	(7,384)	(7,876)	(7,860)	(8,202)	(7,867)	(7,623)	(7,856)	(7,902)	(7,891)
Labour	**(258,244)**	-	-	-	(5,434)	(10,652)	(11,531)	(11,531)	(11,531)	(11,531)	(11,531)	(11,531)	(11,531)	(11,531)
Logistics	**-**	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Opex	**(1,067,476)**	**-**	**-**	**-**	**(22,376)**	**(44,132)**	**(47,661)**	**(47,644)**	**(47,987)**	**(47,651)**	**(47,408)**	**(47,640)**	**(47,686)**	**(47,676)**
Operating Cash Flow (pre-tax)	**1,013,740**	**-**	**-**	**-**	**20,498**	**41,071**	**44,164**	**45,015**	**49,019**	**45,810**	**45,501**	**44,461**	**43,715**	**44,214**
Corporate Income Tax	**(14,226)**	-	-	-	-	-	-	-	-	-	-	-	-	-
Operating Cash Flow (post-tax)	**999,514**	**-**	**-**	**-**	**20,498**	**41,071**	**44,164**	**45,015**	**49,019**	**45,810**	**45,501**	**44,461**	**43,715**	**44,214**
Capital														
Project Capital	**(442,912)**	-	(55,364)	(332,184)	(55,364)	-	-	-	-	-	-	-	-	-
Sustaining Capital	**(87,407)**	-	-	-	-	(719)	(1,437)	(2,875)	(2,875)	(2,875)	(12,127)	(2,875)	(2,875)	(2,875)
Total Capex	**(530,319)**	**-**	**(55,364)**	**(332,184)**	**(55,364)**	**(719)**	**(1,437)**	**(2,875)**	**(2,875)**	**(2,875)**	**(12,127)**	**(2,875)**	**(2,875)**	**(2,875)**
Free Cash Flow (pre-tax)	**519,688**	-	(55,364)	(332,184)	(35,625)	39,526	42,516	43,371	47,304	44,165	43,907	42,818	42,063	42,563
Free Cash Flow (post-tax)	**432,281**	**-**	**(55,364)**	**(332,184)**	**(35,625)**	**38,808**	**41,079**	**40,497**	**44,429**	**41,290**	**31,780**	**39,943**	**39,188**	**39,689**
Discounted Cash Flow (pre-tax)	**(36,233)**	-	(51,402)	(286,336)	(28,510)	28,835	28,338	25,937	26,418	22,795	16,289	19,008	17,314	16,280
Discounted Cash Flow (post-tax)	**(41,532)**	**-**	**(51,402)**	**(286,336)**	**(28,510)**	**28,835**	**28,338**	**25,937**	**26,418**	**22,795**	**16,289**	**19,008**	**17,314**	**16,280**

Description	Total (USD '000)	14	15	16	17	18	19	20	21	22	23	24	25	26
Physicals														
Concentrate tonnage (ktpa)		300	300	300	300	300	300	300	300	300	300	300	300	300
Cu metal grade (%)		36%	36%	36%	36%	36%	36%	36%	36%	36%	36%	36%	36%	36%
Ag metal grade (g/t)		271	344	344	344	344	344	344	344	344	344	344	344	344
Sulphur grade (%)		21%	23%	23%	23%	23%	23%	23%	23%	23%	23%	23%	23%	23%
Cash Flow														
Copper Price (US$/t)		8,752	8,752	8,752	8,752	8,752	8,752	8,752	8,752	8,752	8,752	8,752	8,752	8,752
Silver Price (US$/kg)		727	727	727	727	727	727	727	727	727	727	727	727	727
Sulphuric Acid (US$/t)		360	360	360	360	360	360	360	360	360	360	360	360	360
Total Commodity Value														
Copper Sales, Metal Value	**20,742,575**	935,262	934,382	934,382	934,382	934,382	934,382	934,382	934,382	934,382	934,382	934,382	934,382	934,382
Silver Sales, Metal Value	**1,601,821**	57,239	72,514	72,514	72,514	72,514	72,514	72,514	72,514	72,514	72,514	72,514	72,514	72,514
Sulhpuric Acid Sales, Value	**417,037**	17,089	18,682	18,682	18,682	18,682	18,682	18,682	18,682	18,682	18,682	18,682	18,682	18,682
Facility Revenue														
Free Metal Recovery Cu	**349,403**	15,754	15,739	15,739	15,739	15,739	15,739	15,739	15,739	15,739	15,739	15,739	15,739	15,739
Free Metal Recovery Ag	**106,477**	3,805	4,820	4,820	4,820	4,820	4,820	4,820	4,820	4,820	4,820	4,820	4,820	4,820
Free Com. Recovery H2SO4	**417,037**	17,089	18,682	18,682	18,682	18,682	18,682	18,682	18,682	18,682	18,682	18,682	18,682	18,682
Transport Premium	**-**	-	-	-	-	-	-	-	-	-	-	-	-	-
Copper Treatment Charge Income	**604,663**	27,000	27,000	27,000	27,000	27,000	27,000	27,000	27,000	27,000	27,000	27,000	27,000	27,000
Copper Refining Charge Income	**429,672**	19,195	19,177	19,177	19,177	19,177	19,177	19,177	19,177	19,177	19,177	19,177	19,177	19,177
Copper Minimum Deduction	**-**	-	-	-	-	-	-	-	-	-	-	-	-	-
Silver Refining Charge Income	**28,807**	1,013	1,284	1,284	1,284	1,284	1,284	1,284	1,284	1,284	1,284	1,284	1,284	1,284
Silver Minimum Deduction	**144,247**	6,545	6,545	6,545	6,545	6,545	6,545	6,545	6,545	6,545	6,545	6,545	6,545	6,545
Penalty Credits	**910**	40	40	40	40	40	40	40	40	40	40	40	40	40
Cathode premium	**-**	-	-	-	-	-	-	-	-	-	-	-	-	-
Royalty deferral	**-**	-	-	-	-	-	-	-	-	-	-	-	-	-
Net Revenue	**2,081,216**	**90,441**	**93,287**	**93,287**	**93,287**	**93,287**	**93,287**	**93,287**	**93,287**	**93,287**	**93,287**	**93,287**	**93,287**	**93,287**
Operating Costs														
Power	**(478,107)**	(21,349)	(21,349)	(21,349)	(21,349)	(21,349)	(21,349)	(21,349)	(21,349)	(21,349)	(21,349)	(21,349)	(21,349)	(21,349)
Reagents	**(154,615)**	(6,904)	(6,904)	(6,904)	(6,904)	(6,904)	(6,904)	(6,904)	(6,904)	(6,904)	(6,904)	(6,904)	(6,904)	(6,904)
Maintenance and consumables	**(176,509)**	(7,884)	(7,878)	(7,878)	(7,878)	(7,878)	(7,878)	(7,878)	(7,878)	(7,878)	(7,878)	(7,878)	(7,878)	(7,878)
Labour	**(258,244)**	(11,531)	(11,531)	(11,531)	(11,531)	(11,531)	(11,531)	(11,531)	(11,531)	(11,531)	(11,531)	(11,531)	(11,531)	(11,531)
Logistics	**-**	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Opex	**(1,067,476)**	**(47,669)**	**(47,662)**	**(47,662)**	**(47,662)**	**(47,662)**	**(47,662)**	**(47,662)**	**(47,662)**	**(47,662)**	**(47,662)**	**(47,662)**	**(47,662)**	**(47,662)**
Operating Cash Flow (pre-tax)	**1,013,740**	**42,773**	**45,625**	**45,625**	**45,625**	**45,625**	**45,625**	**45,625**	**45,625**	**45,625**	**45,625**	**45,625**	**45,625**	**45,625**
Corporate Income Tax	**(14,226)**	-	(29)	(1,417)	(1,417)	(1,417)	(1,417)	(29)	(1,417)	(1,417)	(1,417)	(1,417)	(1,417)	(1,417)
Operating Cash Flow (post-tax)	**999,514**	**42,773**	**45,596**	**44,208**	**44,208**	**44,208**	**44,208**	**45,596**	**44,208**	**44,208**	**44,208**	**44,208**	**44,208**	**44,208**
Capital														
Project Capital	**(442,912)**	-	-	-	-	-	-	-	-	-	-	-	-	-
Sustaining Capital	**(87,407)**	(2,875)	(12,127)	(2,875)	(2,875)	(2,875)	(2,875)	(12,127)	(2,875)	(2,875)	(2,875)	(2,875)	(2,875)	(2,875)
Total Capex	**(530,319)**	**(2,875)**	**(12,127)**	**(2,875)**	**(2,875)**	**(2,875)**	**(2,875)**	**(12,127)**	**(2,875)**	**(2,875)**	**(2,875)**	**(2,875)**	**(2,875)**	**(2,875)**
Free Cash Flow (pre-tax)	**519,688**	41,124	43,948	42,561	42,561	42,561	42,561	43,948	42,561	42,561	42,561	42,561	42,561	42,561
Free Cash Flow (post-tax)	**432,281**	**38,249**	**31,821**	**39,686**	**39,686**	**39,686**	**39,686**	**31,821**	**39,686**	**39,686**	**39,686**	**39,686**	**39,686**	**39,686**
Discounted Cash Flow (pre-tax)	**(36,233)**	14,566	11,262	13,493	12,527	11,631	10,798	7,769	9,308	8,642	8,023	7,449	6,916	6,421
Discounted Cash Flow (post-tax)	**(41,532)**	**14,566**	**11,251**	**13,028**	**12,095**	**11,230**	**10,426**	**7,761**	**8,987**	**8,344**	**7,747**	**7,192**	**5,677**	**5,199**

Baseline scenario | 300 ktpa | Pyro

7.2 Serowe Optimised Cash Flow

Description	Total (USD '000)	1	2	3	4	5	6	7	8	9	10	11	12	13
Physicals														
Concentrate tonnage (ktpa)		-	-	-	141	277	300	300	300	300	450	450	450	450
Cu metal grade (%)		0%	0%	0%	35%	37%	36%	36%	38%	36%	32%	33%	33%	33%
Ag metal grade (g/t)		-	-	-	311	352	320	364	420	376	250	276	282	253
Sulphur grade (%)		0%	0%	0%	26%	24%	24%	24%	22%	22%	23%	21%	20%	23%
Cash Flow														
Copper Price (US$/t)		6,107	8,996	8,382	7,535	7,885	7,966	8,417	9,414	8,752	8,752	8,752	8,752	8,752
Silver Price (US$/kg)		658	797	689	644	652	654	650	727	727	727	727	727	727
Sulphuric Acid (US$/t)		86	86	347	360	360	360	360	360	360	360	360	360	360
Total Commodity Value														
Copper Sales, Metal Value	**26,919,083**	-	-	-	370,622	788,959	850,328	896,475	1,046,264	932,983	1,231,200	1,284,835	1,291,029	1,288,829
Silver Sales, Metal Value	**1,809,032**	-	-	-	27,399	61,534	60,723	68,661	88,537	79,233	79,188	87,264	89,237	79,924
Sulhpuric Acid Sales, Value	**544,542**	-	-	-	9,934	18,234	20,171	19,611	18,380	18,342	28,449	25,488	24,681	28,014
Facility Revenue														
Free Metal Recovery Cu	**561,121**	-	-	-	7,726	16,446	17,725	18,687	21,809	19,448	25,664	26,782	26,911	26,865
Free Metal Recovery Ag	**120,609**	-	-	-	1,827	4,103	4,048	4,578	5,903	5,283	5,280	5,818	5,949	5,329
Free Com. Recovery H2SO4	**544,542**	-	-	-	9,934	18,234	20,171	19,611	18,380	18,342	28,449	25,488	24,681	28,014
Transport Premium	**819,893**	-	-	-	12,505	24,513	26,538	26,538	26,538	26,538	39,807	39,807	39,807	39,807
Copper Treatment Charge Income	**834,163**	-	-	-	12,723	24,940	27,000	27,000	27,000	27,000	40,500	40,500	40,500	40,500
Copper Refining Charge Income	**554,602**	-	-	-	8,835	17,974	19,174	19,133	19,965	19,148	25,166	26,263	26,389	26,344
Copper Minimum Deduction	**-**	-	-	-	-	-	-	-	-	-	-	-	-	-
Silver Refining Charge Income	**32,470**	-	-	-	548	1,215	1,196	1,359	1,567	1,402	1,401	1,544	1,579	1,414
Silver Minimum Deduction	**199,882**	-	-	-	2,730	5,421	5,884	5,852	6,545	6,545	9,818	9,818	9,818	9,818
Penalty Credits	**910**	-	-	-	40	40	40	40	40	40	40	40	40	40
Cathode premium	**-**	-	-	-	-	-	-	-	-	-	-	-	-	-
Royalty deferral	**287,281**	-	-	-	3,980	8,505	9,111	9,651	11,348	10,122	13,104	13,721	13,803	13,688
Net Revenue	**3,955,473**	**-**	**-**	**-**	**60,848**	**121,389**	**130,886**	**132,448**	**139,094**	**133,869**	**189,229**	**189,781**	**189,477**	**191,819**
Operating Costs														
Power	**(597,343)**	-	-	-	(9,111)	(17,859)	(19,335)	(19,335)	(19,335)	(19,335)	(29,002)	(29,002)	(29,002)	(29,002)
Reagents	**(213,794)**	-	-	-	(3,261)	(6,392)	(6,920)	(6,920)	(6,920)	(6,920)	(10,380)	(10,380)	(10,380)	(10,380)
Maintenance and consumables	**(228,565)**	-	-	-	(3,629)	(7,384)	(7,876)	(7,860)	(8,202)	(7,867)	(10,379)	(10,832)	(10,884)	(10,865)
Labour	**(290,857)**	-	-	-	(4,436)	(8,696)	(9,414)	(9,414)	(9,414)	(9,414)	(14,122)	(14,122)	(14,122)	(14,122)
Logistics	**(277,331)**	-	-	-	(4,404)	(8,959)	(9,557)	(9,537)	(9,953)	(9,546)	(12,594)	(13,143)	(13,206)	(13,183)
Total Opex	**(1,607,890)**	**-**	**-**	**-**	**(24,841)**	**(49,290)**	**(53,102)**	**(53,067)**	**(53,825)**	**(53,081)**	**(76,477)**	**(77,478)**	**(77,594)**	**(77,551)**
Operating Cash Flow (pre-tax)	**2,347,583**	**-**	**-**	**-**	**36,007**	**72,099**	**77,784**	**79,382**	**85,270**	**80,787**	**112,752**	**112,302**	**111,883**	**114,268**
Corporate Income Tax	**(27,506)**	-	-	-	-	-	-	-	-	-	-	-	-	-
Operating Cash Flow (post-tax)	**2,320,077**	**-**	**-**	**-**	**36,007**	**72,099**	**77,784**	**79,382**	**85,270**	**80,787**	**112,752**	**112,302**	**111,883**	**114,268**
Capital														
Project Capital	**(514,159)**	-	(55,150)	(330,901)	(55,150)	-	-	-	-	(72,958)	-	-	-	-
Sustaining Capital	**(92,464)**	-	-	-	-	(830)	(1,659)	(3,319)	(3,319)	(3,319)	(3,319)	(3,319)	(3,319)	(3,319)
Total Capex	**(606,623)**	-	(55,150)	(330,901)	(55,150)	(830)	(1,659)	(3,319)	(3,319)	(76,277)	(3,319)	(3,319)	(3,319)	(3,319)
Free Cash Flow (pre-tax)	**1,758,113**	-	(55,150)	(330,901)	(19,902)	70,555	76,137	77,738	83,554	6,184	110,582	110,037	109,607	111,995
Free Cash Flow (post-tax)	**1,665,650**	**-**	**(55,150)**	**(330,901)**	**(19,902)**	**69,725**	**74,477**	**74,420**	**80,236**	**2,865**	**107,263**	**106,718**	**106,288**	**108,677**
Discounted Cash Flow (pre-tax)	**391,083**	-	(51,203)	(285,230)	(15,927)	51,806	51,377	47,663	47,710	1,582	54,978	50,784	46,959	44,578
Discounted Cash Flow (post-tax)	**384,618**	**-**	**(51,203)**	**(285,230)**	**(15,927)**	**51,806**	**51,377**	**47,663**	**47,710**	**1,582**	**54,978**	**50,784**	**46,959**	**44,578**

Description	Total (USD '000)	14	15	16	17	18	19	20	21	22	23	24	25	26
Physicals														
Concentrate tonnage (ktpa)		450	450	450	450	450	450	450	450	450	450	450	450	450
Cu metal grade (%)		33%	35%	36%	33%	33%	33%	33%	33%	33%	33%	33%	33%	33%
Ag metal grade (g/t)		261	268	245	266	266	266	266	266	266	266	266	266	266
Sulphur grade (%)		21%	21%	21%	21%	21%	21%	21%	21%	21%	21%	21%	21%	21%
Cash Flow														
Copper Price (US$/t)		8,752	8,752	8,752	8,752	8,752	8,752	8,752	8,752	8,752	8,752	8,752	8,752	8,752
Silver Price (US$/kg)		727	727	727	727	727	727	727	727	727	727	727	727	727
Sulphuric Acid (US$/t)		360	360	360	360	360	360	360	360	360	360	360	360	360
Total Commodity Value														
Copper Sales, Metal Value	**26,919,083**	1,277,884	1,341,051	1,395,073	1,292,355	1,292,355	1,292,355	1,292,355	1,292,355	1,292,355	1,292,355	1,292,355	1,292,355	1,292,355
Silver Sales, Metal Value	**1,809,032**	82,676	84,843	77,418	84,240	84,240	84,240	84,240	84,240	84,240	84,240	84,240	84,240	84,240
Sulhpuric Acid Sales, Value	**544,542**	25,634	25,634	25,634	25,634	25,634	25,634	25,634	25,634	25,634	25,634	25,634	25,634	25,634
Facility Revenue														
Free Metal Recovery Cu	**561,121**	26,637	27,954	29,080	26,939	26,939	26,939	26,939	26,939	26,939	26,939	26,939	26,939	26,939
Free Metal Recovery Ag	**120,609**	5,512	5,657	5,161	5,616	5,616	5,616	5,616	5,616	5,616	5,616	5,616	5,616	5,616
Free Com. Recovery H2SO4	**544,542**	25,634	25,634	25,634	25,634	25,634	25,634	25,634	25,634	25,634	25,634	25,634	25,634	25,634
Transport Premium	**819,893**	39,807	39,807	39,807	39,807	39,807	39,807	39,807	39,807	39,807	39,807	39,807	39,807	39,807
Copper Treatment Charge Income	**834,163**	40,500	40,500	40,500	40,500	40,500	40,500	40,500	40,500	40,500	40,500	40,500	40,500	40,500
Copper Refining Charge Income	**554,602**	26,121	27,412	28,516	26,416	26,416	26,416	26,416	26,416	26,416	26,416	26,416	26,416	26,416
Copper Minimum Deduction	**-**	-	-	-	-	-	-	-	-	-	-	-	-	-
Silver Refining Charge Income	**32,470**	1,463	1,501	1,370	1,491	1,491	1,491	1,491	1,491	1,491	1,491	1,491	1,491	1,491
Silver Minimum Deduction	**199,882**	9,818	9,818	9,818	9,818	9,818	9,818	9,818	9,818	9,818	9,818	9,818	9,818	9,818
Penalty Credits	**910**	40	40	40	40	40	40	40	40	40	40	40	40	40
Cathode premium	**-**	-	-	-	-	-	-	-	-	-	-	-	-	-
Royalty deferral	**287,281**	13,606	14,259	14,725	13,766	13,766	13,766	13,766	13,766	13,766	13,766	13,766	13,766	13,766
Net Revenue	**3,955,473**	**189,137**	**192,581**	**194,651**	**190,026**	**190,026**	**190,026**	**190,026**	**190,026**	**190,026**	**190,026**	**190,026**	**190,026**	**190,026**
Operating Costs														
Power	**(597,343)**	(29,002)	(29,002)	(29,002)	(29,002)	(29,002)	(29,002)	(29,002)	(29,002)	(29,002)	(29,002)	(29,002)	(29,002)	(29,002)
Reagents	**(213,794)**	(10,380)	(10,380)	(10,380)	(10,380)	(10,380)	(10,380)	(10,380)	(10,380)	(10,380)	(10,380)	(10,380)	(10,380)	(10,380)
Maintenance and consumables	**(228,565)**	(10,773)	(11,305)	(11,760)	(10,895)	(10,895)	(10,895)	(10,895)	(10,895)	(10,895)	(10,895)	(10,895)	(10,895)	(10,895)
Labour	**(290,857)**	(14,122)	(14,122)	(14,122)	(14,122)	(14,122)	(14,122)	(14,122)	(14,122)	(14,122)	(14,122)	(14,122)	(14,122)	(14,122)
Logistics	**(277,331)**	(13,071)	(13,717)	(14,268)	(13,219)	(13,219)	(13,219)	(13,219)	(13,219)	(13,219)	(13,219)	(13,219)	(13,219)	(13,219)
Total Opex	**(1,607,890)**	**(77,348)**	**(78,526)**	**(79,532)**	**(77,618)**	**(77,618)**	**(77,618)**	**(77,618)**	**(77,618)**	**(77,618)**	**(77,618)**	**(77,618)**	**(77,618)**	**(77,618)**
Operating Cash Flow (pre-tax)	**2,347,583**	**111,789**	**114,055**	**115,119**	**112,409**	**112,409**	**112,409**	**112,409**	**112,409**	**112,409**	**112,409**	**112,409**	**112,409**	**112,409**
Corporate Income Tax	**(27,506)**	-	(620)	(2,445)	(2,503)	(2,503)	(2,503)	(1,913)	(2,503)	(2,503)	(2,503)	(2,503)	(2,503)	(2,503)
Operating Cash Flow (post-tax)	**2,320,077**	**111,789**	**113,435**	**112,674**	**109,905**	**109,905**	**109,905**	**110,496**	**109,905**	**109,905**	**109,905**	**109,905**	**109,905**	**109,905**
Capital														
Project Capital	**(514,159)**	-	-	-	-	-	-	-	-	-	-	-	-	-
Sustaining Capital	**(92,464)**	(3,319)	(15,119)	(3,319)	(3,319)	(3,319)	(3,319)	(15,119)	(3,319)	(3,319)	(3,319)	(3,319)	(3,319)	(3,319)
Total Capex	**(606,623)**	(3,319)	(15,119)	(3,319)	(3,319)	(3,319)	(3,319)	(15,119)	(3,319)	(3,319)	(3,319)	(3,319)	(3,319)	(3,319)
Free Cash Flow (pre-tax)	**1,758,113**	109,536	111,070	110,214	107,627	107,627	107,627	108,217	107,627	107,627	107,627	107,627	107,627	107,627
Free Cash Flow (post-tax)	**1,665,650**	**106,217**	**95,951**	**106,896**	**104,308**	**104,308**	**104,308**	**93,097**	**104,308**	**104,308**	**104,308**	**104,308**	**104,308**	**104,308**
Discounted Cash Flow (pre-tax)	**391,083**	40,451	34,145	35,893	32,553	30,223	28,060	23,174	24,187	22,456	20,849	19,357	17,972	16,685
Discounted Cash Flow (post-tax)	**384,618**	**40,451**	**33,926**	**35,091**	**31,790**	**29,515**	**27,403**	**22,707**	**23,621**	**21,930**	**20,361**	**18,903**	**17,550**	**16,294**

Combined upside scenario | 300 – 450 ktpa | Pyro

7.3 Orapa Optimised Cash Flow

ɔtion	Total (USD '000)	1	2	3	4	5	6	7	8	9	10	11	12	13
Physicals														
Concentrate tonnage (ktpa)		-	-	-	141	277	300	300	300	300	450	450	450	450
Cu metal grade (%)		0%	0%	0%	35%	37%	36%	36%	38%	36%	32%	33%	33%	33%
Ag metal grade (g/t)		-	-	-	311	352	320	364	420	376	250	276	282	253
Sulphur grade (%)		0%	0%	0%	26%	24%	24%	24%	22%	22%	23%	21%	20%	23%
Cash Flow														
Copper Price (US$/t)		6,107	8,996	8,382	7,535	7,885	7,966	8,417	9,414	8,752	8,752	8,752	8,752	8,752
Silver Price (US$/kg)		658	797	689	644	652	654	650	727	727	727	727	727	727
Sulphuric Acid (US$/t)		86	86	347	360	360	360	360	360	360	360	360	360	360
Total Commodity Value														
Copper Sales, Metal Value	**26,919,083**	-	-	-	370,622	788,959	850,328	896,475	1,046,264	932,983	1,231,200	1,284,835	1,291,029	1,288,829
Silver Sales, Metal Value	**1,809,032**	-	-	-	27,399	61,534	60,723	68,661	88,537	79,233	79,188	87,264	89,237	79,924
Sulhpuric Acid Sales, Value	**544,542**	-	-	-	9,934	18,234	20,171	19,611	18,380	18,342	28,449	25,488	24,681	28,014
Facility Revenue														
Free Metal Recovery Cu	**561,121**	-	-	-	7,726	16,446	17,725	18,687	21,809	19,448	25,664	26,782	26,911	26,865
Free Metal Recovery Ag	**120,609**	-	-	-	1,827	4,103	4,048	4,578	5,903	5,283	5,280	5,818	5,949	5,329
Free Com. Recovery H2SO4	**544,542**	-	-	-	9,934	18,234	20,171	19,611	18,380	18,342	28,449	25,488	24,681	28,014
Transport Premium	**973,079**	-	-	-	14,841	29,093	31,496	31,496	31,496	31,496	47,245	47,245	47,245	47,245
Copper Treatment Charge Income	**834,163**	-	-	-	12,723	24,940	27,000	27,000	27,000	27,000	40,500	40,500	40,500	40,500
Copper Refining Charge Income	**554,602**	-	-	-	8,835	17,974	19,174	19,133	19,965	19,148	25,166	26,263	26,389	26,344
Copper Minimum Deduction	**-**	-	-	-	-	-	-	-	-	-	-	-	-	-
Silver Refining Charge Income	**32,470**	-	-	-	548	1,215	1,196	1,359	1,567	1,402	1,401	1,544	1,579	1,414
Silver Minimum Deduction	**199,882**	-	-	-	2,730	5,421	5,884	5,852	6,545	6,545	9,818	9,818	9,818	9,818
Penalty Credits	**910**	-	-	-	40	40	40	40	40	40	40	40	40	40
Cathode premium	**-**	-	-	-	-	-	-	-	-	-	-	-	-	-
Royalty deferral	**287,281**	-	-	-	3,980	8,505	9,111	9,651	11,348	10,122	13,104	13,721	13,803	13,688
Net Revenue	**4,108,659**	**-**	**-**	**-**	**63,184**	**125,969**	**135,844**	**137,407**	**144,053**	**138,827**	**196,666**	**197,218**	**196,915**	**199,257**
Operating Costs														
Power	**(604,440)**	-	-	-	(9,219)	(18,072)	(19,564)	(19,564)	(19,564)	(19,564)	(29,347)	(29,347)	(29,347)	(29,347)
Reagents	**(213,794)**	-	-	-	(3,261)	(6,392)	(6,920)	(6,920)	(6,920)	(6,920)	(10,380)	(10,380)	(10,380)	(10,380)
Maintenance and consumables	**(228,565)**	-	-	-	(3,629)	(7,384)	(7,876)	(7,860)	(8,202)	(7,867)	(10,379)	(10,832)	(10,884)	(10,865)
Labour	**(290,857)**	-	-	-	(4,436)	(8,696)	(9,414)	(9,414)	(9,414)	(9,414)	(14,122)	(14,122)	(14,122)	(14,122)
Logistics	**(455,914)**	-	-	-	(7,239)	(14,728)	(15,711)	(15,679)	(16,362)	(15,692)	(20,703)	(21,606)	(21,710)	(21,672)
Total Opex	**(1,793,570)**	**-**	**-**	**-**	**(27,785)**	**(55,272)**	**(59,486)**	**(59,438)**	**(60,464)**	**(59,458)**	**(84,931)**	**(86,286)**	**(86,443)**	**(86,385)**
Operating Cash Flow (pre-tax)	**2,315,089**	**-**	**-**	**-**	**35,399**	**70,697**	**76,358**	**77,969**	**83,589**	**79,369**	**111,736**	**110,932**	**110,472**	**112,872**
Corporate Income Tax	**(38,275)**	-	-	-	-	-	-	-	-	-	(581)	(2,436)	(2,394)	(2,547)
Operating Cash Flow (post-tax)	**2,276,814**	**-**	**-**	**-**	**35,399**	**70,697**	**76,358**	**77,969**	**83,589**	**79,369**	**111,155**	**108,496**	**108,078**	**110,325**
Capital														
Project Capital	**(522,446)**	-	(56,186)	(337,116)	(56,186)	-	-	-	-	(72,958)	-	-	-	-
Sustaining Capital	**(92,464)**	-	-	-	-	(830)	(1,659)	(3,319)	(3,319)	(3,319)	(3,319)	(3,319)	(3,319)	(3,319)
Total Capex	**(614,909)**	**-**	**(56,186)**	**(337,116)**	**(56,186)**	**(830)**	**(1,659)**	**(3,319)**	**(3,319)**	**(76,277)**	**(3,319)**	**(3,319)**	**(3,319)**	**(3,319)**
Free Cash Flow (pre-tax)	**1,706,564**	-	(56,186)	(337,116)	(21,546)	69,153	74,711	76,325	81,874	4,766	108,984	106,231	105,801	108,053
Free Cash Flow (post-tax)	**1,614,100**	**-**	**(56,186)**	**(337,116)**	**(21,546)**	**68,324**	**73,052**	**73,007**	**78,555**	**1,447**	**105,665**	**102,912**	**102,483**	**104,734**
Discounted Cash Flow (pre-tax)	**369,392**	-	(52,165)	(290,587)	(17,243)	50,765	50,393	46,758	46,711	799	54,457	50,132	46,336	44,005
Discounted Cash Flow (post-tax)	**358,212**	**-**	**(52,165)**	**(290,587)**	**(17,243)**	**50,765**	**50,393**	**46,758**	**46,711**	**799**	**54,159**	**48,973**	**45,278**	**42,961**

Description	Total (USD '000)	14	15	16	17	18	19	20	21	22	23	24	25	26
Physicals														
Concentrate tonnage (ktpa)		450	450	450	450	450	450	450	450	450	450	450	450	450
Cu metal grade (%)		33%	35%	36%	33%	33%	33%	33%	33%	33%	33%	33%	33%	33%
Ag metal grade (g/t)		261	268	245	266	266	266	266	266	266	266	266	266	266
Sulphur grade (%)		21%	21%	21%	21%	21%	21%	21%	21%	21%	21%	21%	21%	21%
Cash Flow														
Copper Price (US$/t)		8,752	8,752	8,752	8,752	8,752	8,752	8,752	8,752	8,752	8,752	8,752	8,752	8,752
Silver Price (US$/kg)		727	727	727	727	727	727	727	727	727	727	727	727	727
Sulphuric Acid (US$/t)		360	360	360	360	360	360	360	360	360	360	360	360	360
Total Commodity Value														
Copper Sales, Metal Value	**26,919,083**	1,277,884	1,341,051	1,395,073	1,292,355	1,292,355	1,292,355	1,292,355	1,292,355	1,292,355	1,292,355	1,292,355	1,292,355	1,292,355
Silver Sales, Metal Value	**1,809,032**	82,676	84,843	77,418	84,240	84,240	84,240	84,240	84,240	84,240	84,240	84,240	84,240	84,240
Sulhpuric Acid Sales, Value	**544,542**	25,634	25,634	25,634	25,634	25,634	25,634	25,634	25,634	25,634	25,634	25,634	25,634	25,634
Facility Revenue														
Free Metal Recovery Cu	**561,121**	26,637	27,954	29,080	26,939	26,939	26,939	26,939	26,939	26,939	26,939	26,939	26,939	26,939
Free Metal Recovery Ag	**120,609**	5,512	5,657	5,161	5,616	5,616	5,616	5,616	5,616	5,616	5,616	5,616	5,616	5,616
Free Com. Recovery H2SO4	**544,542**	25,634	25,634	25,634	25,634	25,634	25,634	25,634	25,634	25,634	25,634	25,634	25,634	25,634
Transport Premium	**973,079**	47,245	47,245	47,245	47,245	47,245	47,245	47,245	47,245	47,245	47,245	47,245	47,245	47,245
Copper Treatment Charge Income	**834,163**	40,500	40,500	40,500	40,500	40,500	40,500	40,500	40,500	40,500	40,500	40,500	40,500	40,500
Copper Refining Charge Income	**554,602**	26,121	27,412	28,516	26,416	26,416	26,416	26,416	26,416	26,416	26,416	26,416	26,416	26,416
Copper Minimum Deduction	**-**	-	-	-	-	-	-	-	-	-	-	-	-	-
Silver Refining Charge Income	**32,470**	1,463	1,501	1,370	1,491	1,491	1,491	1,491	1,491	1,491	1,491	1,491	1,491	1,491
Silver Minimum Deduction	**199,882**	9,818	9,818	9,818	9,818	9,818	9,818	9,818	9,818	9,818	9,818	9,818	9,818	9,818
Penalty Credits	**910**	40	40	40	40	40	40	40	40	40	40	40	40	40
Cathode premium	**-**	-	-	-	-	-	-	-	-	-	-	-	-	-
Royalty deferral	**287,281**	13,606	14,259	14,725	13,766	13,766	13,766	13,766	13,766	13,766	13,766	13,766	13,766	13,766
Net Revenue	**4,108,659**	**196,574**	**200,018**	**202,088**	**197,464**	**197,464**	**197,464**	**197,464**	**197,464**	**197,464**	**197,464**	**197,464**	**197,464**	**197,464**
Operating Costs														
Power	**(604,440)**	(29,347)	(29,347)	(29,347)	(29,347)	(29,347)	(29,347)	(29,347)	(29,347)	(29,347)	(29,347)	(29,347)	(29,347)	(29,347)
Reagents	**(213,794)**	(10,380)	(10,380)	(10,380)	(10,380)	(10,380)	(10,380)	(10,380)	(10,380)	(10,380)	(10,380)	(10,380)	(10,380)	(10,380)
Maintenance and consumables	**(228,565)**	(10,773)	(11,305)	(11,760)	(10,895)	(10,895)	(10,895)	(10,895)	(10,895)	(10,895)	(10,895)	(10,895)	(10,895)	(10,895)
Labour	**(290,857)**	(14,122)	(14,122)	(14,122)	(14,122)	(14,122)	(14,122)	(14,122)	(14,122)	(14,122)	(14,122)	(14,122)	(14,122)	(14,122)
Logistics	**(455,914)**	(21,488)	(22,550)	(23,456)	(21,732)	(21,732)	(21,732)	(21,732)	(21,732)	(21,732)	(21,732)	(21,732)	(21,732)	(21,732)
Total Opex	**(1,793,570)**	**(86,109)**	**(87,703)**	**(89,064)**	**(86,475)**	**(86,475)**	**(86,475)**	**(86,475)**	**(86,475)**	**(86,475)**	**(86,475)**	**(86,475)**	**(86,475)**	**(86,475)**
Operating Cash Flow (pre-tax)	**2,315,089**	**110,465**	**112,315**	**113,024**	**110,989**	**110,989**	**110,989**	**110,989**	**110,989**	**110,989**	**110,989**	**110,989**	**110,989**	**110,989**
Corporate Income Tax	**(38,275)**	(2,441)	(1,805)	(2,340)	(2,432)	(2,432)	(2,432)	(1,842)	(2,432)	(2,432)	(2,432)	(2,432)	(2,432)	(2,432)
Operating Cash Flow (post-tax)	**2,276,814**	**108,024**	**110,510**	**110,684**	**108,557**	**108,557**	**108,557**	**109,147**	**108,557**	**108,557**	**108,557**	**108,557**	**108,557**	**108,557**
Capital														
Project Capital	**(522,446)**	-	-	-	-	-	-	-	-	-	-	-	-	-
Sustaining Capital	**(92,464)**	(3,319)	(15,119)	(3,319)	(3,319)	(3,319)	(3,319)	(15,119)	(3,319)	(3,319)	(3,319)	(3,319)	(3,319)	(3,319)
Total Capex	**(614,909)**	**(3,319)**	**(15,119)**	**(3,319)**	**(3,319)**	**(3,319)**	**(3,319)**	**(15,119)**	**(3,319)**	**(3,319)**	**(3,319)**	**(3,319)**	**(3,319)**	**(3,319)**
Free Cash Flow (pre-tax)	**1,706,564**	105,771	108,145	108,224	106,278	106,278	106,278	106,868	106,278	106,278	106,278	106,278	106,278	106,278
Free Cash Flow (post-tax)	**1,614,100**	**102,452**	**93,026**	**104,905**	**102,960**	**102,960**	**102,960**	**91,749**	**102,960**	**102,960**	**102,960**	**102,960**	**102,960**	**102,960**
Discounted Cash Flow (pre-tax)	**369,392**	39,947	33,530	35,205	32,121	29,822	27,687	22,828	23,866	22,158	20,572	19,100	17,733	14,464
Discounted Cash Flow (post-tax)	**358,212**	**39,017**	**32,892**	**34,437**	**31,379**	**29,134**	**27,048**	**22,378**	**23,315**	**21,647**	**20,097**	**18,659**	**17,323**	**14,084**

Combined upside scenario | 300 – 450 ktpa | Pyro

7.4 Maun Optimised Cash Flow

Description	Total (USD '000)	1	2	3	4	5	6	7	8	9	10	11	12	13
Physicals														
Concentrate tonnage (ktpa)		-	-	-	141	277	300	300	300	300	450	450	450	450
Cu metal grade (%)		0%	0%	0%	35%	37%	36%	36%	38%	36%	32%	33%	33%	33%
Ag metal grade (g/t)		-	-	-	311	352	320	364	420	376	250	276	282	253
Sulphur grade (%)		0%	0%	0%	26%	24%	24%	24%	22%	22%	23%	21%	20%	23%
Cash Flow														
Copper Price (US$/t)		6,107	8,996	8,382	7,535	7,885	7,966	8,417	9,414	8,752	8,752	8,752	8,752	8,752
Silver Price (US$/kg)		658	797	689	644	652	654	650	727	727	727	727	727	727
Sulphuric Acid (US$/t)		86	86	347	360	360	360	360	360	360	360	360	360	360
Total Commodity Value														
Copper Sales, Metal Value	**26,919,083**	-	-	-	370,622	788,959	850,328	896,475	1,046,264	932,983	1,231,200	1,284,835	1,291,029	1,288,829
Silver Sales, Metal Value	**1,809,032**	-	-	-	27,399	61,534	60,723	68,661	88,537	79,233	79,188	87,264	89,237	79,924
Sulhpuric Acid Sales, Value	**544,542**	-	-	-	9,934	18,234	20,171	19,611	18,380	18,342	28,449	25,488	24,681	28,014
Facility Revenue														
Free Metal Recovery Cu	**561,121**	-	-	-	7,726	16,446	17,725	18,687	21,809	19,448	25,664	26,782	26,911	26,865
Free Metal Recovery Ag	**120,609**	-	-	-	1,827	4,103	4,048	4,578	5,903	5,283	5,280	5,818	5,949	5,329
Free Com. Recovery H2SO4	**544,542**	-	-	-	9,934	18,234	20,171	19,611	18,380	18,342	28,449	25,488	24,681	28,014
Transport Premium	**1,248,290**	-	-	-	19,039	37,322	40,404	40,404	40,404	40,404	60,607	60,607	60,607	60,607
Copper Treatment Charge Income	**834,163**	-	-	-	12,723	24,940	27,000	27,000	27,000	27,000	40,500	40,500	40,500	40,500
Copper Refining Charge Income	**554,602**	-	-	-	8,835	17,974	19,174	19,133	19,965	19,148	25,166	26,263	26,389	26,344
Copper Minimum Deduction	**-**	-	-	-	-	-	-	-	-	-	-	-	-	-
Silver Refining Charge Income	**32,470**	-	-	-	548	1,215	1,196	1,359	1,567	1,402	1,401	1,544	1,579	1,414
Silver Minimum Deduction	**199,882**	-	-	-	2,730	5,421	5,884	5,852	6,545	6,545	9,818	9,818	9,818	9,818
Penalty Credits	**910**	-	-	-	40	40	40	40	40	40	40	40	40	40
Cathode premium	**-**	-	-	-	-	-	-	-	-	-	-	-	-	-
Royalty deferral	**287,281**	-	-	-	3,980	8,505	9,111	9,651	11,348	10,122	13,104	13,721	13,803	13,688
Net Revenue	**4,383,870**	**-**	**-**	**-**	**67,381**	**134,198**	**144,752**	**146,315**	**152,961**	**147,735**	**210,028**	**210,580**	**210,276**	**212,619**
Operating Costs														
Power	**(696,695)**	-	-	-	(10,626)	(20,830)	(22,550)	(22,550)	(22,550)	(22,550)	(33,826)	(33,826)	(33,826)	(33,826)
Reagents	**(213,794)**	-	-	-	(3,261)	(6,392)	(6,920)	(6,920)	(6,920)	(6,920)	(10,380)	(10,380)	(10,380)	(10,380)
Maintenance and consumables	**(228,565)**	-	-	-	(3,629)	(7,384)	(7,876)	(7,860)	(8,202)	(7,867)	(10,379)	(10,832)	(10,884)	(10,865)
Labour	**(290,857)**	-	-	-	(4,436)	(8,696)	(9,414)	(9,414)	(9,414)	(9,414)	(14,122)	(14,122)	(14,122)	(14,122)
Logistics	**(363,965)**	-	-	-	(5,779)	(11,758)	(12,542)	(12,517)	(13,063)	(12,528)	(16,528)	(17,248)	(17,332)	(17,301)
Total Opex	**(1,793,877)**	**-**	**-**	**-**	**(27,732)**	**(55,060)**	**(59,304)**	**(59,262)**	**(60,150)**	**(59,279)**	**(85,234)**	**(86,408)**	**(86,543)**	**(86,493)**
Operating Cash Flow (pre-tax)	**2,589,993**	**-**	**-**	**-**	**39,650**	**79,138**	**85,449**	**87,053**	**92,811**	**88,456**	**124,794**	**124,172**	**123,733**	**126,126**
Corporate Income Tax	**(35,491)**	-	-	-	-	-	-	-	-	-	-	-	-	-
Operating Cash Flow (post-tax)	**2,554,502**	**-**	**-**	**-**	**39,650**	**79,138**	**85,449**	**87,053**	**92,811**	**88,456**	**124,794**	**124,172**	**123,733**	**126,126**
Capital														
Project Capital	**(555,464)**	-	(60,313)	(361,879)	(60,313)	-	-	-	-	(72,958)	-	-	-	-
Sustaining Capital	**(92,464)**	-	-	-	-	(830)	(1,659)	(3,319)	(3,319)	(3,319)	(3,319)	(3,319)	(3,319)	(3,319)
Total Capex	**(647,928)**	**-**	**(60,313)**	**(361,879)**	**(60,313)**	**(830)**	**(1,659)**	**(3,319)**	**(3,319)**	**(76,277)**	**(3,319)**	**(3,319)**	**(3,319)**	**(3,319)**
Free Cash Flow (pre-tax)	**1,951,233**	-	(60,313)	(361,879)	(21,422)	77,594	83,802	85,409	91,096	13,853	122,623	121,907	121,457	123,853
Free Cash Flow (post-tax)	**1,858,770**	**-**	**(60,313)**	**(361,879)**	**(21,422)**	**76,764**	**82,142**	**82,091**	**87,777**	**10,534**	**119,305**	**118,588**	**118,138**	**120,534**
Discounted Cash Flow (pre-tax)	**413,321**	-	(55,997)	(311,933)	(17,144)	57,037	56,664	52,576	52,194	5,815	61,150	56,432	52,195	49,442
Discounted Cash Flow (post-tax)	**401,820**	**-**	**(55,997)**	**(311,933)**	**(17,144)**	**57,037**	**56,664**	**52,576**	**52,194**	**5,815**	**61,150**	**56,432**	**52,195**	**49,442**

cription	Total (USD '000)	14	15	16	17	18	19	20	21	22	23	24	25	26
Physicals														
Concentrate tonnage (ktpa)		450	450	450	450	450	450	450	450	450	450	450	450	450
Cu metal grade (%)		33%	35%	36%	33%	33%	33%	33%	33%	33%	33%	33%	33%	33%
Ag metal grade (g/t)		261	268	245	266	266	266	266	266	266	266	266	266	266
Sulphur grade (%)		21%	21%	21%	21%	21%	21%	21%	21%	21%	21%	21%	21%	21%
Cash Flow														
Copper Price (US$/t)		8,752	8,752	8,752	8,752	8,752	8,752	8,752	8,752	8,752	8,752	8,752	8,752	8,752
Silver Price (US$/kg)		727	727	727	727	727	727	727	727	727	727	727	727	727
Sulphuric Acid (US$/t)		360	360	360	360	360	360	360	360	360	360	360	360	360
Total Commodity Value														
Copper Sales, Metal Value	**26,919,083**	1,277,884	1,341,051	1,395,073	1,292,355	1,292,355	1,292,355	1,292,355	1,292,355	1,292,355	1,292,355	1,292,355	1,292,355	1,292,355
Silver Sales, Metal Value	**1,809,032**	82,676	84,843	77,418	84,240	84,240	84,240	84,240	84,240	84,240	84,240	84,240	84,240	84,240
Sulhpuric Acid Sales, Value	**544,542**	25,634	25,634	25,634	25,634	25,634	25,634	25,634	25,634	25,634	25,634	25,634	25,634	25,634
Facility Revenue														
Free Metal Recovery Cu	**561,121**	26,637	27,954	29,080	26,939	26,939	26,939	26,939	26,939	26,939	26,939	26,939	26,939	26,939
Free Metal Recovery Ag	**120,609**	5,512	5,657	5,161	5,616	5,616	5,616	5,616	5,616	5,616	5,616	5,616	5,616	5,616
Free Com. Recovery H2SO4	**544,542**	25,634	25,634	25,634	25,634	25,634	25,634	25,634	25,634	25,634	25,634	25,634	25,634	25,634
Transport Premium	**1,248,290**	60,607	60,607	60,607	60,607	60,607	60,607	60,607	60,607	60,607	60,607	60,607	60,607	60,607
Copper Treatment Charge Income	**834,163**	40,500	40,500	40,500	40,500	40,500	40,500	40,500	40,500	40,500	40,500	40,500	40,500	40,500
Copper Refining Charge Income	**554,602**	26,121	27,412	28,516	26,416	26,416	26,416	26,416	26,416	26,416	26,416	26,416	26,416	26,416
Copper Minimum Deduction	**-**	-	-	-	-	-	-	-	-	-	-	-	-	-
Silver Refining Charge Income	**32,470**	1,463	1,501	1,370	1,491	1,491	1,491	1,491	1,491	1,491	1,491	1,491	1,491	1,491
Silver Minimum Deduction	**199,882**	9,818	9,818	9,818	9,818	9,818	9,818	9,818	9,818	9,818	9,818	9,818	9,818	9,818
Penalty Credits	**910**	40	40	40	40	40	40	40	40	40	40	40	40	40
Cathode premium	**-**	-	-	-	-	-	-	-	-	-	-	-	-	-
Royalty deferral	**287,281**	13,606	14,259	14,725	13,766	13,766	13,766	13,766	13,766	13,766	13,766	13,766	13,766	13,766
Net Revenue	**4,383,870**	**209,936**	**213,380**	**215,450**	**210,826**	**210,826**	**210,826**	**210,826**	**210,826**	**210,826**	**210,826**	**210,826**	**210,826**	**210,826**
Operating Costs														
Power	**(696,695)**	(33,826)	(33,826)	(33,826)	(33,826)	(33,826)	(33,826)	(33,826)	(33,826)	(33,826)	(33,826)	(33,826)	(33,826)	(33,826)
Reagents	**(213,794)**	(10,380)	(10,380)	(10,380)	(10,380)	(10,380)	(10,380)	(10,380)	(10,380)	(10,380)	(10,380)	(10,380)	(10,380)	(10,380)
Maintenance and consumables	**(228,565)**	(10,773)	(11,305)	(11,760)	(10,895)	(10,895)	(10,895)	(10,895)	(10,895)	(10,895)	(10,895)	(10,895)	(10,895)	(10,895)
Labour	**(290,857)**	(14,122)	(14,122)	(14,122)	(14,122)	(14,122)	(14,122)	(14,122)	(14,122)	(14,122)	(14,122)	(14,122)	(14,122)	(14,122)
Logistics	**(363,965)**	(17,154)	(18,002)	(18,726)	(17,349)	(17,349)	(17,349)	(17,349)	(17,349)	(17,349)	(17,349)	(17,349)	(17,349)	(17,349)
Total Opex	**(1,793,877)**	**(86,255)**	**(87,635)**	**(88,813)**	**(86,571)**	**(86,571)**	**(86,571)**	**(86,571)**	**(86,571)**	**(86,571)**	**(86,571)**	**(86,571)**	**(86,571)**	**(86,571)**
Operating Cash Flow (pre-tax)	**2,589,993**	**123,681**	**125,745**	**126,637**	**124,255**	**124,255**	**124,255**	**124,255**	**124,255**	**124,255**	**124,255**	**124,255**	**124,255**	**124,255**
Corporate Income Tax	**(35,491)**	-	(2,107)	(3,021)	(3,095)	(3,095)	(3,095)	(2,505)	(3,095)	(3,095)	(3,095)	(3,095)	(3,095)	(3,095)
Operating Cash Flow (post-tax)	**2,554,502**	**123,681**	**123,639**	**123,617**	**121,159**	**121,159**	**121,159**	**121,749**	**121,159**	**121,159**	**121,159**	**121,159**	**121,159**	**121,159**
Capital														
Project Capital	**(555,464)**	-	-	-	-	-	-	-	-	-	-	-	-	-
Sustaining Capital	**(92,464)**	(3,319)	(15,119)	(3,319)	(3,319)	(3,319)	(3,319)	(15,119)	(3,319)	(3,319)	(3,319)	(3,319)	(3,319)	(3,319)
Total Capex	**(647,928)**	**(3,319)**	**(15,119)**	**(3,319)**	**(3,319)**	**(3,319)**	**(3,319)**	**(15,119)**	**(3,319)**	**(3,319)**	**(3,319)**	**(3,319)**	**(3,319)**	**(3,319)**
Free Cash Flow (pre-tax)	**1,951,233**	121,428	121,274	121,157	118,881	118,881	118,881	119,471	118,881	118,881	118,881	118,881	118,881	118,881
Free Cash Flow (post-tax)	**1,858,770**	**118,110**	**106,155**	**117,838**	**115,562**	**115,562**	**115,562**	**104,351**	**115,562**	**115,562**	**115,562**	**115,562**	**115,562**	**115,562**
Discounted Cash Flow (pre-tax)	**413,321**	44,980	38,279	39,674	33,164	30,575	28,172	23,063	23,870	21,947	20,161	18,504	16,965	15,536
Discounted Cash Flow (post-tax)	**401,820**	**44,980**	**37,534**	**35,683**	**32,220**	**29,700**	**27,359**	**22,452**	**23,169**	**21,296**	**19,557**	**17,943**	**16,444**	**15,052**

Combined upside scenario | 300 – 450 ktpa | Pyro

7.5 Francistown Optimised Cash Flow

Description	Total (USD '000)	1	2	3	4	5	6	7	8	9	10	11	12	13
Physicals														
Concentrate tonnage (ktpa)		-	-	-	141	277	300	300	300	300	450	450	450	450
Cu metal grade (%)		0%	0%	0%	35%	37%	36%	36%	38%	36%	32%	33%	33%	33%
Ag metal grade (g/t)		-	-	-	311	352	320	364	420	376	250	276	282	253
Sulphur grade (%)		0%	0%	0%	26%	24%	24%	24%	22%	22%	23%	21%	20%	23%
Cash Flow														
Copper Price (US$/t)		6,107	8,996	8,382	7,535	7,885	7,966	8,417	9,414	8,752	8,752	8,752	8,752	8,752
Silver Price (US$/kg)		658	797	689	644	652	654	650	727	727	727	727	727	727
Sulphuric Acid (US$/t)		86	86	347	360	360	360	360	360	360	360	360	360	360
Total Commodity Value														
Copper Sales, Metal Value	**26,443,754**	-	-	-	362,680	772,054	832,107	877,266	1,023,845	912,992	1,210,489	1,263,222	1,269,312	1,267,149
Silver Sales, Metal Value	**1,787,270**	-	-	-	27,074	60,804	60,002	67,845	87,486	78,292	78,232	86,210	88,160	78,959
Sulhpuric Acid Sales, Value	**378,710**	-	-	-	6,909	12,681	14,028	13,639	12,782	12,757	19,785	17,726	17,165	19,483
Facility Revenue														
Free Metal Recovery Cu	**112,679**	-	-	-	1,545	3,290	3,546	3,738	4,363	3,890	5,158	5,383	5,409	5,399
Free Metal Recovery Ag	**98,300**	-	-	-	1,489	3,344	3,300	3,732	4,812	4,306	4,303	4,742	4,849	4,343
Free Com. Recovery H2SO4	**378,710**	-	-	-	6,909	12,681	14,028	13,639	12,782	12,757	19,785	17,726	17,165	19,483
Transport Premium	**866,100**	-	-	-	13,210	25,895	28,034	28,034	28,034	28,034	42,051	42,051	42,051	42,051
Copper Treatment Charge Income	**834,163**	-	-	-	12,723	24,940	27,000	27,000	27,000	27,000	40,500	40,500	40,500	40,500
Copper Refining Charge Income	**554,602**	-	-	-	8,835	17,974	19,174	19,133	19,965	19,148	25,166	26,263	26,389	26,344
Copper Minimum Deduction	**-**	-	-	-	-	-	-	-	-	-	-	-	-	-
Silver Refining Charge Income	**32,470**	-	-	-	548	1,215	1,196	1,359	1,567	1,402	1,401	1,544	1,579	1,414
Silver Minimum Deduction	**199,882**	-	-	-	2,730	5,421	5,884	5,852	6,545	6,545	9,818	9,818	9,818	9,818
Penalty Credits	**910**	-	-	-	40	40	40	40	40	40	40	40	40	40
Cathode premium	**3,975**				151	158	159	168	188	175	175	175	175	175
Royalty deferral	**282,310**	-	-	-	3,898	8,329	8,921	9,451	11,113	9,913	12,887	13,494	13,575	13,461
Net Revenue	**3,364,101**	**-**	**-**	**-**	**52,077**	**103,285**	**111,281**	**112,145**	**116,409**	**113,210**	**161,284**	**161,735**	**161,548**	**163,028**
Operating Costs														
Power	**(692,298)**	-	-	-	(10,559)	(20,698)	(22,408)	(22,408)	(22,408)	(22,408)	(33,612)	(33,612)	(33,612)	(33,612)
Reagents	**(348,599)**	-	-	-	(5,317)	(10,422)	(11,283)	(11,283)	(11,283)	(11,283)	(16,925)	(16,925)	(16,925)	(16,925)
Maintenance and consumables	**(176,191)**	-	-	-	(2,787)	(5,670)	(6,048)	(6,036)	(6,299)	(6,041)	(8,008)	(8,357)	(8,397)	(8,383)
Labour	**(249,918)**	-	-	-	(3,812)	(7,472)	(8,089)	(8,089)	(8,089)	(8,089)	(12,134)	(12,134)	(12,134)	(12,134)
Logistics	**(275,483)**	-	-	-	(4,358)	(8,866)	(9,457)	(9,438)	(9,849)	(9,446)	(12,521)	(13,067)	(13,130)	(13,106)
Total Opex	**(1,742,489)**	**-**	**-**	**-**	**(26,832)**	**(53,129)**	**(57,286)**	**(57,254)**	**(57,929)**	**(57,268)**	**(83,200)**	**(84,095)**	**(84,199)**	**(84,160)**
Operating Cash Flow (pre-tax)	**1,621,612**	**-**	**-**	**-**	**25,245**	**50,156**	**53,995**	**54,891**	**58,480**	**55,943**	**78,084**	**77,640**	**77,350**	**78,868**
Corporate Income Tax	**(35,491)**	-	-	-	-	-	-	-	-	-	-	-	-	-
Operating Cash Flow (post-tax)	**1,586,120**	**-**	**-**	**-**	**25,245**	**50,156**	**53,995**	**54,891**	**58,480**	**55,943**	**78,084**	**77,640**	**77,350**	**78,868**
Capital														
Project Capital	**(392,258)**	-	(42,122)	(252,734)	(42,122)	-	-	-	-	(55,279)	-	-	-	-
Sustaining Capital	**(54,805)**	-	-	-	-	(660)	(1,321)	(2,641)	(2,641)	(2,641)	(2,641)	(2,641)	(2,641)	(2,641)
Total Capex	**(447,063)**	**-**	**(42,122)**	**(252,734)**	**(42,122)**	**(660)**	**(1,321)**	**(2,641)**	**(2,641)**	**(57,920)**	**(2,641)**	**(2,641)**	**(2,641)**	**(2,641)**
Free Cash Flow (pre-tax)	**1,682,589**	-	(42,122)	(252,734)	(10,517)	63,929	68,866	70,659	77,090	17,139	99,985	100,502	100,323	101,802
Free Cash Flow (post-tax)	**1,627,784**	**-**	**(42,122)**	**(252,734)**	**(10,517)**	**63,268**	**67,545**	**68,018**	**74,449**	**14,498**	**97,344**	**97,861**	**97,682**	**99,160**
Discounted Cash Flow (pre-tax)	**428,582**	-	(39,108)	(217,852)	(8,417)	47,009	46,595	43,563	44,269	8,004	49,894	46,569	43,157	40,674
Discounted Cash Flow (post-tax)	**422,248**	**-**	**(39,108)**	**(217,852)**	**(8,417)**	**47,009**	**46,595**	**43,563**	**44,269**	**8,004**	**49,894**	**46,569**	**43,157**	**40,674**

Description	Total (USD '000)	14	15	16	17	18	19	20	21	22	23	24	25	26
Physicals														
Concentrate tonnage (ktpa)		450	450	450	450	450	450	450	450	450	450	450	450	450
Cu metal grade (%)		33%	35%	36%	33%	33%	33%	33%	33%	33%	33%	33%	33%	33%
Ag metal grade (g/t)		261	268	245	266	266	266	266	266	266	266	266	266	266
Sulphur grade (%)		21%	21%	21%	21%	21%	21%	21%	21%	21%	21%	21%	21%	21%
Cash Flow														
Copper Price (US$/t)		8,752	8,752	8,752	8,752	8,752	8,752	8,752	8,752	8,752	8,752	8,752	8,752	8,752
Silver Price (US$/kg)		727	727	727	727	727	727	727	727	727	727	727	727	727
Sulphuric Acid (US$/t)		360	360	360	360	360	360	360	360	360	360	360	360	360
Total Commodity Value														
Copper Sales, Metal Value	**26,443,754**	1,256,387	1,318,492	1,371,605	1,270,615	1,270,615	1,270,615	1,270,615	1,270,615	1,270,615	1,270,615	1,270,615	1,270,615	1,270,615
Silver Sales, Metal Value	**1,787,270**	81,678	83,819	76,483	83,222	83,222	83,222	83,222	83,222	83,222	83,222	83,222	83,222	83,222
Sulhpuric Acid Sales, Value	**378,710**	17,827	17,827	17,827	17,827	17,827	17,827	17,827	17,827	17,827	17,827	17,827	17,827	17,827
Facility Revenue														
Free Metal Recovery Cu	**112,679**	5,354	5,618	5,844	5,414	5,414	5,414	5,414	5,414	5,414	5,414	5,414	5,414	5,414
Free Metal Recovery Ag	**98,300**	4,492	4,610	4,207	4,577	4,577	4,577	4,577	4,577	4,577	4,577	4,577	4,577	4,577
Free Com. Recovery H2SO4	**378,710**	17,827	17,827	17,827	17,827	17,827	17,827	17,827	17,827	17,827	17,827	17,827	17,827	17,827
Transport Premium	**866,100**	42,051	42,051	42,051	42,051	42,051	42,051	42,051	42,051	42,051	42,051	42,051	42,051	42,051
Copper Treatment Charge Income	**834,163**	40,500	40,500	40,500	40,500	40,500	40,500	40,500	40,500	40,500	40,500	40,500	40,500	40,500
Copper Refining Charge Income	**554,602**	26,121	27,412	28,516	26,416	26,416	26,416	26,416	26,416	26,416	26,416	26,416	26,416	26,416
Copper Minimum Deduction	**-**	-	-	-	-	-	-	-	-	-	-	-	-	-
Silver Refining Charge Income	**32,470**	1,463	1,501	1,370	1,491	1,491	1,491	1,491	1,491	1,491	1,491	1,491	1,491	1,491
Silver Minimum Deduction	**199,882**	9,818	9,818	9,818	9,818	9,818	9,818	9,818	9,818	9,818	9,818	9,818	9,818	9,818
Penalty Credits	**910**	40	40	40	40	40	40	40	40	40	40	40	40	40
Cathode premium	**3,975**	175	175	175	175	175	175	175	175	175	175	175	175	175
Royalty deferral	**282,310**	13,381	14,023	14,481	13,538	13,538	13,538	13,538	13,538	13,538	13,538	13,538	13,538	13,538
Net Revenue	**3,364,101**	**161,221**	**163,575**	**164,828**	**161,847**	**161,847**	**161,847**	**161,847**	**161,847**	**161,847**	**161,847**	**161,847**	**161,847**	**161,847**
Operating Costs														
Power	**(692,298)**	(33,612)	(33,612)	(33,612)	(33,612)	(33,612)	(33,612)	(33,612)	(33,612)	(33,612)	(33,612)	(33,612)	(33,612)	(33,612)
Reagents	**(348,599)**	(16,925)	(16,925)	(16,925)	(16,925)	(16,925)	(16,925)	(16,925)	(16,925)	(16,925)	(16,925)	(16,925)	(16,925)	(16,925)
Maintenance and consumables	**(176,191)**	(8,312)	(8,722)	(9,073)	(8,406)	(8,406)	(8,406)	(8,406)	(8,406)	(8,406)	(8,406)	(8,406)	(8,406)	(8,406)
Labour	**(249,918)**	(12,134)	(12,134)	(12,134)	(12,134)	(12,134)	(12,134)	(12,134)	(12,134)	(12,134)	(12,134)	(12,134)	(12,134)	(12,134)
Logistics	**(275,483)**	(12,995)	(13,638)	(14,186)	(13,143)	(13,143)	(13,143)	(13,143)	(13,143)	(13,143)	(13,143)	(13,143)	(13,143)	(13,143)
Total Opex	**(1,742,489)**	**(83,978)**	**(85,031)**	**(85,930)**	**(84,220)**	**(84,220)**	**(84,220)**	**(84,220)**	**(84,220)**	**(84,220)**	**(84,220)**	**(84,220)**	**(84,220)**	**(84,220)**
Operating Cash Flow (pre-tax)	**1,621,612**	**77,242**	**78,544**	**78,898**	**77,628**	**77,628**	**77,628**	**77,628**	**77,628**	**77,628**	**77,628**	**77,628**	**77,628**	**77,628**
Corporate Income Tax	**(35,491)**	-	(2,107)	(3,021)	(3,095)	(3,095)	(3,095)	(2,505)	(3,095)	(3,095)	(3,095)	(3,095)	(3,095)	(3,095)
Operating Cash Flow (post-tax)	**1,586,120**	**77,242**	**76,437**	**75,878**	**74,532**	**74,532**	**74,532**	**75,122**	**74,532**	**74,532**	**74,532**	**74,532**	**74,532**	**74,532**
Capital														
Project Capital	**(392,258)**	-	-	-	-	-	-	-	-	-	-	-	-	-
Sustaining Capital	**(54,805)**	(2,641)	(2,641)	(2,641)	(2,641)	(2,641)	(2,641)	(2,641)	(2,641)	(2,641)	(2,641)	(2,641)	(2,641)	(2,641)
Total Capex	**(447,063)**	**(2,641)**	**(2,641)**	**(2,641)**	**(2,641)**	**(2,641)**	**(2,641)**	**(2,641)**	**(2,641)**	**(2,641)**	**(2,641)**	**(2,641)**	**(2,641)**	**(2,641)**
Free Cash Flow (pre-tax)	**1,682,589**	99,980	100,873	101,655	98,516	98,516	98,516	98,516	98,516	98,516	98,516	98,516	98,516	98,516
Free Cash Flow (post-tax)	**1,627,784**	**97,338**	**98,232**	**99,014**	**95,875**	**95,875**	**95,875**	**95,875**	**95,875**	**95,875**	**95,875**	**95,875**	**95,875**	**95,875**
Discounted Cash Flow (pre-tax)	**428,582**	37,070	35,277	33,187	29,863	27,725	25,741	23,899	22,188	20,600	19,126	17,757	16,486	15,306
Discounted Cash Flow (post-tax)	**422,248**	**37,070**	**34,732**	**32,503**	**29,220**	**27,129**	**25,187**	**23,385**	**21,711**	**20,157**	**18,714**	**17,375**	**16,131**	**14,577**

Combined upside scenario | 300-450 ktpa | Hydromet

End