United Nations University
Institute for Integrated Management of Material Fluxes and of Resources

Business And Natural Capital Accounting Case Study:
B2 Gold Mine Namibia

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List of Acronyms

AU	
B2Gold	B2 Gold Mine Corporation
CO_2	Carbon Dioxide
g/t	Grams per Tonne
HFO	Heavy Fuel Oil
MFCA	Material Flow Cost Accounting
NCA	Natural Capital Accounting
NCP	Natural Capital Protocol
N$	Namibian Dollar

Abstract

Mining companies globally are often challenged by issues related to waste, material efficiency, productivity and sustainability. Various businesses are now leaning toward green methods and integration of environmental systems. In this case, the material flow cost accounting (MFCA) is utilised to examine how a mining sector can improve the financial and environmental performance to overcome the status quo. This paper utilises a case-based research methodology to exemplify the application of the MFCA tool in Namibia's mining sector. The MFCA assessment was analysed using secondary data from B2 Gold reports, identifying material cost, system cost and energy cost at each quantity centre was calculated to identify inefficiencies and efficiencies in the production process of the Oshikoto B2 Gold mine. The MFCA further evaluated material and energy flows, identifying inefficiencies and hidden costs in resource usage and waste generation. The case study findings demonstrate that the overall annual savings of $65,476,300 (USD 65.5 million) were achieved through an investment of $10,000,000 (USD 10 million). The present study reveals that applying the MFCA tool significantly reduces non-product material costs, optimises energy consumption, reduces waste material handling and energy efficiency, and improves environmental performance. The findings suggest that, post-MFCA implementation, the return on invested capital of the mine increased by approximately 654.76% and the material usage cost reduced by 10.2%. This research would benefit mining operators, sustainability teams, and policymakers for effectively implementing MFCA in mines.

Keywords: Business, Biodiversity, Accountability, Ecosystems, Mining, MFCA, Sustainability,

Introduction

Mining is known to be one of the most destructive drivers of habitat, land and environmental degradation (Hahn et al.,2004). Mining has also been a cause for concern for waste and groundwater contamination (Kossoff et al., 2014). According to a report by the OECD (2018), global consumption and demand for raw materials, including those mined, will be highly sought after and most probably double by 2060. This demonstrates that there might be a surge in the expansion of mining activities and waste production due to the high demand of resources even though, globally, the mining sector only contributes approximately 2% to 3% of the world's Gross Domestic Product (GDP) (UN,2024). In Namibia, mining plays a key role, contributing to the equivalent of USD 4,263.30 million (GDP) (Central Bureau of Statistics Namibia, 2024). Additionally, the mining sector contributes to approximately 16,147 jobs, providing direct employment to individuals as of 2022, marking a 6.9% increase from 2021) (Central Bureau of Statistics Namibia, 2024).

While mining plays a vital role in economic contribution, mines often struggle to implement sustainable and environmentally safe practices as prescribed under the Mine Closure Framework of Namibia, which mandates the timely establishment and implementation of a closure plan for any particular mine. In comparison to large-scale mining operations, small-scale mines generally do not comply with and efficiently manage their resources. Leading to the extraction and depletion of resources faster than can be replenished (Cheng et al., 2023). Resource inefficiencies have been a multifaceted concern in various countries with global ramifications, leading to various United Nations global consensuses on sustainable development policies and tools for financial and environmental resource management (Melo et al., 2023). However, very few management tools have been developed in the past to account for both environmental and economic sustainability holistically. Therefore, the Material Flow Cost Accounting (MFCA) tool has been identified as beneficial for business entities that wish to enhance both environmental and financial performance (Schaltegger & Zvezdov, 2015).

Background

Figure 1: Map showing the location of B2Gold Otjikoto Mine (Source: B2Gold.com)

The Otjikoto Mine is a significant gold mine in north-central Namibia, approximately 300 kilometres from Windhoek, the Otjozondjupa region. Owned and operated by B2Gold Corp, the mine employs over 974 people and is the country's largest gold producer, generating significant revenue. Its operations combine open-pit and underground mining, with open-pit activities winding down while underground mining continues to access deeper gold deposits. Additionally, the mine processes low-grade stockpiles to optimise resource recovery (B2 Gold, 2024). Despite its economic importance, mining operations present challenges such as resource inefficiencies, environmental degradation, and socio-economic impacts on local communities. This case study used the Natural Capital (NCP) Accounting and Material Flow Cost Accounting (MFCA) framework. NCP Accounting quantifies and assigns monetary value to natural resources and ecosystem services affected by the mine, aiding in assessing trade-offs between economic activities and environmental preservation. MFCA complements this by tracking material and energy flows, identifying inefficiencies, and revealing hidden costs associated with resource losses and waste generation. Together, these tools offer a comprehensive approach to improving resource efficiency,

reducing environmental impacts, and ensuring long-term socio-economic benefits, positioning Otjikoto Mine as a model for sustainable mining practices in Namibia and beyond.

Why Natural Capital

Mining companies rely heavily on natural capital, including land, water, and biodiversity, making assessing its impact on natural capital critical. Natural Capital Accounting (NCA) provides a systematic framework to measure, value, and manage mining operations' resources and ecosystem services. By quantifying these interactions, mining companies can make informed decisions that balance economic performance with environmental sustainability and social responsibility. NCA enhances transparency, identifies inefficiencies, and highlights areas for improvement, enabling businesses to align their operations with global sustainability standards and contribute to long-term ecological resilience. This pilot case study applies Natural Capital Accounting (NCA) to B2Gold's Otjikoto Mine, one of Namibia's leading gold producers, to assess how material mining operations affect the environment. By assessing the MFCA, Mining companies can evaluate the costs and benefits of their operations and make well-informed decisions regarding resource extraction, reclamation, and environmental mitigation by calculating the value of natural resources and ecosystem services. Natural capital studies can offer important insights into the long-term profitability of mining operations and contribute to a more sustainable environmental future.

Method

The approach taken to assess the B2Gold Otjikoto Mine Namibia is the Material Flow Cost Accounting (MFCA) that analyses the materials and energy flows in the Otijkoto Mine operation. This assessment was based on the environmental impact and dependencies associated with renewable and non-renewable energy consumption, water usage and discharge, and waste produced across the mining operation. Quantifying both material inputs (resource extraction, water consumption and energy use) and the outputs (waste and emissions) gives mining companies significant information

about their environmental impact and the possible effects of their operations on the ecosystem and natural resources. The Research Nexus concept, which ties the relationship between research, innovation, and policy, has been integrated into mining operations to compare natural capital changes over various land use scenarios and identify potential benefits from enhancing or better utilising these assets in the future. B2Gold was selected as a case based on its commitment to incorporating sustainability into all aspects of its mine cycle. By doing so, the company aims to minimise its environmental impact, contribute to local economic development, and ensure a sustainable future for its operations (B2Gold, 2023).)

A process flow diagram showing the steps followed in compiling the MFCA pilot case study below:

Category	Question
Scope	What are the boundaries of the mining pilot case study?
	What are the natural capital assets relevant for each scenario?
	What are the historic land use scenarios?
	What type of ecosystems characterises each scenario?
	What are the changes in land cover for each scenario?
Measure	What are the changes in ecosystem asset extent and condition over time?
	What datasets are required to define assets and services?
	What are the changes in natural capital stocks and services (functional analysis)?
	What methods are used to measure changes in flows and stocks?
	What are the appropriate valuation methods?
Assess and Report	What are the natural capital impacts and dependencies for each scenario?
	Which impacts and dependencies are material for the case study?
	What do the monetary accounts for the B2 Gold case study reveal?
	What are the next steps?
	What are the gaps and limitations in the assessment?

Figure 2: B2 Gold Case study process diagram: adapted from Been up case study

Dependencies and Impacts

The Otjikoto Mine relies on and impacts several materials in its operations, so assessing its sustainability practices is critical. Key focus areas identified in the assessment include waste

management, energy use, resource extraction, and community engagement. The B2Gold's Otjikoto mine demonstrates a close relationship between its operations and natural resources, relying heavily on minerals, energy, water, and ecosystems. The mine depends on rich gold deposits, with 3.4 million tonnes of probable reserves and 40.97 million tonnes of indicated resources, forming the economic backbone of its activities. Energy is another critical dependency, historically powered by a hybrid plant using heavy fuel oil (HFO) and solar energy. Recent integration with Namibia's national grid has reduced fossil fuel reliance, cutting costs and greenhouse gas emissions. Water is vital for processing and dust control, while healthy ecosystems provide essential services like air and water quality regulation, underscoring the need for sustainable resource management. Table 10 below shows the most critical dependencies of the Otjikoto Mine, which heavily depends on its substantial gold reserves and resources. Of these, 3.4 million tonnes are probable reserves grading 2.07 g/t, containing 220,000 ounces of gold. Additionally, 40.97 million tonnes of indicated resources at 0.74 g/t provide 980,000 ounces, ensuring sustained operations and economic viability for B2Gold.

	100% Project Basis		
	Tonnes (x 1,000)	Gold Grade (g/t Au)	Contained Gold Ounces (x 1,000)
Probable Mineral Reserves	3,400	2.07	220
Indicated Mineral Resources	40,970	0.74	980

Figure 3: Probable mineral reserves and indicated mineral resources for B2Gold Otjikoto mine (Source: B2 Gold Mine)

Assuming a gold price of US$1,850/oz, metallurgical recovery of 98%, selling costs of US$77.92/oz including royalties and levies, and operating cost estimates of US$3.17/t mined (mining), US$12.32/t processed (processing), and US$3.87/t processed (general and administrative), the mineral resource estimates that are amenable to open pit mining methods are reported within a conceptual open pit. The cut-off grade for mineral resources that can be mined in an open pit is 0.27 g/t Au. The cut-off

grades for mineral resources that can be mined underground are 1.6, 2.40 or 3.45 g/t Au and a minimum thickness of 1.5 m (B2Gold, 2024). Despite its economic contributions, the mine's operations have notable environmental and social impacts. Mining activities can disrupt land and habitats, leading to biodiversity loss, while improper waste disposal risks contaminating water sources. In 2022, the mine emitted 126,000 tonnes of CO2 equivalent, highlighting the environmental toll of energy use, although emissions are steadily declining due to cleaner energy initiatives.

Material Flow Cost Accounting (MFCA) in the Mining Industry

Material Flow Cost Accounting (MFCA) is valuable for managing environmental impact and conducting accounting analysis. It assesses the costs associated with the flow of materials and energy (Walls et al., 2023). This case study calculates the MFCA for B2Gold's Otjikoto mine by examining essential resource components, including soil, mineral extractions, energy, and water. The cost assessment will be based on specific production and environmental data relevant to the B2Gold mine as observed, using the methodology established by Strobel and Redmann (2000).

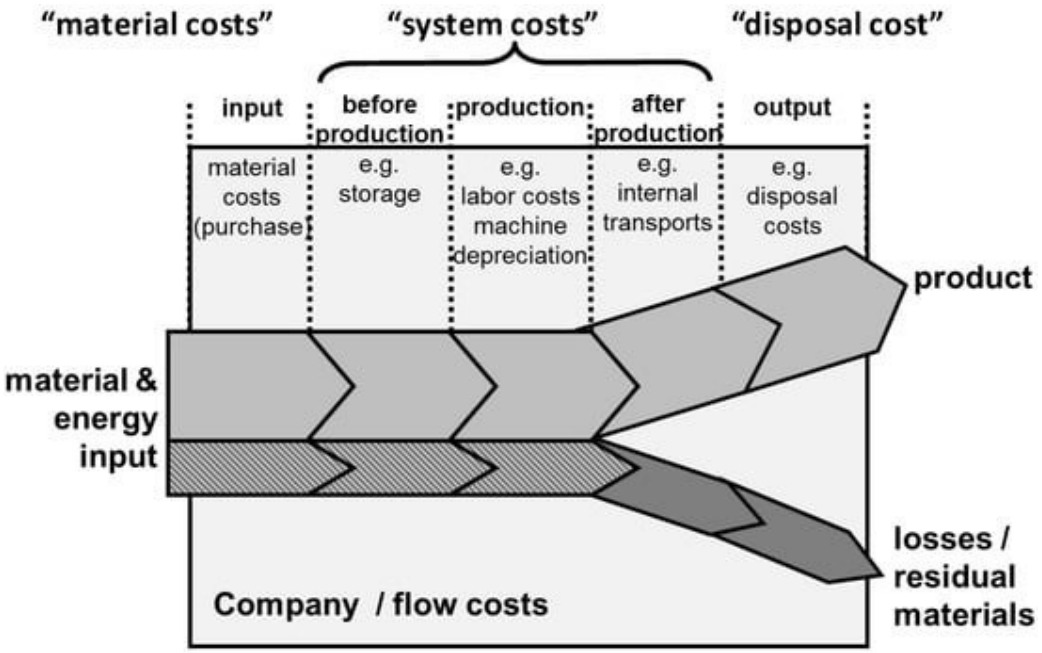
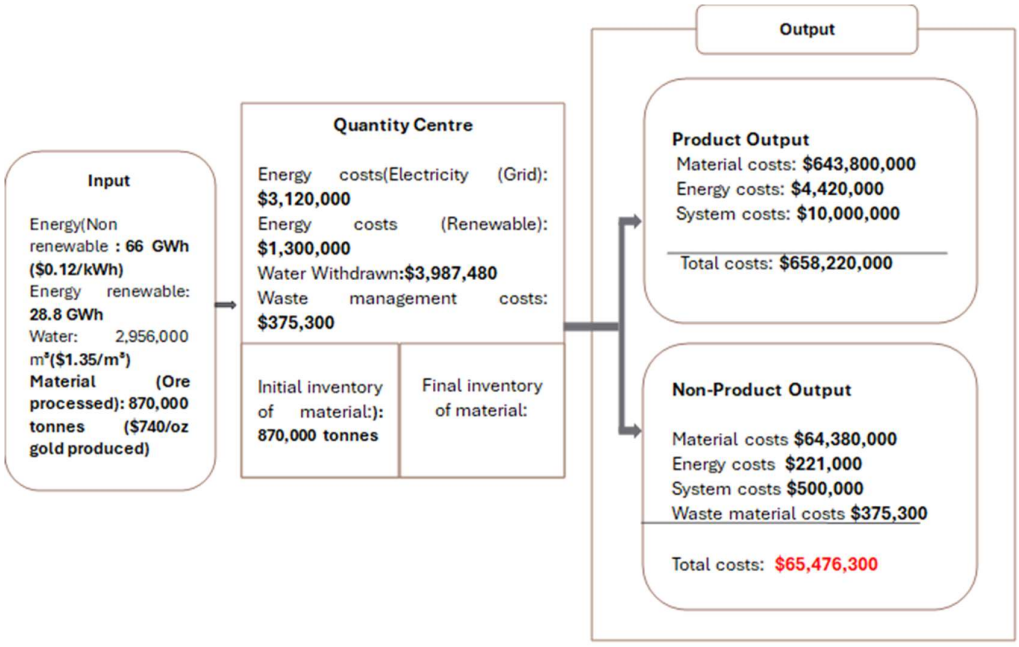


Figure 4: Distribution of various costs in the product and residual material flows. (Source: Strobel, M. & Redmann, C. (2000).

In conventional cost accounting, all expenses are assigned solely to the product. MFCA, on the other hand, distributes material costs between the final product and any residual materials, depending on their ultimate destination. Furthermore, MFCA incorporates system costs, such as those incurred during storage, processing, or transportation. These system costs are apportioned between products and residual materials using suitable key performance indicators. While physical quantities can be used for this allocation, alternative methods can be employed (Schmidt & Nakajima, 2013). For this case study, the following Material Flow Cost Account (MFCA) for Otjikoto Mine calculations were based on Otijkoto mine environmental reports and estimates:



Results and Discussion

The MFCA analysis indicates that B2Gold processes 870,000 tonnes of ore, incurring significant expenses for energy and water. Specifically, the company spends $7,920,000 on non-renewable energy, $3,456,000 on renewable energy, and $3,987,600 on water. Additionally, the MFCA reveals that the material costs for the ore processed amount to $643,800,000, with total product costs reaching $658,220,000. This total includes expenses related to energy, systems, and materials required for gold production. The assessment also tracks non-product output, such as material losses and waste management costs, which total $65,476,300. By identifying material inefficiencies and quantifying environmental costs, MFCA enables B2Gold to address areas needing improvement. This allows the company to reduce waste and increase resource efficiency, minimising its ecological footprint. Furthermore, the MFCA assessment demonstrates the importance of managing the initial and final inventory of materials, reflecting the mine's operational efficiency throughout the year. B2Gold began operations with 870,000 tonnes of processed ore and concluded with 50,000 tonnes, suggesting a significant reduction in material stockpiles as the company extracted and processed gold. This reduction highlights effective resource management while emphasising the continuous

need to balance resource extraction with sustainable practices. By understanding these material flows, B2Gold and other mines can better anticipate future resource demands, optimise energy and water usage, and improve waste management strategies. Integrating these findings will enhance B2Gold's sustainability efforts, ensuring its operations at the Otjikoto Mine thrive without compromising the long-term availability of essential resources.

Opportunities and Risk Assessments

A. Opportunities:

Mining companies integrating natural capital considerations into their operations can foster innovation and enhance efficiency. For example, adopting advanced renewable technological systems can significantly reduce operational costs, improve safety, and increase productivity (Alarifi et al., 2021). Companies prioritising sustainability position themselves strategically to attract investments and strengthen their reputation among key stakeholders, including banks, governments, consumer communities, and investors (Korzhevskyi & Mihus, 2022). Additionally, by complying with environmental and social regulations, mining businesses can secure a competitive advantage, avoiding legal cases and establishing environmentally ethical and sustainable mining practices, as highlighted by Eccles et al. (2007). Therefore, by understanding the opportunities of the mining business through natural capital accounting and MFCA, companies can maintain innovative and adaptable resource management and utilisation that considers future resource constraints.

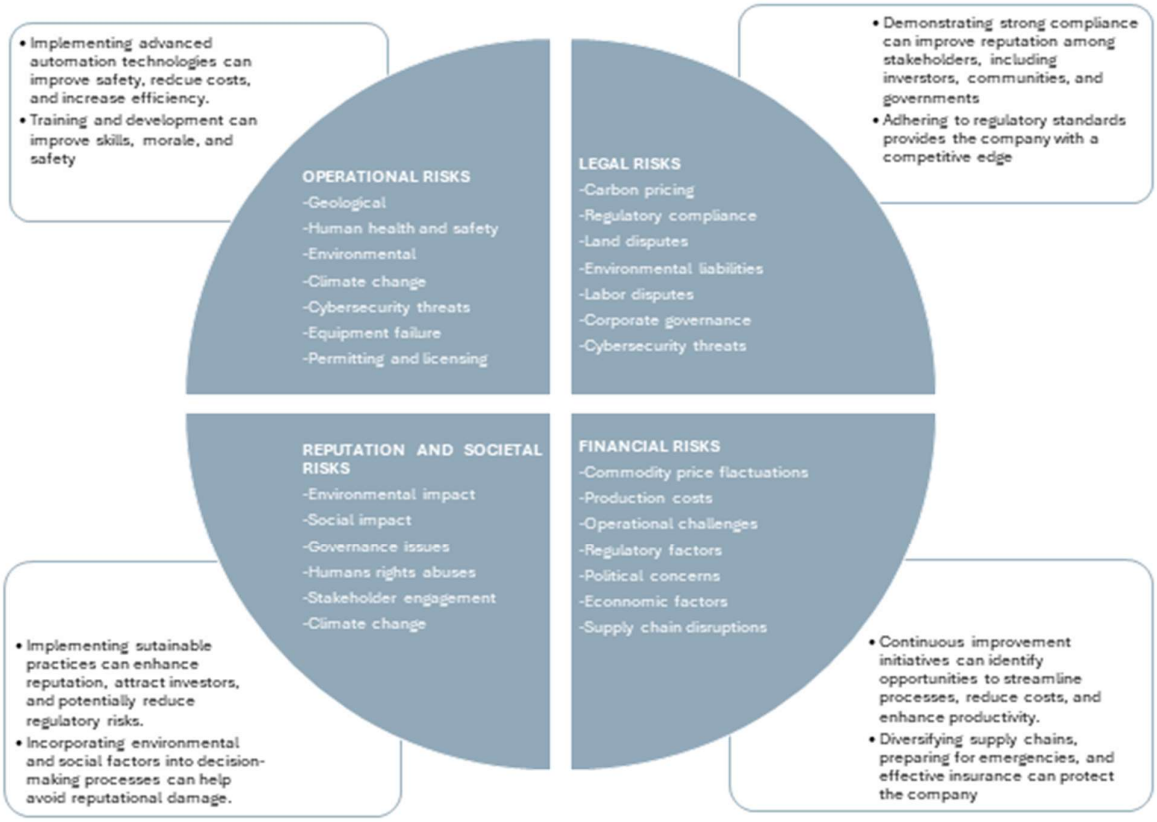


Figure 5: Opportunities and risks for B2Gold Otjikoto Mine

B. **Risks**

Risk assessment is a critical element of business management, so it cannot be neglected. Mining businesses can face significant risks if they do not comply with environmental regulations. In this case, these business risks have been identified across several dimensions. Firstly, operational risks, including resource scarcity, lack of resources, climate change impacts, and environmental degradation, can disrupt business activities and significantly reduce profitability (Joint Research Centre, 2017). Additionally, the mining business may incur reputational risks; companies that fail to address their environmental and social impacts may alienate communities and investors, jeopardising their social license to operate (National Geographic, 2019). Therefore, inefficient resource utilisation may increase mining entity vulnerability and operation costs (Arenas-Collao et

al., 2024). Moreover, businesses that fail to align environmental accounting can suffer Legal risks that result in hefty fines, lawsuits, and operational problems. These risks highlight the need for mining companies to integrate natural capital concepts into their decision-making frameworks to ensure long-term resilience and sustainability and remain competitive in a rapidly changing business environment. B2 Gold addresses these challenges through proactive mechanisms such as waste reduction initiatives, strategic plans, and land rehabilitation projects such as planting Indigenous plants in sites needing rehabilitation and using renewable energy sources. Community engagement has been another focus, fostering local development projects and reducing social tensions. By balancing its dependencies with efforts to mitigate impacts, B2Gold aims to set a responsible and sustainable mining standard.

Outcomes of the assessment

The assessment of B2Gold's Otjikoto Mine using Natural Capital Accounting (NCA) and Material Flow Cost Accounting (MFCA) highlighted critical opportunities for enhancing resource efficiency and environmental sustainability. Key outcomes include identifying inefficiencies in material and energy flows, which present opportunities to reduce costs and environmental impacts. The findings revealed that the mine's reliance on renewable energy sources, such as solar power and integration with Namibia's national grid, significantly reduced greenhouse gas emissions and operational costs, showcasing a successful transition towards sustainable energy use. Additionally, quantifying water consumption and waste generation demonstrated the need for optimised water recycling practices and effective waste management systems to mitigate environmental degradation. The assessment also demonstrated how integrating NCA into decision-making can enhance the mine's resilience to resource scarcity, climate change, and socio-environmental risks. By aligning its operations with sustainability goals, B2Gold has positioned itself as a model for responsible mining, providing a framework that other mining entities can adopt to balance economic growth with environmental stewardship.

Lessons learned and recommendations.

The B2Gold's Otjikoto Mine assessment revealed that integrating Natural Capital Accounting (NCA) and Material Flow Cost Accounting (MFCA) into mining operations fosters resource efficiency, cost reduction, and environmental sustainability. Key lessons include the benefits of transitioning to renewable energy, optimising water recycling systems, and enhancing waste management practices. These insights demonstrate the value of sustainability-oriented practices for minimising environmental impacts while improving operational resilience. Other mining operations can learn the importance of embedding sustainability into strategic decision-making to ensure long-term viability and alignment with global environmental standards.

The following recommendations have been established through the assessment:

- **Adopt Renewable Energy Sources:** Prioritise solar and other renewables to reduce greenhouse gas emissions and energy costs.
- **Implement Water Recycling Systems:** Optimise water usage through advanced recycling technologies to mitigate scarcity risks.
- **Enhance Waste Management Practices:** Develop and integrate effective waste minimisation and recycling systems.
- **Incorporate NCA in Decision-Making:** Use NCA and MFCA frameworks to align operational goals with environmental sustainability.
- **Promote Stakeholder Engagement:** Foster collaboration with local communities and governments to address socio-environmental challenges.
- **Conduct Regular Environmental Audits:** Monitor and evaluate resource use and waste generation to ensure continuous improvement.

References

B2Gold. (2023). Sustainability report 2023: Integrating environmental, social, and governance practices. Retrieved from https://www.b2gold.com.

B2Gold. (2024). Technical report on the Otjikoto Mine, Namibia. Retrieved from https://www.b2gold.com.

Strobel, M., & Redmann, C. (2000). Material Flow Cost Accounting in industrial practices: Framework and methodology. International Journal of Production Economics, 65(3), 361–370.

Walls, J., Hume, M., & Wilkes, S. (2023). Integrating MFCA into the mining industry: Addressing environmental costs. Environmental Accounting Review, 15(2), 110–125.

Hahn L, Solesbury F, Mwiya S (2004). Assessment of potential environmental impacts and rehabilitation of abandoned mine sites in Namibia. Communications of the Geological Survey of Namibia 13: 85–91.

Hoffmann T (2015) SunCalc. https://www.suncalc.org/.Accessed 15 December 2024.

Kossoff D, Dubbin WE, Alfredsson M, Edwards SJ, Macklin MG, Hudson-Edwards KA (2014). Mine tailings dams: Characteristics, failure, environmental impacts, and remediation. Applied Geochemistry 51: 229–245.

Central Bureau of Statistics, Namibia. (2024). *GDP from mining in Namibia*. Retrieved from https://tradingeconomics.com/namibia/gdp-from-mining

Cheng, S., Shu, C., Jin, M., & He, Y. (2023). Balancing resources and sustainability: Analyzing the impact of mineral resources utilisation on green growth. Resources Policy, 86(Part A), Article 104143. https://doi.org/10.1016/j.resourpol.2023.104143.

Costa Melo, I., Queiroz, G. A., Alves Junior, P. N., de Sousa, T. B., Yushimito, W. F., & Pereira, J. (2023). Sustainable digital transformation in small and medium enterprises (SMEs): A review on performance. Heliyon, 9(3), e13908. https://doi.org/10.1016/j.heliyon.2023.e13908.