A Valuation Framework considering the effects of climate change legislation and demand trends: The case of Freeport McMoRan

Agustín Gomez & Arnau Domènech

June 2024

Abstract

The goal of this paper is to present a novel valuation framework that integrates traditional valuation frameworks with a detailed assessment of climate-related risks, legislative costs, and demand trends. The framework is specifically designed for leading global mining company Freeport McMoRan, studying the mining industry's substantial positive and negative potential catalysts within the energy transition trend. Building from the Discounted Cash Flow (DCF) method, the framework incorporates 4 scenarios; a "Base Case" assuming current conditions, a "Net Zero Emissions" assuming increased legislative pressure and increased copper demand because of current Net Zero by 2050 goals, a "Mid-Point" as an average of both, and a Monte Carlo Simulation to explore a spectrum of probable outcomes. This multiple scenario methodology paired with a Monte Carlo simulation provides a nuanced view of future valuation under varying environmental, economic, and legislative landscapes. The findings suggest that costs related to carbon pricing regulations are substantially offset by positive copper price and demand dynamics, even in the scenarios where legislative assumptions are more optimistic.

We thank Didier Saintot, our supervisor, and Jerome Blin for their guidance and support.

Table of Contents

1 Introduction

With climate change becoming the defining challenge of the 21st century, the global economy faces the challenge of mitigating environmental degradation whilst maintaining sustainable growth. Few industries exemplify this duality better than the mining industry, especially those companies that are involved in the extraction and transformation of the denominated Critical Raw Materials (CRMs). This is because mining companies, characterized by a significant environmental footprint due to its resource extraction practices, are also one of the most key players in this transition as suppliers of the key metals needed to make the energy transition and decarbonization of the global economy a reality. Freeport-McMoRan (FCX) is perhaps one of the best examples of this duality. A global leader in the mining of copper, gold, and molybdenum, FCX operates at the dynamic crossroad of increasing environmental scrutiny and regulation, and increasing demand for its main product, a vital raw material for the energy transition, copper.

This thesis proposes a novel valuation framework tailored specifically for Freeport-McMoRan, with the aim of incorporating to traditional valuation methods a detailed understanding of the potential climate risks and legislative costs inherent to a global shift towards Net Zero emissions by 2050, and its impact on the company's value. The proposed valuation framework is rooted in the Discounted Cash Flow (DCF) method, a cornerstone financial modeling tool, and is extended to include a set of three tailored scenarios, each underpinned by distinct assumptions about future environmental, economic, and policy landscapes. The "Base Case" (BC) Scenario assumes a 'business as usual' approach where existing operational, economic, and regulatory conditions persist over the forecast period. The "Net Zero Emissions" (NZE) Scenario assumes the gradual adoption of all the necessary legislations and demand trends necessary to advance towards the Net Zero by 2050 climate objective. This scenario incorporates assumptions such as increased demand and prices for copper, driven by its critical role in green technologies and energy transition, and the widespread implementation of robust carbon pricing systems. Finally, the "Mid-point" Scenario is simply an average between the Base Case and Net Zero Emissions scenarios. Additionally, a Monte Carlo simulation is employed to conciliate the assumptions and explore a spectrum of probable outcomes, facilitating a more nuanced view of the company's valuation. By analyzing in detail how different climate-related scenarios could impact the company's future cash flows and valuation, this research provides critical insights into the interplay between mining operations and sustainable practices, and between a path to decarbonization and the financial performance of mining companies.

2 Literature Review

Recent literature has studied how the effects of climate change and its related mitigating policies can impact the valuation of companies.

In their 2021 paper "How carbon pricing affects values of firms: The case of oil and gas companies", Franck Bancel and Henri Philippe address how growing awareness and regulatory measures related to climate change are influencing financial assessments of companies, with a clear focus on how carbon taxes and emissions trading systems affect company assets due to the cost of carbon emissions being factored into financial valuations. This article highlights the emergence of a carbon risk premium and examines the phenomenon of stranded assets, where fossil fuel-based assets might become devalued under stringent climate policies aimed at reducing carbon emissions. This points to the potential overvaluation of fossil assets, following the hypothesis that current market prices do not accurately reflect future cash flows, as they might be significantly restricted by policy changes. Like our paper, Bancel and Philippe (2021) employ a scenario analysis where the impact of different levels of carbon pricing are considered, concluding that current financial models are inadequate for a context with growing uncertainties and long-term impacts as part of the nature of climate change, and suggesting the enforcement of more stringent disclosures of carbon emissions and climate-related risks (Bancel and Philippe, 2021). Similarly, Kruger (2015) studied the impact of mandatory Green House Gas (GHG) emissions disclosures for listed companies in the London Stock Exchange using a difference-in-difference approach on the stock prices and compares firms that were already voluntarily disclosing GHG emissions ("Quasi-compliant") with firms that began disclosing GHG emissions only after the regulation ("non-compliant"). The paper finds significant positive valuation effects for firms that were heavily affected by the regulation (especially the "non-compliant"), indicating that the market values increased transparency, although there was no evidence of the regulation translating into real operations such as capital expenditures or operational efficiencies. These findings suggest that GHG disclosures leads to higher firm valuations, especially for larger firms and those in carbon-intensive industries, primarily through capital markets effects (value of increased transparency) instead of operational changes.

Other studies have focused on studying how asset prices can be impacted by disasters and environmental changes. Pagano et.al. (2023) explored how asset markets responded to the Covid-19 pandemic. The paper developed a theoretical model that incorporated the concept of stochastic disaster risk and accounted for the updating of investors' beliefs about the possibility of disaster as it unfolded and paired it with a regression analysis that related firm resilience (how jobs in different sectors could adapt to remote work and social distancing) to changes in expected and realized stock returns in different phases of the pandemic. Pagano et al. (2023) found that there was a positive relationship between firm resiliency and stock market returns, and that different measures of resilience – financial, operational, environmental – played distinct roles in how firms' risks are priced in the market. Additionally, a very important finding was that even after the most extreme phase of the pandemic ended the market continued to price the disaster resilience of firms, suggesting that shocks can force a long-term actualization of beliefs in investors as long as the risk of disasters is still material. On the other hand, Addoum et.al. (2023) showed how extreme temperatures can affect corporate profitability across industries and how sell-side analysts interpret said relationship. The study takes daily data on temperatures across the United States and correlates it with the locations of public companies to create a detailed panel of quarterly firm-level temperature exposures, and then uses regression techniques to establish a relationship between temperature exposure and changes in expected and realized stock returns. The study is able to find that extreme temperatures can significantly impact earnings in more than 40% of the industries analyzed, with varying effects depending on the seasons, and with sectors like consumer discretionary, industrials, utilities, and healthcare showing particular sensitivity. The study also finds that, although sell-side analysts and investors do not tend to immediately react to intra-quarter temperature shocks, earnings forecasts at the end of the quarter do incorporate temperature-related effects, showing the market's delayed adjustment to climate-related information. This is, of course, very relevant to our study, as it shows that the more extreme global temperatures become due to climate change, the more volatility we can expect from company earnings and valuations.

As we have also mentioned in the introduction, a very relevant part of our study focuses on developing an understanding of how existing and upcoming (or expected) legislations can impact the valuation of Freeport McMoran. To do so we take advantage of existing literature that has researched how climate-related legislations and policies have impacted the mining sector. One such paper is Yıldız et.al. (2024), which examines how the Turkish mining sector has adapted to EU-compliant mining waste regulations adopted in 2015, involving the characterization, classification, storage, management, and recovery of mineral waste. The paper finds that these regulatory changes resulted in increased operational costs for Turkish mining companies and calls for refinement (especially when it comes to recovery) to better adapt the policies to the specific needs of the Turkish mining sector and make them more cost-effective.

Other studies, although not based on real-life examples, have also researched the potential effects of policies like the establishment of emission trading systems or green construction policies on the mining industry. Zhang et.al. (2023) approaches the study of the implications of the China Emissions Trading Policy (CETP) in the mining industry according to the Porter hypothesis. Using a difference-in-difference approach and data from 31 provinces from 2006 to 2019, the paper finds that the CETP had a negative impact on the business performance of the sector, with increased costs from compliance not translating into financial benefits. Furthermore, the study finds that the CETP caused no improvement in Green Total Factor Productivity (GTFP) in the sector, indicating weak Porter effects where regulatory costs are supposed to be offset by gains in productivity. This finding is contrasted by an increase in the level of scientific and technological innovation, further aligning with the weak Porter hypothesis stating that regulations can stimulate innovation even if they do not directly enhance productivity. Previous research by Qi et al. (2019) simulated the effects of environmental taxes and subsidies under China's Green Mining Construction (GMC) policies on the performance and productivity of the coal industry. Using a Systems Dynamics (SD) model integrating the Malmquist-Luenberger index of productivity, the paper found that those companies that emphasized technical innovation and environmental protection over scale expansion would outperform, although with a time lag. The study also found, like the findings from Zhang et.al. (2023), that GMC policies initially reduced the Green Total Factor Productivity of mining companies.

Finally, this paper provides valuable context to existing literature studying the effects of sustainability signaling on financial markets and investor's decision-making. Studies like Guidry and Patten (2010) and Jacobs et.al. (2010) both used event study methodology to study how sustainability signals like announcements of self-reported Corporate Environmental Initiatives (CEIs) and third-party Environmental Awards and Certifications (AECs) effects market value. An interesting result from Jacobs et.al. (2010) is that investors seem to react distinctly to self-reported and third-party reported signals. One of the most well-known papers in this field is that from Hartzmark and Sussman (2019), who studied the effects that Morningstar's first issuance of their sustainability rating system had on fund flows, finding that low-sustainability rated funds had net outflows of more than $12 billion while high-sustainability rated funds had net inflows of $24 billion (Hartzmark and Sussman, 2019). Furthermore, Hong and Kacperczyk (2009) studied the effects of endogenous non-financial factors like whether a company is perceived as a "sin" according to social norms. Concretely their study found that stock of companies that are perceived as "sins", such as tobacco, alcohol, or gun manufacturing companies, tend to have lower presence in the holdings of norm-constrained institutions and show higher risk premiums (Hong and Kacperczyk, 2009). This paper's study on the concrete financial implications of climate-related factors at the company level can provide very valuable context to this existing literature and provide a better understanding of the degree to which investor reactions to sustainability signaling are rational or irrational.

2.1 Hypothesis

Relying on the findings of existing literature, and the understanding that mining companies like Freeport McMoRan (FCX) have substantial negative and positive catalysts within the context of the energy transition and the Net Zero by 2050 pathway, the main hypothesis of this paper is that the positive effects coming from demand increase of copper will largely offset the negative effects of legislative costs and carbon pricing mechanisms.

3 Freeport McMoRan

Freeport McMoRan ("Freeport") is a leading international mining company with headquarters in Phoenix, Arizona, that operates large, long-lived, geographically diverse assets with significant proven and probable mineral reserves of copper, gold and molybdenum. Freeport is one of the world's largest publicly traded copper producers with a portfolio of assets that includes the Grasberg minerals district in Indonesia, one of the world's largest copper and gold deposits, and significant mining operations in North America and South America, including the large-scale Morenci minerals district in Arizona and the Cerro Verde operation in Peru. Copper production accounted foremost of Freeport's revenue in 2023, with its largest operations being the Grasberg minerals district in Indonesia - one of the world's largest copper and gold deposits -, the Morenci minerals district in Arizona, and the Cerro Verde operation in Peru.

Freeport's proven reserves are quite dispersed when it comes to geographic location. In North America Freeport operates seven copper mines - Morenci, Bagdad, Safford (includes three copper deposits the only one mined at the moment being Lone Star), Sierrita and Miami in Arizona. Also in North America but in the state of New Mexico Freeport operates the Chino and Tyrone mines, and two molybdenum mines – Henderson and Climax - in Colorado. As a result, Freeport's North American operations holds 43% of its total copper reserves, 2% of gold, and 80% of molybdenum. In South America, Freeport operates two copper mines – Cerro Verde in Peru and El Abra in Chile -, which represent 29% of FCX's copper reserves and 20% of molybdenum. Finally, in Indonesia Freeport's subsidiary (with a 48.76% ownership) PT-FI, operates three large-scale underground mines (Grasberg Block Cave, Deep Mill Level Zone (DMLZ), and Big Gossan) in the Grasberg minerals district among the remote highlands of the Sudirman Mountain Range, which represents 28% of copper and 98% of gold reserves. The location of proven reserves somewhat correlates with the consolidated copper, gold, and molybdenum production. North America represents 32% of total copper production, 1% of gold, and 73% of molybdenum, whereas South America represents 29% of copper and 27% of molybdenum production, and Indonesia 39% of copper and 99% of gold production (FCX 10k, 2023).

3.1 Operations

Although FCX considers its "material mines" (under the disclosure requirements of Subpart 1300 of SEC Regulation S-K) to only be the Morenci, Cerro Verde, and Grasberg mines, and thus they are the only ones with Technical Report Summaries available, we believe that to fully understand FCX's operations and the scope of this paper, it is important to develop a more exhaustive view of each of the mines (and other infrastructure) in FCX's portfolio.

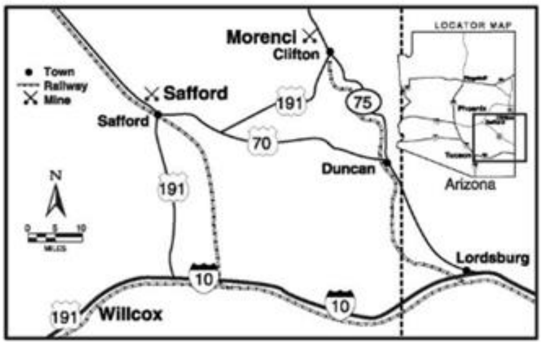

Figure.1: Morenci & Safford mines (FCX 10k, 2023)

Starting with the mines in North America, we have one of FCX's most important mines, Morenci. Morenci, a 72% -28% partnership between FCX and Sumitomo Metal Mining, is an open-pit copper mining complex situated in the Greenlee County in Arizona, that has been in continuous operation since 1939. FCX started operating in the site when it acquired Phelps Dodge & Company, who had operated in the area since 1880, in 2007. A porphyry copper deposit (copper ore bodies originated from hydrothermal fluids), Morenci consists of two concentrators with a milling design capacity of 132,000 metric tons of ore per day (both copper and molybdenum), a 72,500 metric ton-per-day crushed-ore leach pad and stacking system, a low-grade run-of-mine (ROM) leaching system, four Solvent Extraction (SX) plants, and three Electrowinning (EW) tank houses (with a total capacity of 900 million pounds per year) that produce copper cathode by the Solvent Extraction and Electrowinning (SX/EW) method. Morenci's available fleet consists of 141 haul trucks with 235-metric-ton capacity each, which can move on average 785,000 metric tons of material per day. FCX's share of Morenci's net PP&E and mine development costs totaled $2.2bn on December 31, 2023. As a result, Morenci's consolidated production totaled 0.8bn pounds of copper and 3mn pounds of molybdenum in 2023. Finally, the Morenci operation expands over 61,700 acres (51,300 of fee lands and 10,400 of unpatented mining claims under public mineral estate and federal permits, easements and rights-of-way), and has its electrical power supplied by FCX's wholly-owned subsidiary The Morenci Water & Electric Company, which in turn sources its generation services through another of FCX's wholly-owned subsidiaries Freeport-McMoRan Copper & Golds Energy Services LLC, which acquires capacity rights from the Luna Energy facility in Deming, New Mexico and other purchasing power agreements (FCX 10k, 2023).

Fifty miles southwest of the Morenci mine sits the Safford mine, another open-pit copper mining complex operative since 2007 that includes three copper deposits, the only one currently mined being Lone Star. Lone Star began leaching operations in 2020 with a designed production capacity of 200mn pounds of copper per year but has plans to increase volumes up to 300mn pounds per year. The operation has a capacity of 103,500 metric tons of ore per day, which are fed into a SX/EW facility with a copper cathode production capacity of 305mn pounds per year. Safford's fleet consists of 59 235-metric-ton haul trucks, capable of moving on average 408,000 metric tons of material per day. The net PP&E and mine development costs totaled $1.4bn on December 31, 2023. Furthermore, current drilling has indicated the likely opportunity of producing sulfide ores in the future, with metallurgical testing and mine development planning for a significant expansion expected to commence during 2024 (FCX 10k, 2023).

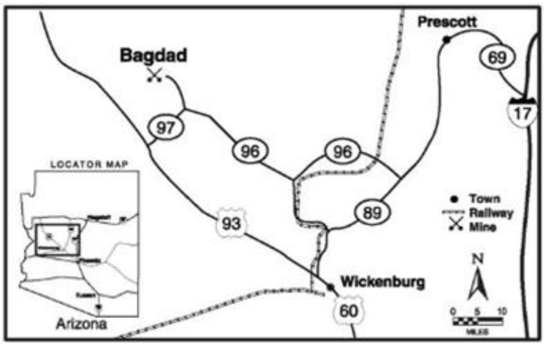

Figure.2: Bagdad mine (FCX 10k, 2023)

The Bagdad mine is a wholly owned open-pit copper and molybdenum mine in the Yavapai County in west-central Arizona, which has been in continuous operation since 1945. Like Morenci, Bagdad is a porphyry copper deposit containing both sulfide and oxide mineralization. The operation consists of a single concentrator with a capacity of 77,100 metric tons of copper and molybdenum ore per day, a SX/EW plant with capacity to produce 9mn pounds per year of copper cathode, and a pressure-leach plant to process molybdenum concentrate. The available fleet consists of 35 235-metric-tonhaul trucks capable of moving 236,000 metric tons of material per day. The PP&E and mine development costs of the mine totaled $0.8bn on December 31, 2023. Bagdad's total production in 2023 was of 146mn pounds of copper and 10mn pounds of molybdenum. Additionally, FCX is studying an expansion of the project to more than double the capacity of the concentrator to between 165,000 and 185,000 tons of ore per day, supported by Bagdad's reserve life exceeding 80 years. Such expansion would require incremental capital costs of $3.5bn and is expected to increase final production by 200-250mn pounds per year. Nevertheless, project economics suggest that the expansion would only be possible with an incentive copper price between $3.50 to $4.00 per pound (which is within the projected copper prices as we will see in the Copper Price subsection and the Methodology) and would take 3-4 years to complete. The Safford operation expands over 78,300 acres (37,700 of fee lands and 40,600 of unpatented claims held on public mineral estate) and, contrary to the Morenci and Safford mines, Bagdad receives electrical power from the Arizona Public Service Company (FCX 10k, 2023).

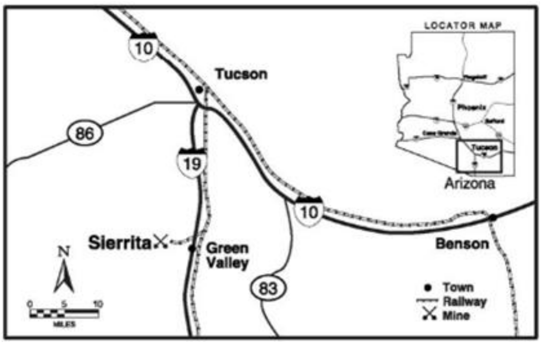

Figure.3: Sierrita mine (FCX 10k, 2023)

The Sierrita mine also a wholly owned open-pit copper and molybdenum mining complex in the pima County in Arizona which has been in operation since 1959. Also, a porphyry copper deposit, the Sierrita operation includes a single concentrator with a capacity of 100,000 metric tons of copper and molybdenum ore per day, an ROM oxide-leaching system, the Twin Buttes EW facility where copper cathode is plated which has a design capacity of 50mn pounds of copper per year, and molybdenum facilities consisting of a leaching circuit, two molybdenum roasters and a packaging facility. The molybdenum facilities in the Sierrita complex process molybdenum concentrate from the Sierrita mine as well as other mines and third-party sources. Sierrita's available fleet has 24 haul trucks of 235-metric-ton capacity which are capable of moving an average of 200,000 metric tons of material per day. The PP&E and mine development costs of the operation totaled $0.8bn on December 31, 2023. Total production at the Sierrita operation in 2023 totaled 185mn pounds of copper and 18mn pounds of molybdenum. The Sierrita operation, including the Twin Buttes facility, expands over 47,700 acres (38,700 of fee lands and 9,000 of unpatented claims held on public mineral estate), and receives electrical power through long-term contracts with the Tucson Electric Power Company (FCX 10k, 2023).

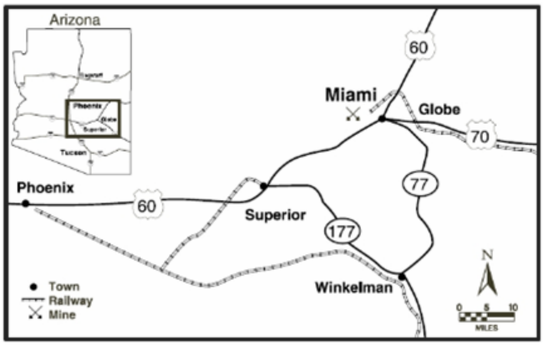

Figure.4: Miami mine (FCX 10k, 2023)

The Miami mine is another of FCX's wholly owned open-pit copper mines. A porphyry copper deposit, the Miami mine is located in the Gila County in Arizona and has been processing copper using flotation and leaching technologies since 1915. Given that the operation is no longer mining copper ore, Miami consists solely of a SX/EW plant with a capacity of 200mn pounds of copper per year that produces copper through leaching the material already on its stockpiles. Miami's net PP&E and mine development costs totaled $9mn on December 31, 2023. Total production of copper in the Miami operation was 12mn pounds in 2023. The operation extends over 14,800 acres (14,400 of fee lands and 4,400 of unpatented mining claims held on public mineral estate), and receives electrical power and natural gas through long-term contracts with the Salt River Project and the El Paso Natural Gas (as transporter) respectively (FCX 10k, 2023).

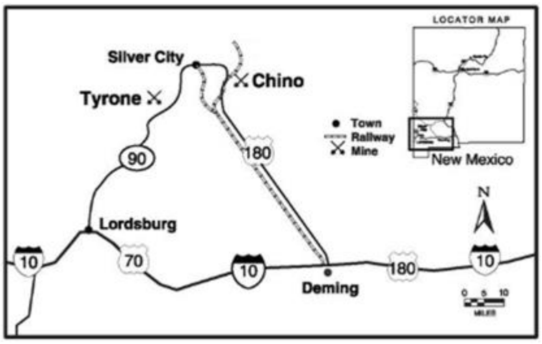

Figure.5: Chino & Tyrone mines (FCX 10k, 2023)

The Chino operation is an open-pit mining complex located in the Grant County in New Mexico, which has been in operation since 1910. Also a porphyry copper deposit, the operation consists of a single concentrator with a design capacity of 36,000 metric tons of ore per day to create copper concentrate, as well as a ROM leaching plant and a SX/EW plant that produces 150mn pounds of copper cathode per year. The available fleet consists of 19 haul trucks with 240-metric-ton capacity, capable of moving an average of 180,000 metric tons of material per day. The net PP&E and mine development costs of Chino totaled $0.5bn on December 31, 2023. Over the past three years the operation has been running at a 50% capacity, with copper production in 2023 totaling 141mn pounds. The operation expands over 127,800 acres (110,000 of fee lands and

17,800 of unpatented mining claims held on public mineral estate), and like the Morenci mine it receives electrical power from the Luna Energy facility and from the open market when necessary. Also in the Grant County in Arizona, we can find FCX's wholly owned **Tyrone** open-pit copper mining complex. Also a porphyry deposit, the complex has been operational since 1967. The complex consists of a SX/EW plant with a maximum capacity of 100mn pounds of copper cathode per year, and a fleet of 9 haul trucks with 240-metric-ton capacity capable of moving on average 108,000 metric tons of material per day. The net PP&E and mine development costs of the operation totaled $0.1bn on December 31, 2023. Like the Chino mine, Tyrone has also been operating at close to 50% capacity, with its copper production totaling 51mn pounds in 2023. The Tyrone operation expands over 80,700 acres (67,700 fee lands and 13,000 of unpatented mining claims held on public mineral estate) and receives electrical power from the Luna Energy facility and the open market as well (FCX 10k, 2023).

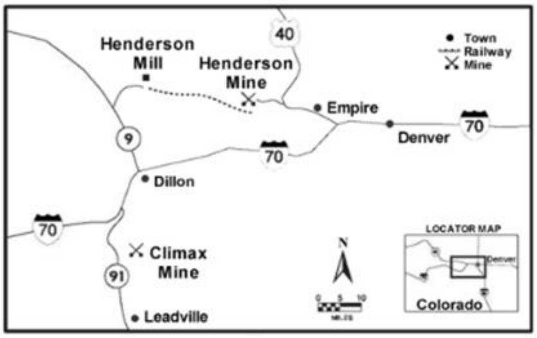

Figure.6: Climax & Henderson mines (FCX 10k, 2023)

In the state of Colorado, we can find FCX's Climax and Henderson mines. Climax is a wholly owned open-pit molybdenum mine located near Leadville in Colorado. Under its previous owner the site was placed on care and maintenance status in 1995, but after being acquired it began commercial production in 2012. The complex includes a mill facility with the capacity for 25,000 metric tons of ore per day, which results in an approximate capacity of 30mn pounds of molybdenum per year. Climax's available fleet consists of 11 haul trucks with 177-metric-ton capacity capable of moving on average 90,000 metric tons per day. The net PP&E and development costs totaled $1.3bn on December 31, 2023. Over the past volatile three years the mine has been operating at 75% capacity with molybdenum production totaling 17mn pounds in 2023. The operation expands over 15,100 acres (14,300 privately owned and 800 federal claims) and receives electrical power through long-term contracts with Xcel Energy and natural gas supply with united Energy Trading (with Xcel as the transporter) (FCX 10k, 2023).

The Henderson operation is a wholly owned molybdenum underground mining complex located close to Denver in Colorado and that has been in operation since 1976. The operation consists of a block-cave system feeding a concentrator with a design capacity of 32,000 metric tons per day and 15mn pounds of molybdenum per year. The Henderson mill is located 15 miles west of the mines, and both are connected by a 10-mile conveyor tunnel and a 5-mile surface conveyor. The available underground mining equipment fleet consists of 15 load-haul-dumps (LHD) with 9-metric-ton capacity each, which deliver ore to a gyratory crusher that feeds a series of 3 overland conveyors to the mill stockpiles. The net PP&E and development costs of the mines totaled $0.2bn on December 31, 2023. Most of the molybdenum concentrate produced is shipped to FCX's Fort Madison processing facility in Iowa, and Henderson's production for 2023 totaled at 13mn pounds. The operation expands over 17,200 acres (13,00 of fee lands, 4,200 of unpatented claims on public mineral estate, and a 50-acre easement with the US Forest Services for the surface portion of the connecting conveyor) and receives electrical power and natural gas through the same agreements as Climax (FCX 10k, 2023).

Contrary to the mines in the Arizona state, the Climax and Henderson mines are in a mountainous region that experiences heavy snowfall during the winter months.

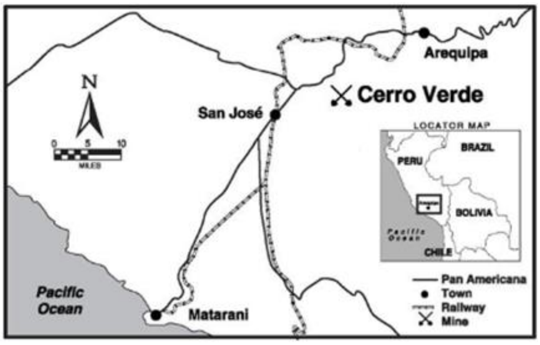

Figure.7: Cerro Verde mine (FCX 10k, 2023)

Continuing with FCX's South American projects, located 20 miles southwest of Arequipa in Peru we find the Cerro Verde open-pit copper and molybdenum mining complex. One of FCX's most important projects, it is 53.56% owned by FCX with the remaining 46.44% shared between SMM Cerro Verde Netherlands B.V (21.0%), Compañia de Minas Buenaventura S.A.A. (19.58%) and other stakeholders owning publicly traded shares on the Lima Stock Exchange (5.86%) and has been operating since 1976. The porphyry copper deposit mine used to be operated by the Peru government until it was acquired in 1994 by a predecessor of Phelps Dodge. Cerro Verde's operation consists of two concentrating facilities with an annual average permitted milling capacity of 409,500 metric tons of ore per day (with the ability to annually treat an excess 5% for a total of 430,000). Due to several efficiency initiatives during the past couple of years in 2023 Cerro Verde's concentrators were able to achieve a combined average milling rate of 417,400 metric tons of ore per day in 2023. Additionally, Cerro Verde operates SX/EW leaching facilities with a production capacity of 200mn pounds of copper per year and a 100,000-metric-ton-per-day ROM leach system. The operation had a crushed leach facility with a capacity of 39,000 metric tons of ore per day which it started dismantling in in 2023 because of a pit expansion. The fleet consists of 54 haul trucks of 300-metric-ton capacity (1 currently on stand-by), 93 haul trucks of 250-metric-ton capacity (10 currently on standby), and 7 leased haul trucks of 380-metric-ton capacity. This fleet can move an average of 1,000,000 metric tons of material per day. Net PP&E and development costs for Cerro Verde totaled $5.9bn on December 31, 2023. Cerro Verde's production totaled 1.0bn pounds of copper and 22mn pounds of molybdenum in 2023. Cerro Verde has a mining concession over approximately 175,000 acres, including 62,000 acres of surface rights, access to 14,600 acres granted through an easement from the Peru National Assets Office, 151 acres of owned property, and 1,151 acres of rights-of-way outside the mining concession area. The operation receives electrical power (including hydro-generated) through long-term contracts with ElectroPeru and Engie Energia Peru S.A. Additionally, Cerro Verde is enhancing its sustainability entering into a new power purchase agreement in 2023 that is expected to transition to fully renewable sources by 2026, as well as sourcing the water for its processing operations from renewable sources through a series of storage reservoirs on the Rio Chili watershed that collects seasonal precipitation water and wastewater from the city of Arequipa. Finally, we must note that the environment in which Cerro Verde is located is an active seismic zone (FCX 10k, 2023).

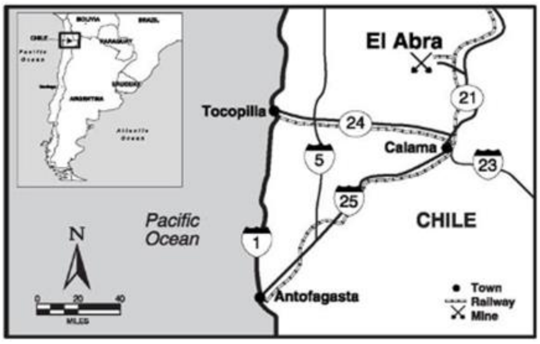

Figure.8: El Abra mine (FCX 10k, 2023)

The El Abra mine is 51% owned by FCX, with the remaining 49% interest held by state-owned Corporación Nacional del Cobre de Chile. It is an open-pit copper mining complex located in Chile's El Loa province, and it has been in operation since 1996. The operation consists of a SX/EW facility with a capacity of 125,000 metric tons of ore per day and 500mn pounds of copper cathode per year, and a ROM leaching operation. The available fleet consists of 23 haul trucks of 242-metric-ton capacity which can move 217,000 metric tons of material per day. Net PP&E and development costs of the mine totaled $0.8bn on December 31, 2023. El Abra's copper production totaled 217mn pounds in 2023. Additionally, a large sulfide resource has been identified, which would support a major mill project akin to the large-scale concentrator at Cerro Verde, although technical, environmental and economic studies are still underway. The project extends over 183,900 acres of mining claims covering the ore deposit, stockpiles, process plant, water wellfield, and pipeline. Additionally, El Abra has surface rights for the road connecting the processing plant with the rest pf the infrastructure. Electrical power is received under long-term contracts with Engie Energia Chile S.A. and water for the processing operations from the groundwater of the Salar de Ascotán aquifer. Like Cerro Verde, El Abra is located in an active seismic zone (FCX 10k, 2023).

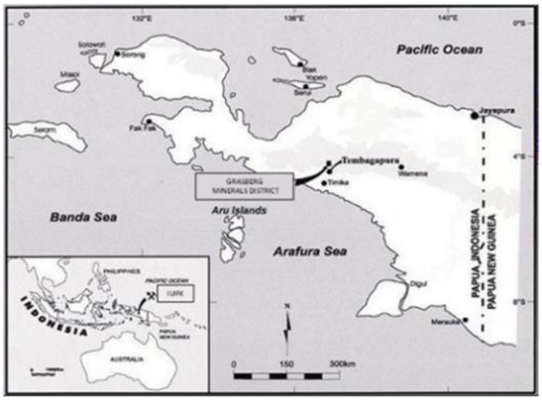

Figure.9: FCX's Indonesia Operations (FCX 10k, 2023)

Like we mentioned before, Freeport's Indonesia operations are one of the firm's most important. FCX operates in Indonesia through its subsidiary PT-FI, which is a limited liability company under the regulatory regime of the Republic of Indonesia. On December 21st 2018 FCX bought from the Indonesian government the long-term mining rights and the share of PT-FI, resulting in a shared ownership where FCX has 48.76% of PT-FI and the remaining 51.24% is collectively owned by PT Mineral Industri Indonesia (MIND ID) – an Indonesia state-owned company – and PT Indonesia Papua Metal Dan Mineral, which is expected to be owned by MIND ID in the Central Papua region. After closing the 2018 operation, the Indonesia government granted PT-FI a special mining license (IUPK) to conduct operations in the Grasberg mineral district until 2041, subject to PT-FI constructing additional domestic smelting and refining capacity and fulfilling its defined fiscal obligations. By the end of 2023, progress of the Manyar smelter and precious metals refinery (PMR), which groups all the Indonesian smelter projects, was measured at over 90%. The government is currently updating regulations that would enable PT-Fi to apply for an extension beyond 2041, enabling the continuity of large-scale operations and potential expansions (FCX 10k, 2023).

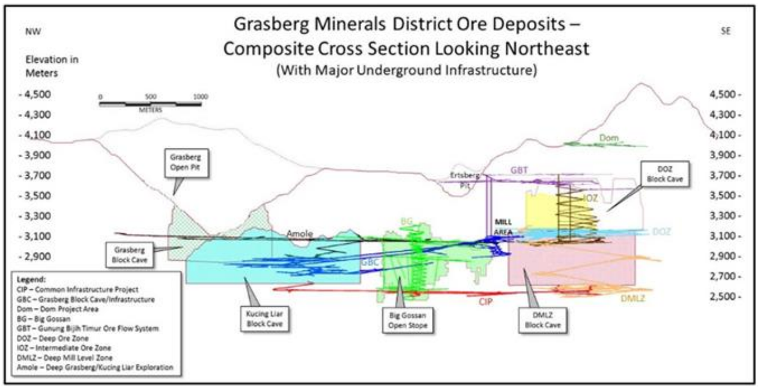

Figure.10: Grasberg Minerals District Deposits (FCX 10k, 2023)

PT-FI operates in the Grasberg Minerals District (GMD), which is located in the remote highlands of the Sudirman Mountain Range in the region of Central Papua on the eastern half of the New Guinea island. FCX and its predecessors have been the only exploration and mining operator in the 24,600-acre area since 1967. Due to its remoteness, the project site is accessible by its own coastal portside facilities on the Arafura Sea and the Timika airport, which are connected to the mill by a 70-mile main service road. Pt-FI's net PP&E and development costs for the project totaled $19.1bn on December 31, 2023. Total production from the GMD in 2023 was 1.7bn pounds of copper and 2.0mn ounces of gold. The totality of GMD's production comes from three successfully commissioned large-scale underground mines (Grasberg Block Cave, Deep Mill Level Zone (DMLZ), and Big Gossan), which during 2023 had an average milling rate of 198,300 metric tons of ore per day. New milling facilities were completed during 2023, and by the second half of 2024 a new mill recovery project requiring the installation of a new copper cleaner circuit that would increase production by 60mn pounds of copper and 40mn ounces of gold per year is expected to be completed, which is a signal of FCX's expansion of operations in the area. Although the principal source of energy for the GMD operations is a coal-fired power plant built in 1998 with diesel generators to supply peaking and backup capacity, PT-FI is advancing plans to transition its energy source to liquified natural gas investing in a new gas-fired combined cycle facility. The capex for the new facilities would be incurred over the next four years and would approximate $1bn, which would represent an incremental cost of $0.4bn over the previously planned investments to refurbish the existing coal units. All water for operations is sourced from naturally occurring mountain streams and water derived from PT-FI's own underground operations, and the operations are in an active seismic zone that experiences an average annual rainfall of approximately 200 inches (FCX 10k, 2023). To better understand FCX's operations in the GMD, it is interesting to have a more detailed outlook of each of the current and projected mines.

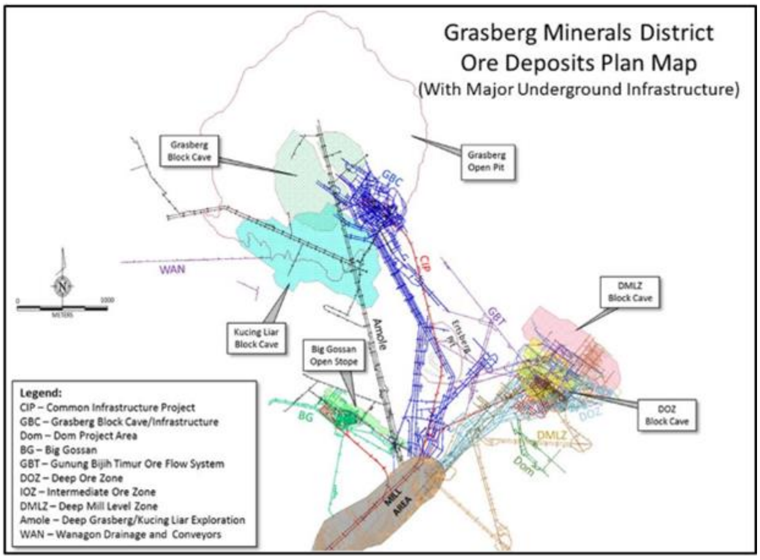

Figure.11: Grasberg Minerals District Plan Map (FCX 10k, 2023)

The Grasberg Block Cave is the same ore body that was historically mined from the surface in the Grasberg open pit mine, which was depleted in 2019. As of December 31, 2023, the underground mine had 425 open drawbells, with undercutting and drawbell construction in the area continuing to create expectations. Milled ore from the Grasberg Block Cave averaged 117,300 metric tons per day in 2023. The mine's fleet consists of approximately 870 pieces of mobile equipment, including a fleet of 98 LDH 11-metric-ton units and 22 haul trucks which are directly involved in the production and development activities, and a rail haulage system with 13 locomotives and 143 ore wagons with 35 metric tons of capacity each directed to 3 underground gyratory crushers (FCX 10k, 2023). The DMLZ ore body lies below the Deep Ore Zone underground mine, which was depleted in 2021. The cave has been pre-conditioned through hydraulic fracturing after mining-induced seismic activity that is experienced regularly. With 132 open drawbells as of December 31, 2023, the DMZ underground mine averaged 75,900 metric tons of milled ore per day in 2023. The available fleet consists of 425 pieces of mobile equipment, including 60 LHD 9-metric-ton units and 33 haul trucks with 55 to 60 metric tons of capacity each. The haul trucks directly transfer the material to two underground gyratory crushers, the product of which is then conveyed to the surface for stockpiling and processing (FCX 10k, 2023). The Big Gossan Underground Mine is a near-vertical ore body with 1,200 meters along strike and 800 meters down dip with thickness varying from 20 to 120 meters. The method used is blasthole stopping with delayed paste backfill, where the ore is dropped to a truck haulage level where trucks transport the ore to a jaw crusher. The crushed ore is then hoisted vertically to a system of conveyor belts to be eventually transferred to the surface stockpiles for processing. Ore milled averaged 7,900 metric tons per day in 2023. The Big Gossan fleet consists of 79 pieces of mobile equipment including 10 LHD units and 8 haul trucks for development and production activities (FCX 10k, 2023). The Kucing Liar Underground Mine deposit is PT-FI's largest long-term project currently in development. The deposit is expected to produce over 7bn pounds of copper and 6mn ounces of gold between 2029 and 2041, with project life left if rights are extended beyond 2041. Capex for this project is expected to average $400mn per year until 2032, and at full operating rates of 90,000 metric tons per day annual production is expected to approximate 560mn pounds of copper and 520,000 ounces of gold at a low cost (FCX 10k, 2023).

Equally important to understanding FCX's mining activities is to understand its smelting and refining activities. FCX operates 4 major smelting and refining operations across its mining regions. In Arizona, FCX owns and operates its Miami Smelter, which has been operating for 100 years with numerous upgrades along the way and FCX focuses on processing copper concentrate from the North American mines with 810,900 metric tons of concentrate processed resulting in a production of 222,000 metric tons of copper anode in 2023. In Indonesia, PT-FI owns 39.5% of the copper smelter and refinery PT Smelting, with a copper concentrate capacity of 1.3mn metric tons per year and a production of 251,300 metric tons of copper anode in 2023. A recent expansion on the smelter was funded by PT-FI with borrowings that are expected to convert to equity in 2024, which would increase PT-FI's ownership to approximately 65%. Despite PT-FI's partial ownership of the smelter, both entities operate under a tolling agreement. As previously mentioned, PT-FI is actively developing its Manyar Smelter and Precious Metal Refinery. The Manyar Smelter would have a capacity of 1.7mn metric tons of copper concentrate per year under an estimated construction cost of $3.0bn ($2.8bn for the smelter and $0.2bn for a desalination plant), and the PMR would process gold and silver from the Manyar smelter and PT Smelting at a construction cost of $665mn. Both facilities are expected to be operational within 2024.FCX also owns its Atlantic Copper smelter and refinery in Huelva, Spain, with a smelter of 300,000 metric tons per year and a refinery capacity of 286,000 metric tons per year. During 2023, Atlantic Copper purchased 40% of its copper concentrate from FCX's own mining operations (20% from PT-FI, 17% from South American mines, and 3% from North American mines) and 60% from third parties, resulting in 260,300 metric tons of copper cathode produced. Taking advantage of the global growth in electronic waste, Atlantic Copper is developing an e-material recycling project to recover copper, gold, silver, palladium, tin, nickel, and platinum from electronic materials. The project would require an additional smelting furnace and has an initial project capex of $345mn, with operations expected to commence in 2025. Additionally, FCX owns Rod & Refining operations in North America (a refinery in El Paso, Texas and rod mills in El Paso, Texas and Miami, Arizona), and Molybdenum Conversion facilities to process molybdenum concentrate in Arizona, Iowa, the Netherlands, and the United Kingdom (FCX 10k, 2023).

It is relevant to note, however, that each of the mines has a specific useful life. As we can see in Image.1, there is a noticeable threshold in the year 2041, where most of the mines will be exhausted. However, the lives of the Indonesian mines would be extended if PT-FI's operating rights are extended as expected.

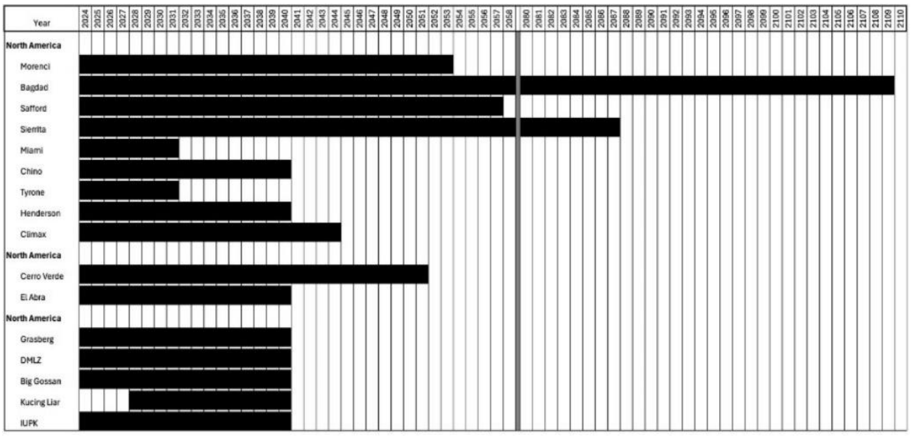

Figure.12: Life-of-mine plans (FCX 10k, 2023)[1]

3.2 Products and Sales

As we can see in the recent detailed descriptions, FCX's mining operations extract gold and molybdenum in addition to copper. Gold is almost exclusively produced from the mines in the GMD and is sold as components of the copper concentrate or in anode slimes (a product of the

[1] The ultimate timing of the start of production at Kucing Liar is dependent upon a number of factors and may vary from the date shown here (FCX 10k, 2023)

smelting and refining process), priced at the average London price for the specific month of shipment. Molybdenum, for which FCX is the world's largest producer, is extracted as the main product from the Henderson and Climax mines and as a by-product from some of the North American mines and Cerro Verde. Most of the molybdenum concentrate is processed in FCX's own facilities and is priced on the average published *Platts Metals Daily* price for the month of shipment. As one of the world's leading producers of copper products, in 2023 51% of the mined copper was sold as concentrate, 27% as cathode, and 22% as rod from the North American operations. Copper concentrate refers to the crushed and treated copper ore with a copper content of approximately 20% to 30%, whilst copper cathode refers to the copper ore that has been subjected to an SX/EW process (where copper is extracted from the ore by dissolving it with a weak sulfuric acid solution) to have, on average, 99.99% copper, and is mainly used as the raw material input for copper rod and brass mill products. Copper product sales can vary with the regions. Most of the copper produced in north America is refined in the El Paso Texas refinery and consumed at the rod mills to produce copper rods, which are then sold to wire and cable manufacturers. Production from south American mines in 2023 was sold 74% as copper concentrate and 26% as cathode. PT-FI historically sold its copper production as copper concentrate, with its adjacent gold and silver as by-products. However, since PT Smelting's tolling agreement PT has started selling more of its production as refined copper cathodes. In 2023 75% of PT-FI copper production was sold as concentrate and 25% as cathodes.

3.3 Financial Results

In 2023, FCX's consolidated copper sales totaled 4.1 billion pounds (at an average realized price of $3.85), while gold and molybdenum sales were 1.7 million ounces (at an average realized price of $1.972) and 81 million pounds (at an average price of $26.46) respectively. Freeport's activity in 2023 has resulted in total revenues of $22.9 billion, with operating cash flows of $5.3 billion and net income per share of $1.28. Copper primary sales represented 75% of the 2023 consolidated revenues, while gold was 15% and molybdenum 8%. Capital expenditures during the 2023 exercise were $3.1 billion (excluding investments in Indonesia smelter projects), and it maintained a net debt of $0.8 billion. Mining operations are quite energy-intensive, which explains how energy represented 19% of FCX's copper mine site operating costs in 2023. That includes the purchase of 250mn gallons of diesel fuel, 8,650 gigawatt hours of electricity for the North America and South America operations, 700,000 metric tons of coal for the Indonesia coal power plant, and approximately 2mn MMBtu (million British thermal units) of natural gas for some of the North America mines. Following current trends, FCX estimates energy to represent 29% of copper mine operating costs in 2024 (FCX 10k, 2023).

The top ten producers of copper represent approximately 41% of total worldwide copper production, Freeport being ranked third overall in 2023 with approximately 6% of the estimated total worldwide mined copper production on an attributable basis. All in all, Freeport's competitiveness is based on its ability to acquire and retain quality deposits, recruit and develop a skilled workforce, and manage its costs driven by location, grade and nature of ores, and inputs such as energy, labor and equipment, throughout a cyclical metals market.

4 Copper Demand & Supply

When it comes to valuing a copper mining company, it is imperative to make an accurate forecast of the projected demand it will face and the supply it will have available.

Copper is a metal with many properties. Its outstanding conductivity, resistance to corrosion, and antimicrobial properties makes it a great choice for wiring, renewable energy technologies, plumbing fittings, electric vehicles, and even for future cancer treatments (Almeida da Silva et al., 2022). This varied set of properties and uses makes Copper so in-demand and closely linked to global economic growth. FCX believes the long-term fundamentals of copper are positive due to copper's role in the global transition to renewable power, electric vehicles (EVs), continued urbanization in developing countries, and growing global connectivity and public health. For instance, EVs consume up to four times the amount of copper relative to car weight than standard cars and renewable energy technologies consume four to five times the amount of copper of fossil fuels (FCX 10k, 2023). As a result of these trends, as well as economic growth and population growth, the demand for copper has been rising rapidly (USGS, 2009) and it's expected to continue in the future. Nevertheless, studies have noticed that the growth in copper demand has been higher than the growth in supply from secondary sources, which has led to an increase in demand for primary sources (Gómez et al., 22007; ICSG, 2012; ICSG, 2015) and raising concerns about the availability of copper which is vital for the transformation of transportation, industrial, and energy systems (Elshkaki and Graedel, 2015; Nassar et al., 2012; Nassar et al., 2015). Similar concerns have arisen about the energy intensity of the mining industry and its resulting emissions. The mining industry is already one of the largest contributors CO2 emitters, but Copper is an especially energy-intensive metal with Chile, the world's largest copper-producing country, the Copper mining industry is the largest energy consumer and GHG emitter (Alvarado, 2002). Furthermore, It is foreseeable that as demand for copper continues to increase, the ore grade (measurement of the metal content in each unit of ore) will degrade (Northey et al., 2014) and force copper production to become more energy-intensive, likely resulting in more CO2 emissions (Kuckshinrichs et al., 2007).

In their study, Elshaki et al. (2016) develop four scenarios for the global demand, supply, and energy consumption of primary and secondary copper based on the metal scenarios in the Fourth Global Environmental Outlook (GEO-4) by the United Nations Environment Program. These scenarios are Market First (MF), Policy First (PF), Security First (SF), and Equitability First (EF), with each including projections of population, income per capita, and source-specific energy demand. The MF scenario essentially posits that the newly wealthy will wish to acquire possessions similar to those of the existing wealthy, and that market forces will enable that to happen. The PF scenario is similar except that government policies more respectful of renewable energy and the environment will be in force. The SF scenario tilts toward confrontation rather than cooperation, with a consequent reduction in international commerce. Finally, the EF scenario aims toward a more collaborative and inclusive world.

4.1 Demand

Using a regression method, Elshaki et al. (2016) find that the total demand for copper in 2050 in respects to 2010 grows by 275% (MF), 275% (PF), 213% (SF), and 341% (EF) in each scenario, with the main sector of demand being infrastructure representing 25%, 25%, 26%, and 24% of the total copper demand in each scenario. One of the most interesting results from the article is that copper demand is highest for the EF scenario. That is because global equity ambitions will require widespread increases across the population, driving per capita GDP to its highest point. Following the supply forecast by the study, the EF scenario appears to be unsustainable as long as copper demand is so intrinsically linked to GDP per capita. In contrast, demand is least for the SF scenario in which isolation and income stagnation limits copper demand.

Other more recent studies have aimed to forecast future copper demand. In an October 2023 interview by S&P Global's Katya Bouckley, Peter Varyushin (Head of Commodity Markets Research at Russina mining company Nornickel) stated that Nornickel expects copper demand to increase by 2%-3% in 2024, and to reach a cumulative growth of 20% by 2035 as electric transport, electricity transmission grids and renewable power generation technologies develop. This would push demand to 30 million mt/year in 2035, compared to 24.8 million mt/year in 2022

(Bouckley, 2023). When it comes to industrial demand, Nornickel forecasts consumption of batteries, EVs, and charging infrastructure to reach 4.7 million mt in 2030 and double to 5.5 million mt in 2035, from 2.7 million mt in 2022. Similarly, the development of power transmission and distribution networks, which currently take only 100,000 mt/year of copper, would require 1.1 million mt and 1.8 million mt of it in 2030 and 2035, respectively. Regarding the energy transition trend, the renewable energy sector is expected to require 1.1 million mt and 1.4 million mt in 2030 and 2035 for offshore and onshore wind farms, whereas the intake of copper by photovoltaic installations will double to 1.7 million mt/year, up from 800,000 mt/year currently (Bouckley, 2023). McKinsey & Co has also provided forecasts in their "Bridging the Copper Supply Gap" study in 2023, where they state that electrification alone is projected to increase annual copper demand to 36.6 million metric tons by 2031. However, the article insists that supply projections based certain or probable projects and recycled production offer a pathway to only 30.1 million metric tons, which leaves a deficit of 6.5 million metric tons of capacity (McKinsey, 2023).

4.2 Supply

In their paper, Elshaki et al. (2016) also forecast Copper supply from 2010 to 2050. Their assumptions are that copper demand should be met by copper supply from primary sources (mined copper) and secondary sources. However, primary copper supply has an important constraint in its available reserves, calculated in different methods such as Reserves, Reserve Base (RB), Ultimate Recoverable Resources (URR), and Remaining Resources. The forecasts show that cumulative global copper production is expected to exceed its current reserves by approximately 2038 in the MF and PF scenarios, and by 2040 and 2036 in the SF and EF scenarios. When considering the more expansive Reserve Base figure, cumulative copper production is expected to exceed it in 2048, 2048, and 2044 in the MF, PF, and EF scenarios, without exceeding it in the SF scenario. No scenario is expected to exceed the URR, although the EF scenario edges quite close. To forecast copper supply by copper-producing nation, the assumption is made that all countries keep the individual copper production share they had during the 2007 and 2012 period. Following this approach, only Australia, Mexico, Peru and Poland do not exceed their RB in the MF, PF, and EF scenarios. Chile joins the list of non-exceeding countries in the SF scenario. All other countries are expected to exceed their reserves at different times. In regard to Nornickel, it provides short-term projections forecasting that global cooper mine production in 2023 and 2024 to be 22.3 million mt and 23 million mt respectively, driven by an increase in output in South America and the Democratic Republic of Congo. It also expects smelting and refining capacity expansions in China to boost the world's refined copper supply, topping 26 million mt in 2024 (Bouckley, 2023).

Of course, these forecasts assume that today's copper-enabled technologies will continue to be used throughout the 2010-2050 period, which seems a reasonable approach given that copper is so central to many of our most critical economic activities. Furthermore, although recent studies have suggested ways to substitute copper for silver in Si-based PV solar technology (García-Olivares, 2015), generally there are no realistic available substitutes for copper's major uses (Graedel et.al., 2015). Elshaki et al. (2016) observe this idea in an additional scenario assuming that 30% of copper demand by 2050 is substituted by one or more unspecified minerals. In this scenario total RB is exceeded only in the EF scenario, whereas simple Reserves are exhausted in all.

4.3 Price

As mentioned, the rapid increase in demand for copper in the context of the energy transition will likely not be matched by an increase in supply, which will inevitably lead to substantial price volatility. According to the IAE, copper supply is expected to match only 80% of the global copper needs by 2030 (IEA, 2021). That is mainly since the global economy, and thus also the mining industry, is currently geared towards the STEPS scenario, a gradual and insufficient approach to climate change, which is not prepared to support an energy transition. This context has led to the existence of multiple vulnerabilities that increase the likelihood of price volatility in a tight copper market in the future. One of the main obstacles is the current long project development lead times for mining projects, which the IAE estimates to be 16.5 years on average to move from discovery to first production (IAE, 2021). This puts into question how fast the global mining industry can respond to increases in demand. Additionally, there is the widespread issue of the declining resource quality, as ore quality for many commodities has been falling across the board in recent years. For instance, copper ore quality in Chile has declined by 30% over the past 15 years. Lower-grade ores require more energy and higher overall costs of metal extraction, since larger volumes are needed to acquire the same quantity of metal you were previously able to extract from higher-grade ores, resulting in higher overall costs, GHG emissions, and waste. These factors are further intensified when we account for the fact that copper production is very geographically concentrated amongst a small number of countries, and its high exposure to climate risks, especially when it comes to water use. According to the IAE, 50% of copper production is in areas with high water stress levels, which is of high risks to copper production given how high its water requirements are, and some of these regions (i.e. Australia, China, and Africa) are also exposed to extreme heat and floods, which can severely disrupt supply (IAE, 2021). However, it is important to note that emerging technologies in metal recycling could alleviate some of that pressure. More specifically, the IAE estimates that by 2040 recycled quantities of copper, lithium, nickel and cobalt from spent batteries could reduce primary supply requirements by around 10% (IAE, 2021).

Currently, copper futures oscillate around $4.58/lb. ($10,135/t), close to a five-year high. Citi has predicted that the supply deficits caused by the decarbonization-related demand will result in a mega bull-run in copper that will drive prices to $12k/t during the next three months and, in the most bullish scenario, reach $15k/t (or $6.8/lb.) by the end of 2025 (Thornton, 2023). Disruptions in key mines across producing regions, a severe drought in Zambia, Chinese smelters approaching regulatory approval to cut output, and the US and UK prohibiting metal exchanges to accept copper produced by Russia, are all factors that are likely to cause a rise in copper prices in the short-term future. Finally, a re-activation of the Chinese economy, which accounts for over 50% of the global copper demand, would be an accelerator the increase in copper prices. Given that the higher the price the higher the conviction to initiate greenfield investments, and that in the super-cycle of the 1980s, when the price of copper reached the equivalent of $15k/t today, there was demand destruction (i.e.. rationing) according to Chief Strategy Officer of Energy Pathways at Carlyle and former Global Head of Commodities Research at Goldman Sachs Jeff Currie in his recent interview with Bloomberg, copper is likely to peak at the 15k/t price target. Thus, given that demand in the NZE scenario for copper is expected to dramatically outpace copper demand under current legislations and policies, and the fact that after conviction has been set the development of new mines have long lead times, we will assume that in our NZE scenario copper price will gradually increase to $6.8/lbs. in 2026 and remain at this level until 2035.

5 Regulations on Copper and Carbon Pricing Schemes

5.1 International Climate Change Agreements

The international community has increasingly recognized the urgency of addressing climate change through various comprehensive frameworks under the auspices of the United Nations Framework Convention on Climate Change (UNFCCC). Notably, the Paris Agreement of 2015 signifies a global pledge to restrict global warming to significantly below 2 degrees Celsius, emphasizing the need for nations to peak greenhouse gas emissions expeditiously and achieve a climate-neutral world by mid-century. This is the result of the earlier Kyoto Protocol, initiated in 1997, which marked the first instance of setting binding emission reduction targets for industrialized nations. Both frameworks operate within the ambit of the UNFCCC, serving as a foundational framework for intergovernmental efforts toward climate mitigation. Collectively, these protocols aim to reduce emissions through national commitments, enhance transparency, and promote the development of green technologies, which profoundly impact various industries by influencing regulatory trends, operational costs, and creating market opportunities in sectors focused on green technology.

The United Nations Framework Convention on Climate Change (UNFCCC), established at the Rio Earth Summit in June 1992 and which came into force on March 21, 1994, enjoys near-universal membership with 197 countries having ratified the convention. This framework initially set non-binding greenhouse gas emissions limits for individual countries and provides a platform for negotiating specific international treaties or protocols that may establish binding limits. The UNFCCC's scope and commitments include a voluntary pledge system where it originally did not set mandatory emissions limits for individual countries but allowed for the future establishment of such limits through updates or new protocols. The annual Conferences of the Parties (COPs) assess progress on climate change and initiate negotiations for future agreements. Furthermore, the convention has recently started mandating developed countries to provide financial and technical support to developing nations to help them achieve the objectives of the treaty and adapt to the anticipated impacts of climate change. All in all, the framework set by the UNFCCC influences regulatory trends and creates anticipations of future policies and standards that allows businesses to prepare for these changes, promotes global cooperation fostering multinational partnerships and investments, and encourages the development and diffusion of technologies that reduce greenhouse gas emissions.

As the first major international agreement resulting from the UNFCCC, the Kyoto Protocol, adopted in Kyoto, Japan, in December 1997 and which came into effect in February 2005, commits its state parties to reduce greenhouse gas emissions, based on the consensus that global warming is occurring and is predominantly driven by human-induced emissions. The protocol specifically targeted industrialized countries, setting binding obligations to reduce their greenhouse gas emissions by an average of 5.2% below their 1990 levels during the first commitment period, from 2008 to 2012. The Kyoto Protocol also introduced three market-based mechanisms — International Emissions Trading, the Clean Development Mechanism, and Joint Implementation — which allow participating countries to meet their greenhouse gas emission limits through the purchase of GHG reduction credits from other countries. The Kyoto Protocol brought about several implications to business and investment practices like a rise of compliance costs for industries in signatory countries due to increased regulations, increased costs due to the burden of purchasing emission credits should emission caps be exceeded, and incentives to invest in cleaner technologies and processes to achieve cost-effective emission reductions. Companies may also find it necessary to reassess their supply chains to include considerations of emissions costs, especially when involved in international trade with countries having different obligations under the protocol.

After the Kyoto Protocol the next major international agreement, and the most important so far, was the Paris Agreement. The Paris Agreement, adopted by 196 parties during COP 21 in Paris on December 12, 2015, sets forth a global agreement to limit the increase in global temperatures to well below 2 degrees Celsius above pre-industrial levels, aiming preferably for 1.5 degrees

Celsius. This agreement mandates countries to achieve the peaking of greenhouse gas emissions as swiftly as possible in order to reach a climate-neutral status by the mid-21st century. In terms of its scope and commitments, the Paris Agreement mandates each participating nation to formulate and present Nationally Determined Contributions (NDCs) that outline their self-determined plans for reducing greenhouse gas emissions and adapting to climate change impacts. Additionally, it imposes requirements for regular reporting on emissions and progress in implementation, subject to international scrutiny. To support these efforts, developed countries are required to provide financial and technical assistance to developing nations, helping them both mitigate and adapt to climate change impacts. The specific implications of the Paris Agreement on businesses are substantial, though indirect. Instead of imposing specific emissions limits on businesses, it compels each country to determine its own strategies which may include regulations affecting domestic industries. This leads to potential regulatory compliance costs for businesses that may need to invest in carbon pricing and emissions limitation technologies, adopt new operational processes to minimize their carbon footprint, and modify their supply chains to comply with new regulations or to manage risks associated with climate change.

The suite of international climate agreements, including the United Nations Framework Convention on Climate Change (UNFCCC), the Kyoto Protocol, and the Paris Agreement, provides a foundational framework for global efforts to mitigate climate change. These agreements collectively facilitate a reduction in greenhouse gas emissions, foster transparency, and encourage the development of sustainable technologies, creating both challenges and opportunities for industries worldwide. While they set broad targets and frameworks for action, the implementation is deeply influenced by national policies, which translate these global commitments into actionable regulations. This layered approach allows for tailored strategies that consider local environmental conditions and economic contexts, necessitating those businesses, especially in sectors like copper mining and manufacturing, adapt and innovate to meet both the regulatory requirements and the shifting demands of a more environmentally conscious market.

5.2 Specific Regulations on Copper

Copper mining is particularly targeted due to its substantial water and energy requirements. Regulations may include stringent controls over the use of water resources, safety standards for tailings management, and obligations to rehabilitate mining sites post-closure. These regulations are crucial in nations like Chile and Indonesia, where major copper mines significantly impact local ecosystems and water supplies (United Nations Environment Programme, 2019).

5.2.1 European Union

In Europe, the regulatory landscape for the copper industry is framed by European Union directives and regulations which are both comprehensive and stringent, reflecting the EU's commitment to environmental sustainability and public health. The Registration, Evaluation, Authorisation, and Restriction of Chemicals (REACH) Regulation, established in 2006, serves as a cornerstone in the management of chemical substances within the EU, including those used in copper processing. REACH imposes obligations on companies to identify and manage risks linked to the substances they manufacture and market in the EU. For the copper industry, this means ensuring that any chemicals used in the extraction and processing phases are registered, evaluated for safety, and restricted if found to pose significant risks. The Industrial Emissions Directive (IED) 2010/75/EU, which came into force in 2013, specifically targets large industrial installations, including copper smelters. It mandates the application of Best Available Techniques (BAT) to reduce emissions, manage waste effectively, and conserve energy and resources.

Facilities must obtain permits based on BAT assessments, which detail measures to prevent and reduce pollution. Finally, The Water Framework Directive (WFD) 2000/60/EC aims to achieve good qualitative and quantitative status of all water bodies by 2027. For the copper industry, this directive mandates comprehensive management of water resources, requiring companies to prevent contamination of water through measures such as treating effluents before discharge and monitoring the impact of their use on local water bodies.

5.2.2 United States

In the United States, federal environmental laws are enforced primarily by the Environmental Protection Agency (EPA), and they provide a framework within which the copper industry must operate. The Clean Air Act (CAA), first enacted in 1970 and significantly amended in 1990, regulates air emissions from all sources across the country. Copper smelters, known for emitting sulfur dioxide and other toxic gases, are required to install and operate emission control technologies under National Emission Standards for Hazardous Air Pollutants (NESHAPs) specifically designed for copper smelters. The Clean Water Act (CWA) of 1972 addresses pollution control and water quality standards for all surface waters in the United States. Under this act, copper mining operations must obtain National Pollutant Discharge Elimination System (NPDES) permits to discharge treated wastewater to surface waters and manage stormwater runoff, ensuring that water quality standards are met. The Resource Conservation and Recovery Act (RCRA) of 1976 governs the disposal of solid and hazardous waste. Under RCRA, copper mining and processing facilities generating hazardous wastes are required to follow stringent management protocols, including the correct identification, treatment, and disposal of such wastes to prevent environmental contamination.

5.2.3 Chile

Chile's position as the world's largest copper producer has necessitated the development of specific regulations to manage the substantial environmental impacts associated with mining. The Environmental Impact Assessment System (SEIA), instituted in 1997, requires all major mining projects to undergo rigorous environmental impact assessments before they receive approval to proceed. This process ensures that potential environmental damages are identified, and effective mitigation strategies are developed. Supreme Decree No. 28/2013, which updates a 1992 regulation, sets forth stringent standards for emissions from stationary sources, including copper smelters. The decree outlines permissible limits for contaminants such as arsenic and lead, which are closely monitored due to their potential health impacts. The modifications to Chile's Water Code in 2021 emphasize the sustainable management and allocation of water resources. These modifications prioritize non-consumptive water rights for mining, encouraging the reuse and recycling of industrial water, crucial in arid mining regions to mitigate the impact of mining activities on local water availability.

5.2.4 Indonesia

Indonesia, as a significant player in the global copper market particularly with the Grasberg mine—one of the largest copper and gold mines in the world—, has developed stringent regulatory frameworks to address the environmental impacts of mining activities. The Environmental Protection and Management Law (UU PPLH No. 32, 2009) is the principal legislation governing environmental management in Indonesia. This law emphasizes the importance of managing environmental impacts associated with industrial activities, including mining. It requires all major mining projects to undergo an Environmental Impact Assessment known locally as AMDAL (Analisis Mengenai Dampak Lingkungan), which must be approved before any project development can proceed. This assessment includes a detailed examination of the proposed project's potential impacts on the local environment and communities, and it mandates the development of management and monitoring plans to mitigate those impacts. The Mineral and Coal Mining Law (Law No. 4 of 2009) specifically regulates the mining sector in Indonesia, reinforcing the requirement for environmentally responsible mining practices. Under this law, mining companies are obliged to implement good mining practices that protect the environment, ensure the safety of workers, and contribute to the economic well-being of the local communities. The law also stipulates that companies must rehabilitate mining areas post-extraction to prevent long-term environmental damage, such as soil erosion, water pollution, and deforestation. The Government Regulation on Environmental Protection and Management (PP No. 22 of 2021), which revises earlier regulations, further strengthens environmental protections. It includes detailed provisions for managing hazardous waste, conserving water resources, and controlling air pollution. For the copper industry, this means stringent controls over waste management processes, ensuring that waste materials are treated and disposed of in a manner that minimizes environmental and health risks.

5.2.5 Peru

Peru is one of the world's top producers of copper and, as such, has also established a comprehensive regulatory framework to mitigate the environmental impacts associated with large-scale mining operations. The regulatory landscape in Peru is designed to ensure that mining activities are conducted responsibly, prioritizing environmental conservation and community welfare alongside economic growth. The General Environmental Law (Law No. 28611), established in 2005, is the cornerstone of environmental regulation in Peru. It provides the legal framework for sustainable development and environmental protection across all sectors, including mining. This law emphasizes the prevention of pollution, the conservation of natural resources, and the promotion of environmental culture among citizens and corporations. The Single Text of Administrative Procedures (TUPA) of the Ministry of Energy and Mines includes specific requirements for mining activities, such as the obligation to submit environmental impact assessments (EIAs) for new projects or expansions. These EIAs must detail potential environmental effects and outline strategies for mitigation, monitoring, and remediation. Approval of the EIA is a prerequisite for obtaining the necessary operating permits. And finally, Supreme Decree No. 040-2014-MINAM establishes the Environmental Quality Standards (ECA) and Maximum Permissible Limits (LMP) for air, water, and soil. For the copper industry, these standards dictate the allowable levels of emissions and discharges, ensuring that mining operations do not exceed thresholds that could harm the environment or public health. Compliance with these standards is closely monitored by the Ministry of Environmental Affairs, which has the authority to impose sanctions and require remedial actions if violations occur.

The regulatory frameworks in Europe, the United States, Chile, Indonesia, and Peru demonstrate a global commitment to sustainable mining practices, with each jurisdiction tailoring its approach to address local environmental challenges and societal needs. In Europe, stringent regulations on chemical management and waste treatment push the copper industry towards higher standards of environmental responsibility. The United States enforces robust air and water pollution controls, necessitating advanced technological compliance. Chile and Peru, both with significant mining activities in arid regions, place a strong emphasis on water conservation and sustainable resource management, critical in areas where water scarcity poses a significant challenge to both ecosystems and human populations. While Indonesia focuses on comprehensive environmental impact assessments to protect its unique biodiversity and ensure community welfare.

For companies operating within the copper sector, adapting to these diverse regulatory environments requires a strategic approach to environmental management that not only meets local compliance but also aligns with global sustainability goals. This involves investing in technology and processes that reduce environmental footprints, engaging with local communities to ensure social license to operate, and continuously monitoring and improving environmental performance in line with evolving legal standards and societal expectations. Navigating this complex regulatory landscape is essential not just for legal compliance but also for maintaining competitiveness and securing the industry's future in an increasingly environmentally conscious global market.

6 Methodology

The methodology is based on the Discounted Cash Flow (DCF) method, which involves forecasting the company's future free cash flows and discounting them by the appropriate cost of capital to determine their present value. Data for this analysis was sourced from publicly available information in FCX's Annual Reports as well as the Capital IQ platform. Given the complexity of the firm, we developed detailed schedules and assumptions, which are explained in the following sections. Our valuation framework incorporates three scenarios: the Base Case, which assumes existing conditions persist; the Net Zero Emissions (NZE), which assumes the adoption of policies and trends to achieve Net Zero by 2050; and the Mid-point, which averages the Base Case and NZE scenarios. Additionally, we utilized Monte Carlo simulations to account for a range of probable outcomes and provide a nuanced valuation.

6.1 Income Statement

Starting with Revenues, FCX's revenues are essentially a function of the demand in volume of their products (copper, molybdenum, gold, and silver) and the price per unit of each of these commodities. Simultaneously, the price of each commodity is determined by the interaction between demand and supply forces in the market. For the price of copper, in the BC we assume it stays at current prices, that being $4.46/lb. (COMEX as of 31/05/2024), whereas for the NZE we assume the price increases gradually until reaching the $6.8/lb. mark in 2026 and stays at that level until the end of our forecast period (as explained in more detail in the *Copper Price* section). For the price of molybdenum, gold, and silver we assume the price stays at current levels, since they are not CRMs and thus do not have the same high demand growth projections that copper has. This results in $22.10/lb. (LME May.24 contract) for molybdenum, $2,334/oz (GC: CMX as of 25/05/2024) for gold, and $30.54/lb. (COMEX Silver as of 25/05/2024) for silver.

When it comes to the demand projections, we have different assumptions for copper mines and for molybdenum mines. For the pure molybdenum mines, we assume a CAGR for molybdenum demand of 2.3% which remains constant across scenarios. For copper mines, we assume the same CAGR for all other metals mined (molybdenum, gold, and silver) is the same, since they are all by-products of copper mining. For the BC Copper demand growth is projected at a 1.475% CAGR, extracted from mining company Nornickel's predictions that at the current pace we are expected to reach total copper demand of 30mt/year by 2035 from 24.8 mt/year in 2022. For the NZE we follow the IAE's predictions that to keep on track with the Net Zero 2050 goal we would need a total demand of 35mt/year by 2030, which taken from the 24mt/year in 2022 results in a

CAGR of 4.4%, which we assume is maintained across 2035 (more detail in the Copper Demand section) (IAE, 2021). We take a very detailed approach, considering the output sold for each metal and by region. FCX revenues are computed multiplying the quantity of output sold times the price of the mineral. Additionally, it is important to note that as a principal simplification of the model, we decided not to account for inflation in our projections.

For production (see the PP&E schedule) we forecast in detail the production of each mine, and we assume that production for each will grow at the same pace as the demand CAGR for the scenario in question, until the mine is exhausted. When the mine is exhausted or closes for any reason and it cannot meet demand anymore, the excess production will be distributed among all remaining mines according to their share of total Capex in year 2023, since we assume that more capex eventually translates to more production capacity. It is important to note that FCX does not have a 100% interest in all its mines, however in its financial statements it consolidates 100% of all its mines' production apart from the Morenci mine where the reported production is only the pertaining to FCX's 72% ownership. As a result, we consolidate revenues and then we subtract Non-Controlling Interest at Net Income.

Continuing with Cost of Goods Sold (COGS), we develop a specific schedule for it due to FCX's practice of calculating COGS using a By-Product method. Since FCX labels its mines only as copper or molybdenum mines, due to gold and silver being by-products of production, the By-Product method consists of subtracting from the total costs of operations the revenue achieved from selling said by-products. Thus, in order to get total COGS, we must reverse-engineer FCX's process adding to their By-Product COGS the revenues from their by-products. For Corporate, Other & Eliminations, we also assume that it is a fixed percentage of intersegment revenues (that being the same as the percentage of total revenues represented by intersegment revenues). We account for Exploration & Drilling costs separately, and we assume it is a fixed percentage of revenues as it functions similarly to how Research & Development would in a technology company.

For FCX's Depreciation & Amortization, which is tied to its PP&E schedule, FCX calculates its reserves at a fixed commodity price (i.e. $3/lb. for copper). Although reserve values would be different if current prices were taken, this sensitivity decision by FCX is not explained its publicly available information, if we respect it in our own calculations of the reserves. Additionally, FCX calculates depreciation at the mine-level and using the Unit of Production method, which consists in depreciating the mine proportionally to the volume that is extracted from the reserves. One of the complications of this method is that non-mine depreciation (i.e. Equipment, depreciation, etc.) is not as clearly reported. As a result, to account for this extra depreciation we have added a schedule for "Other Depreciation", we assume its equivalent to the missing difference in depreciation in 2023, and assume it remains constant across the forecast period.

6.2 Balance Sheet

When scheduling debt we notice that current debt maturities will, naturally, drive the company to be completely unlevered at one point, which will have unrealistic effects on the DCF's cost of capital, especially as FCX will need to adapt to growing demand for copper. As such, and in order to simplify our projections, we have added an additional debt tranche that draws-down new debt equal to the amount of debt repaid at any period at an assumed interest rate of 5.13% (which is our cost of debt), with the aim of keeping FCX's Leverage Ratio constant during the forecast period.

On the equity side of the Balance Sheet another modification is necessary. In their financial statements FCX does not account for dividends in the Retained Earnings (Accumulated Deficit) statements, but in Additional Paid-In Capital (APIC). Thus, we have developed an additional schedule for APIC to be consistent with FCX's accounting practices.

6.3 Mineral Reserves

In the mining industry, and in most natural resources industries, there are three terms whose definition is very important to understand, that is Resources, Probable Reserves, and Proven Reserves. The main difference between these terms is their specific degree of confidence. Mineral Resources has the lowest degree of confidence and describes any concentration of mineral deposits of economic interest that could potentially be mined. Within Mineral Resources there are also several levels of confidence, that being "Inferred", "Indicated", and "Measured" (from lowest to highest degree of confidence). A Measured Mineral Resource is a resource for which its quantity and grade is estimated from detailed sampling and a high degree of confidence. An Indicated Mineral Resource is estimated with similar information to the Measured Mineral Resource, but with the sample usually further apart and consequently only an adequate degree of confidence. Finally, an Inferred Mineral Resource is estimated with similar information to the previous ones, but with limited geological evidence and sampling and thus the lowest degree of confidence.

Mineral Resources can qualify as Mineral Reserves when they are technically, legally, and economically feasible to be extracted. Probable Reserves have the lower degree of economic and geological confidence (and higher risk) and Proven Reserves have the highest degree of confidence (and lower risk). FCX discloses its Mineral Reserves following the industry practice detailed under Subpart 1300 of SEC Regulation S-K. Under the accepted methodology, proven and probable reserves are estimated using mapping, drilling, sampling, assaying and evaluation methods, and only account for those resources that are economically mineable. The economic viability component means that size of proven and probable reserves will be directly affected by price assumptions for the mineral in question, as well as the length of the mining concessions and the estimated maximum capacity of the mine. For FCX's estimated proven and probable reserves at December 31, 2023, the used price assumptions were $3.00 per pound of copper, $1,500 per ounce of gold, and $12 per pound of molybdenum. These are conservative assumptions since the three-year average prices were $4.02 per pound of copper, $1,846 per ounce of gold, and $19.62 per pound of molybdenum (FCX 10k, 2023).

Understanding FCX's methodology when calculating reserves is very relevant because it has a direct effect on the valuation of the company. One case where this is very evident is when valuing FCX's Indonesia operations in the GMD, where its estimated proven and probable reserves of 29bn pounds of copper and 23.9mn ounces of gold only reflects its estimates of what can be recovered through 2041, when their current concession rights end (FCX 10k, 2023). Thus, when calculating the Terminal Value of FCX in our DCF using the reserves multiple, we end up undervaluing the company since we don't account for how a potential extension of the concession rights beyond 2041 could affect the calculation of current reserves due to lack of information (see Limitations).

6.4 Cash Flow Statement

The main complication in the Cash Flow statement was projecting the Capital Expenditures (Capex), since the capex from some of the mines is accumulated under the "Other US mines" statement in FCX's Annual Report. To overcome this complication and be able to break down capex by mine, we assume that this excess capex is distributed proportionally to the reserves available in each mine, since we assume that the more reserves are available in a mine the more capex will have to be destined to that mine to extract it. Furthermore, since reserves are reduced every year, we assume that capex will also be reduced per mine proportionally to the decrease in reserves.

6.5 Emissions Schedule

To project FCX's emissions we calculate the emissions per metric ton of material produced for each of the mines, tying future emissions to the total volume of material produced. Additionally, we assume that the emission targets stated in FCX's 2023 Sustainability Report will eventually be successfully implemented. For the targets that are CO2 intensity-based (for all mines in the Americas and Indonesia), we reduce the emission intensity gradually until the target is reached and apply it to forecasted outputs. For the rest of emission targets, which are based on an absolute emission amount, we simply assume that emissions will decrease gradually until the goal is achieved, without tying it to forecasted outputs. For the Miami smelter and EL Paso refinery, which have intensity-based targets, but for which output figures are not disclosed, we take the total Scope 1 & 2 emissions for the 2023 period and the mine-specific reported emissions and solve for the remaining emissions to get the reported total emission intensity of 3.78 in the 2023 Sustainability Report. Going forward in the projection period, we assume that the same percentage relationships to total emissions are maintained.

6.6 Carbon Pricing Mechanisms

For the carbon price and the carbon pricing mechanisms, we have used current active legislation to decide the carbon price for the Base Case scenario and made assumptions based on analyst reports about how much it must increase to reach the Net Zero by 2050 goal for the Net Zero Emissions scenario. For the BC scenario we have looked through the current carbon pricing mechanisms active around all the geographies FCX operates in United States, Chile, Peru, Indonesia, Spain, United Kingdom, and the Netherlands. In the US and Peru there are no currently active carbon pricing mechanisms to account for, in Chile there is the Chile Carbon Tax which charges $5/tCO2 (WBG, 2017), and in Indonesia there is the Indonesia ETS which charges $0.61/tCO2 but for now only covers the coal industry, so essentially there is no carbon price for FCX (WBG, 2023). In the case of the European countries like Spain and the Netherlands they have the EU ETS in common, which charges $61.3/tCO2 (WBG, 2005), and for Netherlands we need to add the Netherlands Carbon Tax which charges an additional $71.48/tCO2 (WBG, 2021), making the total $132.78/tCO2. Finally, in the United Kingdom there is the UK ETS which charges $45.06/tCO2 (WBG, 2021).

Since all the countries that do not currently have an ETS either already have plans for one or will have to eventually develop one to reach the Net Zero by 2050 goal, we assume that they will have an "implementation year" when they will adopt the same carbon price as other existing countries. For Indonesia and Peru, we assume that they will adopt Chile's carbon price, since they are all developing economies. For the US, we assume it will adopt UK's carbon price, since they are both G7 countries and US's politics tend to be less receptive to ESG policies than the EU's so UK's carbon price discount is sensible. In the BC scenario, we assume everything continues like today and there will be no implementation. In the NZE scenario, we assume the US, Peru and Indonesia implement in 2028. And for the MP scenario, as a mid-point between not implementing and implementing in 2028, we assume they implement three years later in 2031.

When it comes to Carbon Price assumptions, both Europe and Chile's ETS have defined price expectations which allow us to extract an implied CAGR for their carbon price in the NZE scenario. Chile's ETS, in its description, expects to rise its carbon price to $35/tCO2 by 2030 to comply with Net Zero by 2050 goals (ICAP, 2021), implying a CAGR of 38.3%, which we assume remains constant during our forecast beyond 2030. EU ETS does not specifically mention any future price expectation in its description (which is a limitation to our study), but after the European Union's new climate commissioner, Wopke Hoekstra, committed in October 2023 to reduce by 90% greenhouse gas emissions by 2040, researchers in the London Stock Exchange Group (LSEG) estimated that it would send EU carbon prices to €400 or $427/tCO2 (according to EU/USD exchange rates in Jun.21 2024) by 2040 (Simon, 2023). This estimation implies a CAGR of 12.9%, which we apply across our forecast. Since the UK's current UK ETS carbon price has a reduction of 26% in contrast to the EU ETS, we assume this relationship is maintained. Finally, we assume Netherland's Carbon Tax, applied on top of the EU ETS, remains constant. For the BC scenario we assume there is no CAGR, and for the Mid-Point scenario we take the average between 0 and the NZE CAGR.

6.7 Terminal Value

For the Terminal Value (TV) in the DCF, we employed a multiples approach due to the finite nature of mining reserves. Traditional exit valuation methodologies, such as those based on EBITDA multiples or the Gordon Growth Model, are unsuitable because they do not account for the eventual depletion of mines. Instead, we used the multiple of Enterprise Value (EV) over proven and probable copper reserves. This approach better reflects the intrinsic value of a mining company. We assumed that the current EV-to-reserves multiple remains constant throughout the forecast period, ensuring a more realistic and applicable valuation for FCX as it considers the natural limitations of its mining operations. We chose specific multiples for different scenarios to reflect varying market conditions. In the Base Case, we used a multiple of 0.9x, which is based on the current multiple that FCX has. For the Mid-Point scenario, we used a multiple of 1.14x, and for the NZE scenario we used a multiple of 1.37x. These higher multiples in the Mid-Point and NZE scenarios are proportional to the projected increase in copper prices in each of those cases. This method ensures that the terminal value appropriately adjusts for the expected market conditions and reflects a realistic valuation under varying future scenarios.

6.8 Monte Carlo Simulation

For the Monte Carlo simulation, we modeled the uncertainty of key variables using appropriate probability distributions. In each case, the mean of the distribution was set to the Mid-Point estimate, ensuring a balanced representation between the Base Case and Net Zero Emissions scenarios. We selected appropriate standard deviations to reflect the variability and uncertainty inherent in each variable. We ran 10,000 simulations to generate a comprehensive range of possible outcomes for the company's valuation. From these simulations, we calculated appropriate summary statistics and created visualizations to help interpret the results. This probabilistic method provides a more nuanced and comprehensive view of the potential impacts of different assumptions and scenarios on FCX's financial performance, enabling us to identify the most likely valuation outcomes and better understand the risks and opportunities faced by the company.

Two of the most important variables that we use in our study are the Compound Annual Growth Rate (CAGR) at which the volume of copper demand will increase until 2035, which is the basis of our revenue forecast, and the Terminal EV/Copper Reserves (in billions of pounds) multiple that we use to calculate the terminal value of FCX in the DCF model. For the 2035 CAGR variable, we use a normal distribution with the "Mid-Point" scenario as the mean and one third of the difference between the "NZE" scenario and the "Base Case" scenario as the standard deviation. This choice ensures that approximately 86.64% of the observations fall within the range between the Base Case and NZE scenarios, as they would be within 1.5 standard deviations from the mean. The remaining 13.36% fall outside this range, reflecting the high uncertainty inherent in long-term demand forecasts for copper, a critical input in our revenue projections. By tuning the numbers in this way, we capture the expected variability and uncertainty in future copper demand growth, emphasizing the range of potential outcomes. For the terminal value multiple, we use a uniform distribution with a lower bound equal to eighty-five percent of the "Base Case" scenario and an upper bound equal to one over eighty-five percent of the "NZE" scenario. The uniform distribution is appropriate here given the high unpredictability of this variable. This method assumes that all outcomes within this range are equally likely, providing a straightforward way to model the terminal value. The bounds are set 15% below and above the respective scenarios to establish a reasonable range that accounts for potential deviations in either direction. This approach ensures that we consider a broad spectrum of possible terminal values while maintaining a realistic scope for the analysis.

Variable	*Distribution*	*Mean*	*Standard Deviation*
2035 CAGR Copper	Normal	"Mid-Point" Scenario	("NZE"-"Base Case")/3
Variable	*Distribution*	*Lower Bound*	Upper Bound
TEV/Copper Reserves	Uniform	85% of "Base Case"	1/85% of "NZE"

Table.1: Monte Carlo Copper CAGR and TEV multiple Distributions

Similarly, for copper prices, we apply the same rationale as for the 2035 CAGR variable. We use a normal distribution with the mean set to the "Mid-Point" scenario and the standard deviation set to one third the difference between the "NZE" scenario and the "Base Case" scenario. This approach allows us to capture the expected range and uncertainty in future copper prices, ensuring that our model reflects the potential variability in market conditions.

Variable	*Distribution*	*Mean*	*Standard Deviation*
Copper Price 2024	Constant	N/A	N/A
Copper Price 2025	Normal	"Mid-Point" scenario	("NZE"–"Base Case")/3
Copper Price 2026	Normal	"Mid-Point" scenario	("NZE"–"Base Case")/3
Copper Price 2027-onwards	Normal	"Mid-Point" scenario	("NZE"–"Base Case")/3

Table.2: Monte Carlo Copper Price Distributions

For all other commodities, including molybdenum, gold, and silver, we have not separated our assumptions by years, so there will only be one distribution for each. As we have shown throughout the paper, each commodity is priced using different units: molybdenum is priced per pound (lb.) and gold and silver per ounce (oz.). We use a normal distribution with the "Mid-Point" scenario as the mean and fifteen percent of the mean as the standard deviation. This choice was made to ensure that approximately 95% of all observations fall within a range of ±30% of the average price, accurately reflecting the uncertainty about these prices. This makes sense because these other raw materials are not the primary focus of our analysis. By applying a consistent and reasonable approach to their pricing, we can account for their contribution to the overall valuation without complicating the model with excessive detail. This method ensures that our assumptions are robust yet simplified, reflecting the secondary importance of these commodities in our study.

Variable	*Distribution*	*Mean*	*Standard Deviation*
Molybdenum Price	Normal	"Mid-Point" scenario	15% of "Mid-Point"
Gold Price	Normal	"Mid-Point" scenario	15% of "Mid-Point"
Silver Price	Normal	"Mid-Point" scenario	15% of "Mid-Point"

Table.3: Monte Carlo Other Metals Price Distributions

All assumptions for Operating Expenses are represented as a percentage of revenues, ensuring that their impact scales appropriately with the company's performance. To calculate the Sales, Inventories, and Account Payables, we use the "Days Outstanding" method, which ties these items directly to revenue, reflecting the efficiency of the company's operational cycle. For the rest of the Balance Sheet items that require assumptions—Other Current Assets, Restricted Cash, Long-term mill & leach Stockpiles, Other Long-Term Assets, Other Long-Term Liabilities, and Environmental and Employee Obligations—these are also structured as a percentage of revenues to maintain consistency in how these items are projected. For all these variables, we use a normal distribution in the Monte Carlo simulation. The mean is set to the value of the "Mid-Point" scenario, and the standard deviation is fifteen percent of the mean. This approach ensures a consistent and reasonable method for modeling the variability of these financial metrics without introducing unnecessary complexity. By applying this distribution, we effectively capture expected fluctuations while keeping the model straightforward and focused on the primary variables. This methodology provides robust yet simplified assumptions, facilitating a clear and comprehensive analysis of FCX's financial performance.

Variable	*Distribution*	*Mean*	*Standard Deviation*
SGA	Normal	"Mid-Point" scenario	15% of "Mid-Point"
Exploration & Drilling	Normal	"Mid-Point" scenario	15% of "Mid-Point"
Other Income	Normal	"Mid-Point" scenario	15% of "Mid-Point"
Income from Affiliates	Normal	"Mid-Point" scenario	15% of "Mid-Point"
Other Non-Operating Income	Normal	"Mid-Point" scenario	15% of "Mid-Point"
Day Sales Outstanding (DSO)	Normal	"Mid-Point" scenario	15% of "Mid-Point"
Days Inventory Outstanding (DIO)	Normal	"Mid-Point" scenario	15% of "Mid-Point"
Days Payable Outstanding (DPO)	Normal	"Mid-Point" scenario	15% of "Mid-Point"
Other Current Assets	Normal	"Mid-Point" scenario	15% of "Mid-Point"
Restricted Cash	Normal	"Mid-Point" scenario	15% of "Mid-Point"
Long-Term Mill & Leach Stockpiles	Normal	"Mid-Point" scenario	15% of "Mid-Point"
Other Long-Term Assets	Normal	"Mid-Point" scenario	15% of "Mid-Point"

Other Long-Term Liabilities	Normal	"Mid-Point" scenario	15% of "Mid-Point"
Environmental and Employee Obligations	Normal	"Mid-Point" scenario	15% of "Mid-Point"

Table.4: Monte Carlo Operating Assumptions Distributions

For the countries in which Freeport McMoRan operates that do not have carbon pricing mechanisms in place, which is the case for the United States, Indonesia, and Peru, we take a random year between the 2025 and 2035 period to be the year of adoption of the carbon pricing mechanism. This was decided because our DCF analysis will only predict the period from 2025 to 2035, allowing us to account for the uncertainty and variability in the timing of carbon pricing implementation within the timeframe of our forecast.

Variable	*Distribution*	*Range*
US Carbon tax year	Discrete Uniform	2025-2035 inclusive
Indonesia Carbon tax year	Discrete Uniform	2025-2035 inclusive
Peru Carbon tax year	Discrete Uniform	2025-2035 inclusive

Table.5: Monte Carlo Carbon tax Adoption Years Distributions

To model the carbon price in the Monte Carlo simulation, for the countries that already have a carbon pricing mechanism in place, such as Chile, the European Union, and the United Kingdom, we use a uniform distribution with 0% as the lower bound and the "NZE" CAGR as the upper bound. With each draw, we select the carbon pricing annual growth rate for each year that will be applied in each simulation. This approach captures the range of potential growth rates in carbon pricing, reflecting both current trends and ambitious future targets. For the countries that do not currently have a carbon pricing mechanism in place, we assume they will adopt carbon pricing aligned with comparable countries once implemented. Specifically, for Indonesia and Peru, we assume they will adopt Chile's carbon price, given their status as developing economies. For the United States, we assume it will adopt the United Kingdom's carbon price, reflecting their similar economic status and considering the political environment in the US, which tends to be less receptive to ESG policies than the EU.

Variable	*Distribution*	*Lower Bound*	*Upper Bound*
Chile carbon tax CAGR	Uniform	0%	"NZE" CAGR
EU carbon tax CAGR	Uniform	0%	"NZE" CAGR
UK carbon tax CAGR	Uniform	0%	"NZE" CAGR

Table.6: Monte Carlo Carbon Price CAGR Distributions

7 Results

The results section focuses on the valuation outcomes under four different scenarios: Base Case, Net Zero Emissions (NZE), Mid-Point, and Monte Carlo simulation.

In the Base Case (BC) Scenario, which assumes a 'business as usual' approach where existing operational, economic, and regulatory conditions persist, the implied share price for Freeport McMoRan (FCX) is $26.96. This scenario reflects the current state without significant changes in environmental policies or market demand shifts, providing a conservative estimate of FCX's value under stable conditions. In the Net Zero Emissions (NZE) Scenario, which assumes the gradual adoption of all necessary legislations and demand trends to advance towards the Net Zero by 2050 climate objective, the implied share price for FCX is $65.24. This scenario incorporates increased demand and prices for copper, driven by its critical role in green technologies and energy transition, and the widespread implementation of robust carbon pricing systems. This optimistic scenario reflects the potential for substantial growth in FCX's valuation under aggressive environmental and regulatory advancements. The Mid-Point (MP) Scenario represents an average between the Base Case and NZE scenarios, providing a balanced perspective that incorporates elements of both scenarios. The implied share price in this scenario is $45.19. This scenario offers a moderate outlook, considering a mix of stable operational conditions with some advancements in environmental policies and market demand for copper.

The Monte Carlo Simulation modeled the uncertainty of key variables using appropriate probability distributions, with the mean set to the Mid-Point estimate and selected standard deviations reflecting the variability and uncertainty inherent in each variable. The simulation ran 10,000 trials, yielding an average implied share price of $46.36 with a standard deviation of $8.51. From the outcomes, it could be observed that 95% of the trials resulted in an implied share price between $30.26 and $63.93, while 90% of the trials fell within a range of $32.81 to $60.59. This wide range of outcomes highlights the significant volatility and uncertainty in FCX's future performance, driven by variability in market conditions, regulatory changes, and demand for copper.

These results provide a comprehensive view of FCX's potential valuation across different scenarios, offering critical insights into the interplay between mining operations, environmental policies, and market dynamics. The Base and NZE scenarios represent the extremes of possible outcomes, while the Mid-Point and Monte Carlo scenarios provide a more nuanced understanding of FCX's valuation under varying assumptions.

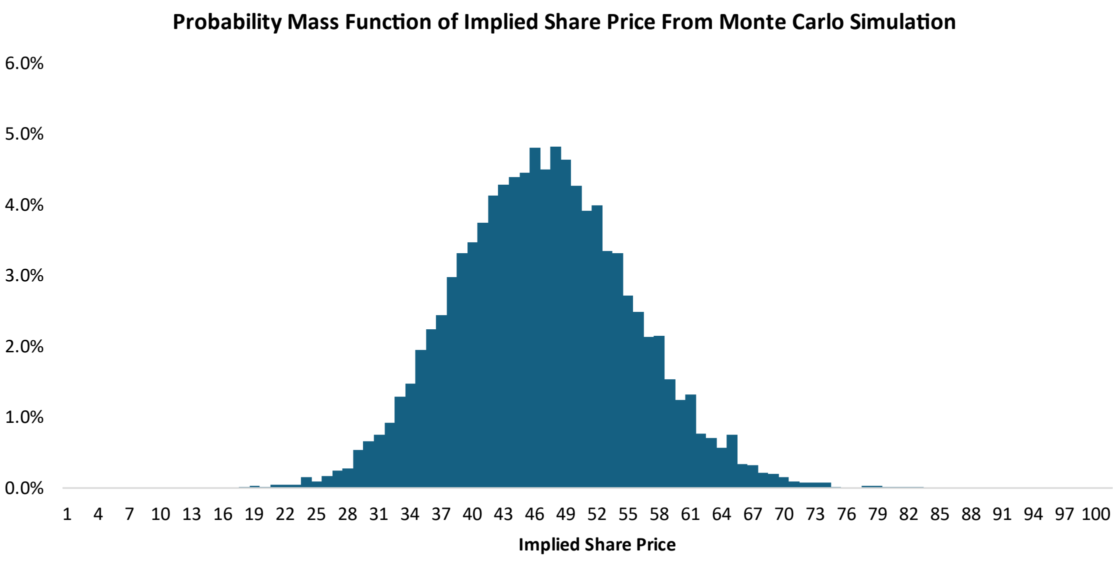

Figure.13: Probability Mass Function of Implied Share Price from Monte Carlo Simulation, showing the distribution of implied share prices derived from 10,000 simulation trials.

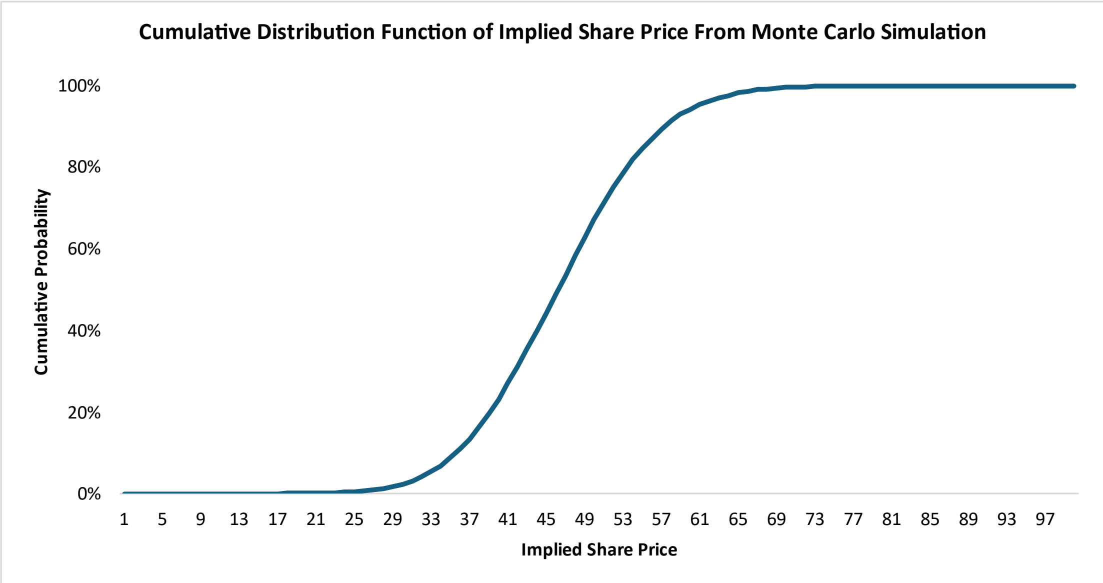

Figure.14: Cumulative Distribution Function of Implied Share Price from Monte Carlo Simulation, illustrating the cumulative probability distribution of the implied share prices from the simulation.

The results of our Monte Carlo simulation, as depicted in the provided graphs, indicate significant insights into the valuation of Freeport McMoRan (FCX). The probability mass function shows a wide distribution of implied share prices, highlighting the substantial volatility and uncertainty in the potential outcomes. The cumulative distribution function further illustrates that 77.6% of the simulated outcomes suggest an implied share price lower than the current market price of $52.73.

8 Limitations

This paper had to face some meaningful limitations in the modelling of FCX and the development of the valuation framework, which have influenced the outcome of our analysis. These limitations primarily stem from lack of access to relevant data and inherent uncertainties to the nature of the study, which we will discuss in this section. By discussing these limitations, we aim to provide a view on the challenges that are currently faced by analysts who would like to value a publicly-traded company considering climate change factors and risks, and which are the key points of improvement in financial transparency that should be tackled to make these type of analysis more accurate in the future.

Firstly, there are certain limitations on the available information when it comes to legislation development and the effects it could potentially have on the company. For instance, currently only some of FCX's operations are affected by active carbon taxes or Emission Trading Systems (ETS), but it is widely accepted that to reach the Net Zero by 2050 goal such carbon pricing mechanisms must be adopted across the world. However, there is a substantial lack of information about the expected development of these mechanisms in the future. The same issue persists with regards to the carbon price. It is widely accepted that to reach Net Zero by 2050 the carbon price applied in carbon-pricing mechanisms will have to rise substantially, but there is no available information on any approved plans or estimations. Furthermore, even for those carbon taxes or ETS FCX is affected by today, such as the Netherlands carbon tax or the EU ETS, there is no information available about how much FCX had to pay for those policies specifically or which is their allocated cap in the ETS mechanism (a key aspect of Emission Trading Systems). Despite FCX being a very transparent company in terms of its environmental and emissions reporting relative to its industry, there are also limitations about the CO_2 emissions reporting for the Miami smelter and El Paso refinery, which makes the calculation of their CO_2 intensity (on which their CO_2 emission targets are based) impossible without substantial assumptions. The same could be said about reporting on the actual financial cost associated to climate-related risks, which FCX already mentions in its reports. Additionally, there are some limitations when it comes to the modeling of the company's mineral reserves. For instance, we do not have access to information regarding the relationship between operational costs, metal price, and the calculation of the reserves. Since our reserves are calculated as a function of the final product's price to ensure economic viability, not having this information is a serious limitation. Similarly, there is no information about how the number of reserves will change after the Indonesian concession extension beyond 2041 is completed, which is a serious limitation since GMD reserves are only those that will be able to be mined until the ending of the mining concessions in 2041 and consequently we are likely undervaluing FCX's Terminal Value. Moreover, in the discounted cash flow analysis, the terminal value of FCX depends directly on the company's reserves. Since most scenarios assume an increase in copper prices, the inability to accurately estimate how much of the mineral resources not included in the current reserves will become recoverable as proven and probable reserves becomes significant. This uncertainty, given the potential rise in copper prices, severely limits our valuation ability for the company. Finally, some limitations in the reporting of relevant financial data were also significant. For instance, the lack of reporting of the operating costs of all mines other than Cerro Verde, Morenci and Grasberg (considered "material mines" and must publish a Technical Report Summary of Mineral Reserves and Mineral Resources), which would have allowed for more detailed modeling of the mine's production.

9 Findings & Discussion

Our analysis has provided several key insights into the valuation drivers for Freeport McMoRan (FCX). The most critical variables influencing FCX's valuation are the copper price, copper CAGR, and WACC. The sensitivity analysis clearly demonstrates that fluctuations in copper price have the most significant impact on the implied share price, followed by changes in the copper CAGR and WACC. The carbon tax, according to our analysis, does not represent a significant driver of valuation, even if an increase in carbon tax is not coupled by an increase in either the copper price or the copper CAGR as done in our methodology.

Our analysis highlights that the copper price is the most influential variable in determining FCX's valuation. Small changes in the copper price can lead to significant variations in the implied share price, underscoring its critical role in the company's financial performance. The copper CAGR also plays a crucial role, with higher growth rates in copper demand significantly boosting FCX's valuation, highlighting the importance of sustained demand growth for copper, driven by its essential role in green technologies and energy transition projects. Furthermore, the inability to properly assess the relationship between copper prices and the conversion of mineral resources not included in the current reserves to proven and probable reserves, underestimates the significant impact of copper prices on the valuation of Freeport McMoRan. In Figure.17, a sensitivity analysis demonstrates how different percentage conversions from total mineral resources not included in the current reserves to proven and probable reserves could affect the per share valuation of the company. As shown in the table, the percentage of conversion can have a substantial impact on the company's valuation.

INCREASE IN USD PER SHARE

		EV / COPPER BLN. LBS IN RESERVES MULTIPLE		
		0.90x	1.14x	1.37x
	100.0%	20.55	25.94	31.34
PERCENTAGE OF RESOURCES	80.0%	16.44	20.76	25.07
NOT INCLUDED IN RESERVES	60.0%	12.33	15.57	18.80
CONVERTED TO RESERVES	40.0%	8.22	10.38	12.53
	20.0%	4.11	5.19	6.27

PERCENTAGE PER SHARE INCREASE

		EV / COPPER BLN. LBS IN RESERVES MULTIPLE		
		0.90x	1.14x	1.37x
	8.3%	39%	49%	59%
PERCENTAGE OF RESOURCES	9.3%	31%	39%	48%
NOT INCLUDED IN RESERVES	10.3%	23%	30%	36%
CONVERTED TO RESERVES	11.3%	16%	20%	24%
	12.3%	8%	10%	12%

Figure.15: Sensitivity Analysis of Per Share Valuation Increase Based on Conversion of Mineral Resources to Proven and Probable Reserves

Additionally, the Weighted Average Cost of Capital (WACC) is another important variable; lower WACC values enhance FCX's valuation by reducing the discount rate applied to future cash flows, thereby increasing their present value.

While carbon taxes are an important consideration, their direct impact on FCX's valuation is mitigated by the corresponding increases in copper price and demand. The analysis indicates that the market seems to expect the Net Zero Emissions (NZE) assumptions to be more likely than the Mid-Point scenario assumptions. This expectation hinges on the successful implementation of NZE plans by both governmental authorities and the private sector, reflecting a broader confidence in global efforts towards decarbonization. Even if carbon taxes are aggressively implemented while copper prices and copper CAGR remain stable (which is unlikely), they do not become a significant factor. This can be seen in Figure.18, where we compare how the sensitivity tables in the base case vary if we implement the NZE case regulations. It is clearly shown that although stricter regulations decrease the valuation of Freeport McMoRan, they do so in a relatively minor fashion, affecting the price by less than 4%.

IMPLIED SHARE PRICE WITH BASE CASE ASSUMPTIONS AND CURRENT REGULATIONS

		COPPER CAGR (%)				
		1.0%	2.0%	3.0%	4.0%	5.0%
	0.90x	26.07	27.97	29.98	32.09	34.63
TERMINAL	1.05x	27.72	29.51	31.38	33.34	35.77
ENTERPRISE VALUE OVER	1.20x	29.38	31.04	32.78	34.58	36.90
COPPER RESERVES MULTIPLE	1.35x	31.03	32.57	34.17	35.83	38.03
	1.50x	32.69	34.10	35.57	37.07	39.16

IMPLIED SHARE PRICE WITH BASE CASE ASSUMPTIONS AND NZE CASE REGULATIONS

		COPPER CAGR (%)				
		1.0%	2.0%	3.0%	4.0%	5.0%
	0.90x	25.03	26.93	28.94	31.05	33.60
TERMINAL	1.05x	26.68	28.47	30.34	32.30	34.73
ENTERPRISE VALUE OVER	1.20x	28.34	30.00	31.74	33.55	35.86
COPPER RESERVES MULTIPLE	1.35x	29.99	31.53	33.13	34.79	36.99
	1.50x	31.65	33.06	34.53	36.04	38.12

Figure.16: Sensitivity Analysis of Implied Share Valuation with the Base Case Assumptions but with NZE Case Regulations

This result may seem counterintuitive given that the current copper price per metric ton is 9,832.61 USD (2,204.62 pounds per metric ton times 4.46 USD per pound) and the current average emissions of tons of CO_2 per metric ton of copper is 3.72. With the European CO_2 carbon price forecasted for 2035 in the NZE scenario of 232.86 USD, this yields a total carbon pricing per metric ton of copper of 866.24 USD. This would result in a carbon tax cost of 8.81% of the revenues generated at the current copper price, which is significant. However, most of Freeport McMoRan's emissions occur in countries with lax or non-existent carbon-pricing mechanisms, reducing the incentive to lower emissions. Regions like Indonesia, Peru, and the United States lack stringent carbon pricing, allowing the company to maintain higher profit margins despite global environmental trends. While beneficial in the short term, this poses long-term risks as policies may tighten, leading to potential future liabilities and abrupt operational adjustments. This reliance on lenient regulations questions the sustainability of such a strategy in the face of evolving global standards.

The Monte Carlo simulation further emphasizes the volatility and uncertainty in FCX's valuation, with a wide range of possible outcomes. The average implied share price from the simulation is $46.36, with a standard deviation of $8.51. This range of outcomes underscores the importance of considering multiple scenarios and probabilistic approaches in financial modeling. In conclusion, our findings highlight the paramount importance of copper prices and demand growth in driving FCX's valuation. While carbon taxes pose regulatory and operational challenges, their impact is counterbalanced by market dynamics favoring higher copper prices and demand. The market's current valuation suggests a tilt towards optimistic NZE scenarios, contingent on robust policy implementation and industry adaptation. These insights are crucial for investors and stakeholders in understanding the key drivers and risks associated with FCX's financial performance.

IMPLIED SHARE PRICE

		WACC				
	45.19	8.3%	9.3%	10.3%	11.3%	12.3%
	0.90x	51.08	46.91	43.12	39.66	36.50
TERMINAL	1.05x	52.84	48.49	44.53	40.93	37.64
ENTERPRISE VALUE OVER	1.20x	54.59	50.06	45.94	42.19	38.78
COPPER RESERVES MULTIPLE	1.35x	56.35	51.64	47.35	43.46	39.92
	1.50x	58.11	53.21	48.77	44.73	41.05

IMPLIED SHARE PRICE

		COPPER PRICE 2027-ONWARDS				
	45.19	$ 4.00	$ 5.00	$ 6.00	$ 7.00	$ 8.00
	1.0%	27.12	35.17	43.22	51.26	59.31
COPPER	2.0%	28.62	37.27	45.93	54.59	63.24
CAGR (%)	3.0%	30.18	39.49	48.80	58.11	67.42
	4.0%	31.80	41.81	51.82	61.83	71.84
	5.0%	33.88	44.65	55.41	66.18	76.94

IMPLIED SHARE PRICE

		COPPER CAGR (%)				
	45.19	1.0%	2.0%	3.0%	4.0%	5.0%
	0.90x	37.63	40.31	43.16	46.16	49.65
TERMINAL	1.05x	39.29	41.85	44.55	47.40	50.78
ENTERPRISE VALUE OVER	1.20x	40.94	43.38	45.95	48.65	51.91
COPPER RESERVES MULTIPLE	1.35x	42.60	44.91	47.35	49.89	53.04
	1.50x	44.26	46.45	48.74	51.14	54.18

IMPLIED SHARE PRICE

		COPPER PRICE 2027-ONWARDS				
	45.19	$ 4.00	$ 5.00	$ 6.00	$ 7.00	$ 8.00
	0.90x	27.87	37.14	46.40	55.67	64.94
TERMINAL	1.05x	29.27	38.54	47.81	57.08	66.34
ENTERPRISE VALUE OVER	1.20x	30.68	39.95	49.21	58.48	67.75
COPPER RESERVES MULTIPLE	1.35x	32.09	41.35	50.62	59.89	69.15
	1.50x	33.49	42.76	52.03	61.29	70.56

IMPLIED SHARE PRICE

		COPPER CAGR (%)				
	45.19	1.0%	2.0%	3.0%	4.0%	5.0%
	8.3%	48.25	51.06	54.03	57.16	60.96
	9.3%	44.12	46.77	49.57	52.51	56.06
WACC	10.3%	40.38	42.88	45.51	48.28	51.60
	11.3%	36.98	39.33	41.81	44.42	47.53
	12.3%	33.88	36.10	38.44	40.90	43.82

IMPLIED SHARE PRICE

		COPPER PRICE 2027-ONWARDS				
	45.19	$ 4.00	$ 5.00	$ 6.00	$ 7.00	$ 8.00
	8.3%	36.41	47.11	57.80	68.50	79.19
	9.3%	33.15	43.11	53.08	63.04	73.00
WACC	10.3%	30.19	39.49	48.78	58.07	67.36
	11.3%	27.51	36.19	44.86	53.54	62.22
	12.3%	25.07	33.18	41.29	49.41	57.52

Figure.17: Sensitivity analysis of FCX's implied share price to various parameters including Terminal Enterprise Value over Copper Reserves Multiple, Copper CAGR, Copper Price from 2027 onwards, and WACC. This analysis highlights the critical impact of these variables on the valuation outcome.

9.1 Comparison with Industry Analysis

Comparing our findings with those of current industry analysts such as JP Morgan's Bill Peterson, Bennet Moore and Mahima Kakani, as well as Deutsche Bank's Liam Fitzpatrick, Edward Goldsmith, and Bastian Synagowitz in their Freeport McMoran Q4 2023 review reports, we note the following differences.

The JP Morgan report cites FCX's stable base of production coming from its existing portfolio of assets and its strong potential for near-term growth, which is reflected in a target price of $43 per share. The report mentions that although near-term growth prospects may not be as impressive as those of other peers like Teck Resources, FCX's long-term growth potential makes it more attractive. This potential is mostly rooted in the studied expansion of their Grasberg Minerals District operation through the undeveloped Kucing Liar deposit which is expected to increase production by 6bn pounds (+550mn lbs./year) of copper and 6mn ounces (+560k oz./year) of gold between FCX's current concession period of 2028 and 2041 (Peterson, 2024). This is an important difference with our methodology as instead of considering the Kucing Liar expansion we have assumed an increase in capex proportional to the current proven reserves of each mine and dependent on whether excess production (relative to the year 2023 and resultant from increased demand and/or production needs due to reserve exhaustion or closure in other mines) is needed or not. Thus, if the JPM analysts are assuming an immediate production increase of 550mn lbs./year in copper and 560k oz./year in gold, it will result in an overestimation of FCX's production at least during the 2028 to 2035 period for the "Base Case" scenario and an underestimation under the "Mid-Point" and "NZE" scenarios, relative to our demand-led methodology. Another difference of approach with the JP Morgan analysts is with their very near-term approach to copper macro perspective, expecting a weak copper market due to weaker economic fundamentals in China. This is not a significant difference as our paper takes a longer-term perspective, with which our estimations and those of the report concur. The JP Morgan analysts expect tightness in mine supply during 2024 and more pressure in Treatment and Refining Charges (which usually cause in cuts in smelter production), resulting in copper deficits across the board and bullish copper pricing with varying intensity depending on the recovery of ex-China demand. Additionally, the analysts argue that demand growth tied to the energy transition will outpace supply growth leading to even more pronounced deficits by the end of the decade (Peterson, 2024). Both macro estimations agree with our own. One of the main differences in valuation methodology is that JP Morgan's analysts value FCX using a 50-50 weighted Net Asset Value (NAV) and Enterprise Value to EBITDA (EV/EBITDA) multiple, instead of our DCF methodology. JP Morgan uses the expected trough in copper pricing, growing cash flow generation (from the expected increase in Free Cash Flows as the Indonesia smelter finished construction), and a pipeline of long-term projects to justify an increase from the historical 6x to the current 8x EV/EBITDA multiple and an increase in the NAV due to the assumed development in the Kucing Liar and efficient leaching initiatives. Through our DCF methodology we take a much more intrinsic and disaggregated approach to valuing FCX.

The Deutsche Bank analysts have also kept an overall neutral outlook on FCX maintaining its price target at $44 per share, citing lower expected EBITDA in 2024 due to increased unit costs that are offset by raising EBITDA in the following years due to higher volumes sold. The report also mentions the ramp-up of the Manyar Smelter in Indonesia, the increase in leaching activity from the actual 200mlbs per year to 400mlbs per year over the next 2-3 years and 800mlbs in 5 years, the likely extension of concession rights in Indonesia beyond 2041, and the $3.5bn in capex Bagdad extension dependent on market conditions and the copper price incentive. The key difference with our valuation is that we have not factored in the likely extension of concession rights for the Grasberg operations beyond 2041 in our terminal value calculations, nor the potential expansion of the Bagdad mine as soon as copper price incentives are met. For the former, we assume that the current operational reality of FCX is maintained and thus we do not assume an extension of FCX's concession rights. This has the indirect effect that we are essentially undervaluing FCX's terminal value since all of the Indonesia proven and probable reserves only count for the material they expect to be able to extract by 2041, not the actual material that is available for extraction if they were to extend the concession beyond 2041. For the latter, we take the gradual demand-led approach to capex and production scheduling mentioned in the methodology section. This was done in the interest of reducing uncertainty and having an accurate image of the company's current operational conditions.

10 Conclusion

The valuation of Freeport McMoRan (FCX) presented in this research highlights several key findings regarding the company's future financial performance under various scenarios and the implications of different market conditions and regulatory frameworks.

Our analysis using the Discounted Cash Flow (DCF) method suggested an implied share price of $26.96 in the Base Case scenario, $65.24 in the NZE scenario, and $45.19 in the Mid-Point scenario. On the other hand, the Monte Carlo Simulation, which modeled uncertainty using probability distributions for key variables, produced an average implied share price of $46.35 with a standard deviation of $8.51. These results indicated that 95% of the trials yielded an implied share price between $30.26 and $63.93, while 90% of the trials fell within the range of $32.81 to $60.59. Overall, the findings highlight the substantial volatility and uncertainty in FCX's future valuation, driven by fluctuations in market conditions, regulatory changes, and demand for copper. The sensitivity analysis demonstrated that the most influential variable on FCX's valuation is the copper price, followed by the copper compound annual growth rate (CAGR) and the weighted average cost of capital (WACC). The limited effect of carbon pricing regulations is largely due to the company's operations in regions with lax or non-existent carbon-pricing mechanisms, which reduces the incentive for emission reductions and highlights the issue of regulatory arbitrage. This underscores the importance of international cooperation in setting global carbon pricing standards. Coordinated global efforts would be more effective in ensuring that companies like Freeport McMoRan are uniformly regulated, thereby preventing them from exploiting regional regulatory discrepancies. Moreover, the most likely scenario is that stricter carbon regulations will coincide with higher copper prices and a higher compound annual growth rate (CAGR) in copper demand. These factors are beneficial to copper companies, as increased prices and demand for copper used in green technologies can offset the costs associated with stricter environmental regulations. Consequently, the financial benefits from rising copper prices make it even less appealing for copper companies to proactively reduce emissions, further emphasizing the need for comprehensive and globally coordinated carbon pricing policies. Furthermore, the additional reserves that could derive from an increase in copper prices may be very significant; nevertheless, given the lack of proper disclosure, this relationship cannot be accurately quantified.

As further research, it would be interesting to expand our findings in this paper studying how climate change affects other high-risk sectors like agriculture, automotive, insurance, and real estate. Further research on this topic could allow us to define direct and indirect impacts such as a rise in insurance claims due to extreme weather events or changes in consumer trends. Following our adopted approach of considering multiple climate and legislative scenarios, we could eventually develop a comprehensive image of which industries are more sensible to climate change in a positive or negative way. Like we mentioned in the literature review section, this information could help expand our current understanding of investor perspectives and the degree to which investor decisions after considering climate-related factors is rationally influenced by the intrinsic value of assets. The same approach could be followed but instead of studying different sectors studying different regions. An additional natural continuation of this study would be to focus on the financial impact of adopting emission-mitigating technologies such as carbon capture and storage. This would take a more project-focused approach and look at the long-term impact on company profitability. With the current limitation of the lack of data on the relationship between physical risks and financial outcomes in companies, further research could also focus on studying how company-specific integrated assessment models, which are increasingly used to assess climate-related physical risks in a company, could be further adapted to be used for financial valuation. The main outcome would be to translate physical risks and potential mitigation strategies into concrete financial terms, which would be a very useful breakthrough in facilitating company valuation with climate-change considerations. Finally, given the politically centered and dynamic nature of climate-related regulations, further research will surely have to consider the impact of the implementation of new regulations as well as the elimination of existing ones.

In conclusion, this paper suggests that the market currently expects the Net Zero assumptions to be more likely than the Mid-Point scenario assumptions. However, this expectation heavily depends on the successful implementation of NZE plans by governmental authorities and the private sector. The insights gained from this analysis are crucial for investors and stakeholders in understanding the key drivers and risks associated with FCX's financial performance and in making informed investment decisions.

References

Literature Review

Addoum, Jawad M, et al. “Temperature Shocks and Industry Earnings News.” Journal of Financial Economics, vol. 150, no. 1, 1 Oct. 2023, pp. 1–45, https://doi.org/10.1016/j.jfineco.2023.07.002. Accessed 19 Oct. 2023.

Bancel, Franck, and Henri Philippe. “How Carbon Pricing Affects Value of Firms: The Case of Oil and Gas Companies.” Bankers, Markets & Investors, vol. 166, 2021.

Guidry, R. P. and Patten, D. M. (2010). Market reactions to the first-time issuance of corporate sustainability reports: Evidence that quality matters. Sustainability accounting, management and policy Journal.

Hartzmark, S. M. and Sussman, A. B. (2019). Do Investors Value Sustainability? A Natural Experiment Examining Ranking and Fund Flows. Journal of Finance, 74(6):2789–2837.

Hong, H. and Kacperczyk, M. (2009). The price of sin: The effects of social norms on markets. Journal of financial economics, 93(1):15–36.

Jacobs, B. W., Singhal, V. R., and Subramanian, R. (2010). An empirical investigation of environmental performance and the market value of the firm. Journal of Operations Management, 28(5):430–441.

Kruger, Philipp. “Climate Change and Firm Valuation: Evidence from a Quasi-Natural Experiment.” University of Geneva & Swiss Finance Institute, 2015.

Pagano, Marco, et al. “Disaster Resilience and Asset Prices.” Journal of Financial Economics, vol. 150, no. 2, Oct. 2023.

Qi, Rui, et al. “Simulating the Sustainable Effect of Green Mining Construction Policies on Coal Mining Industry of China.” Journal of Cleaner Production, vol. 226, July 2019, pp. 392–406, https://doi.org/10.1016/j.jclepro.2019.04.028.

Yıldız, Taşkın Deniz, et al. “Effects of EU-Compliant Mining Waste Regulation on Turkish Mining Sector: A Review of Characterization, Classification, Storage, Management, Recovery of Mineral Wastes.” Resources Policy, vol. 90, 1 Mar. 2024, p. 104836, www.sciencedirect.com/science/article/pii/S0301420724002034, https://doi.org/10.1016/j.resourpol.2024.104836. Accessed 1 June 2024.

Zhang, Yaxin, et al. “A Study on the Impact of the Carbon Emissions Trading Policy on the Mining Industry Based on Porter Hypothesis.” Resources Policy, vol. 87, 2023.

Freeport McMoRan

Freeport McMoRan. Form 10-K. United States Securities and Exchange Commission, 2023.

Freeport McMoRan. 2023 Annual Report. 2023.

Copper Forecast

Almeida da Silva, Daniela, et al. “Copper in Tumors and the Use of Copper-Based Compounds in Cancer.” Journal of Inorganic Biochemistry, vol. 226, no. 111634, Jan. 2022.

Alvarado, S. “Long Term Energy-Related Environmental Issues of Copper Production.” Energy, vol. 27, no. 2, Feb. 2002.

Bouckley, Katya. “Global Copper Demand to Rise 20% by 2035 to 30 Million Mt/Year: Nornickel.” Www.spglobal.com, 10 Oct. 2023, www.spglobal.com/commodityinsights/en/market-insights/latest-news/metals/101023-global-copper-demand-to-rise-20-by-2035-to-30-million-mtyear-nornickel#:~:text=Global%20copper%20demand%20to%20rise.

Elshkaki, Ayman, and T.E Graedel. “Solar Cell Metals and Their Hosts: A Tale of Oversupply and Undersupply.” Applied Energy, vol. 158, 2015.

Elshkaki, Ayman, et al. “Copper Demand, Supply, and Associated Energy Use to 2050.” Global Environmental Change, vol. 39, June 2016.

Fizaine, Florian, and Victor Court. “Renewable Electricity Producing Technologies and Metal Depletion: A Sensitivity Analysis Using the EROI.” Ecological Economics, vol. 110, Feb. 2015.

García-Olivares, Antonio. “Substituting Silver in Solar Photovoltaics Is Feasible and Allows for Decentralization in Smart Regional Grids.” Environmental Innovation and Societal Transitions, vol. 17, June 215AD.

Gómez, Fernando, et al. “Copper Recycling and Scrap Availability.” Resources Policy, vol. 32, no. 4, Dec. 2007, pp. 183–190, https://doi.org/10.1016/j.resourpol.2007.08.002.

Graedel, T. E., et al. “Criticality of Metals and Metalloids.” Proceedings of the National Academy of Sciences, vol. 112, no. 14, 23 Mar. 2015, pp. 4257–4262, https://doi.org/10.1073/pnas.1500415112.

ICSG. “Copper Bulletin: ICSG Monthly Publications.” International Copper Study Group, vol. 19, no. p.3, 2012.

ICSG. “World Refined Copper Production and Usage Trends” International Copper Study Group, 2015.

Kuckshinrichs, Wilhelm, et al. “CO2 Emissions of Global Metal-Industries: The Case of Copper.” Applied Energy, vol. 84, no. 7-8, 2007.

McKinsey & Co. “Copper-Processing Technologies: Growing Global Copper Supply | McKinsey.” Www.mckinsey.com, 17 Feb. 2023, www.mckinsey.com/industries/metals-and-mining/our-insights/bridging-the-copper-supply-gap.

Nassar, Nedal T., et al. “Criticality of the Geological Copper Family.” Environmental Science & Technology, vol. 46, no. 2, 6 Jan. 2012, pp. 1071–1078, https://doi.org/10.1021/es203535w.

Nassar, N. T., et al. “By-Product Metals Are Technologically Essential but Have Problematic Supply.” Science Advances, vol. 1, no. 3, Apr. 2015, p. e1400180, https://doi.org/10.1126/sciadv.1400180.

Northey, S., et al. “Modelling Future Copper Ore Grade Decline Based on a Detailed Assessment of Copper Resources and Mining.” Resources, Conservation and Recycling, vol. 83, Feb. 2014.

USGS. “USGS Mineral Resources Program Copper—a Metal for the Ages.” USGS, 2009, pubs.usgs.gov/fs/2009/3031/FS2009-3031.pdf.

Copper Price

IEA. “Executive Summary – the Role of Critical Minerals in Clean Energy Transitions – Analysis.” IEA, 2021, www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions/executive-summary.

Thornton, David. “Citi: Forget Lithium, Copper Is the Bullish Energy Transition Trade.” Market Index, July 2023.

Methodology

International Carbon Action Partnership (ICAP). “Chile ETS System.” Icapcarbonaction.com, 2021, icapcarbonaction.com/es/ets_system/54. Accessed 21 June 2024.

Simon, Frédéric. “EU Carbon Price to Hit €400 Mark with 90% Climate Goal.” Www.euractiv.com, 5 Oct. 2023, www.euractiv.com/section/emissions-trading-scheme/news/eu-carbon-price-to-hit-e400-mark-with-90-climate-goal-analysts/.

World Bank Group (WBG). “Chile Carbon Tax .” Carbon Pricing Dashboard, 2017, carbonpricingdashboard.worldbank.org/compliance/factsheets?instrument=Tax_CL. Accessed 21 June 2024.

World Bank Group (WBG). “Indonesia ETS.” Carbon Pricing Dashboard, 2023, carbonpricingdashboard.worldbank.org/compliance/factsheets?instrument=ETS_ID. Accessed 21 June 2024.

World Bank Group (WBG). “EU ETS.” Carbon Pricing Dashboard, 2005, carbonpricingdashboard.worldbank.org/compliance/factsheets?instrument=ETS_EU. Accessed 21 June 2024.

World Bank Group (WBG). “Netherlands Carbon Tax.” Carbon Pricing Dashboard, 2021, carbonpricingdashboard.worldbank.org/compliance/factsheets?instrument=Tax_NL. Accessed 21 June 2024.

World Bank Group (WBG). “UK ETS.” Carbon Pricing Dashboard, 2021, carbonpricingdashboard.worldbank.org/compliance/factsheets?instrument=ETS_UK. Accessed 21 June 2024.

Analyst Comparison

Fitzpatrick et.al., Deutsche Bank – Freeport McMoran Q4 Review. Deutsche Bank, Jan. 2024

Peterson et.al., JP Morgan - Freeport McMoRan Q4 Results. JP Morgan, Jan. 2024.