Gold Mining and Net Zero: A Comprehensive Assessment of St Barbara Limited's Carbon Management Strategy and Performance

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Abstract. In today's society, the expansion of industrialization has increased energy consumption and pollution. Global climate change is intensifying. In this context, to control global warming and environmental pollution, net zero and carbon management are being taken seriously by the international community and orgnisations. Consequently, traditional heavy industry enterprises represented by gold mining will face greater pressure and supervision. How to balance the economic goals and external pressure from public will be a severe challenge for enterprises. This paper will discuss emission estimates under different types of scopes. According to St Barbara's 2022 sustainability report, the total Scope 1 emissions were 145 kilotons (kt) Carbon Dioxide Equivalent (CO2e), Scope 2 emissions were 48 kt CO2e and Scope 3 emissions were 436 kt CO2e. Additionally, the relationship between revenue, gold production, and overall performance will also be analyzed.

Secondly, the report discusses St Barbara's carbon management strategies, including Ropecon replacement of traditional trucks, coral and mangrove plantings, and wetland restoration projects. These initiatives share a common trait: high initial investment aimed at achieving long-term stable economic and social benefits. The report questions the company's Scope 2 carbon emission estimation data and believes that further investigation and demonstration should be conducted.

Finally, this report acknowledges the limitations and puts forward three suggestions for improving carbon management performance in traditional heavy industrial enterprises represented by St Barbara. These suggestions are: implementing more clean energy or renewable energy, enforcing stricter monitoring and management of carbon emissions, and strengthening employee training on environmental protection.

Keywords: Carbon Management, Net Zero, Gold Mining, St Barbara Limited, Emission Estimates, Sustainability Strategies, Renewable Energy, Environmental Protection.

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1 Introduction

With the development of industrialization, the severity of global climate change has intensified (IPCC, 2023) [3]. Accordingly, governments and many international organisations have realized the seriousness of the problem and have proposed a series of policies and measures. Net-zero has become a worldwide common goal (United Nations, 2022) [19], which refers to a country, region or organisation reducing Greenhouse Gases (GHGs) emissions to zero as much as possible. Net-zero will face many challenges because it involves many factors such as environmental policy, technology and funding. However, Net-zero has great value and significance for sustainable social development and environmental and ecological balance.

From a meso-level perspective, carbon management is an essential factor in achieving net zero. It involves an organization's quantification, monitoring, and reporting of carbon emissions to effectively formulate and implement emission reduction strategies. Using effective carbon management strategies, organisations not only reduce negative impacts on the environment, but also improve energy efficiency, reduce operating costs, and enhance corporate competitiveness. For example, an electricity conservation strategy can reduce electricity usage, lower the company's electricity expenditure, and enhance corporate social responsibility. In addition, effective carbon management often requires an organisation to conduct comprehensive carbon emissions estimates for its operational activities. This enables the development of emission reduction targets and strategies, and to continuous monitoring to ensure the effectiveness of the plan.

In general, effective carbon management not only positively impacts the enterprise, but also serves as the crucial means of achieving Net-zero and sustainable development. In light of the challenge of climate change, it is essential to acknowledge the importance of carbon management.

2 Literature Review

2.1 Gold Mining and Environmental Impact

Since the mining of metal mines will lead to the destruction of the surface environment, the impact on the surface environment must be taken into account in the process of mining metal mines (Sonter et al., 2018) [10]. According to relevant statistics, the metal mining industry discharges approximately 22 billion tons of solid waste annually. Most of this waste consists of waste residue and waste liquid (United Nations Environment Programme, 2018) [19]. These wastes contain a large number of harmful and toxic substances, if not properly treated, they will cause serious damage to the surface environment (Tayebi-Khorami et al.) [18]. Additionally, due to the relatively complex terrain of metal mines, the mining process will inevitably cause ground collapse and landslide and other related issues (Rinkevich, 2014) [9]. The occurrence of these problems will not only result in serious threat to the life and property safety of the residents in the mining area, but also serious soil erosion in the surrounding area (Ma et al., 2022) [5].

2.2 Application of Carbon Management Strategies in the Mining Industry

Mineral enterprises first need to establish a sound carbon emission monitoring system, including monitoring and data collection of carbon emissions in various links such as mine, production line and transportation system. Through the installation of monitoring equipment and systems, real-time monitoring and collection of carbon emissions data, including carbon dioxide, methane and other greenhouse gases emissions (Zhou er al., 2020) [22]. At the same time, it is necessary to establish an accurate, comprehensive and real-time carbon emission statistical database to provide a reliable data basis for the carbon emission management of companies. Based on the collected carbon emission data, mineral enterprises need to conduct carbon emission accounting and evaluation (ICMM, 2019) [2]. By analyzing the carbon emissions at each stage of the industrial chain, mineral enterprises can determine the overall carbon footprint of their production process and identify the main sources of emissions and high energy consumption areas. At the same time, it is necessary to make use of national, regional and industrial carbon emission standards and guidelines to assess the carbon emission situation of enterprises, which may help identify existing problems and room for improvement (Wu et al., 2022) [20].

3 Methodology

3.1 Data Collection

The data provided in this paper are from the annual report and so on. The data collected include Category I, Category II, and Category III, gold production and related economic data. In addition, industry averages were collected from environmental protection websites and financial market reports for comparison. Statistical software is used to explore the specific impact of different carbon management strategies on carbon emissions and corporate performance by using trend analysis, comparative analysis, regression analysis and other analytical methods.

Quantitative analysis mainly evaluates the effectiveness of carbon management by analyzing the data of carbon emission, output and financial performance of enterprises. In the qualitative aspect, it mainly evaluates the implementation and effect of enterprises' carbon emission control and uses case study to deepen the understanding of enterprise strategy application.

3.2 Scope and Limitations of the Study

The study examined Santa Barbara Co.'s carbon emissions and management strategies from 2017 to 2022. The research relied on publicly available information and does not encompass all internal data and operational details. Therefore, the integrity of the data and the depth of the analysis will be affected. In addition, due to different regulatory regimes and market conditions in different countries, the findings of this project may not necessarily be generalized to other industries. At last, the impact of the COVID-19

pandemic on global supply chains and economic activities will also have a certain impact on the accuracy and relevance of the results of this study.

4 Industry Background and Challenge

Gold mining enterprises provide a compelling example for net-zero and carbon management research, demonstrating how to balance environmental and economic goals (Sonter et al., 2018) [10]. Gold mining has traditionally been viewed as an energy-intensive and environmentally destructive industry. During operations such as mining and transportation, companies release significant amounts of greenhouse gases (GHGs), contributing to climate change. In addition, gold mining business operations can lead to many other environmental problems, such as the destruction of environmental ecology and biodiversity. As the popularity of net-zero is increasing, companies must implement effective carbon management strategies to protect the environment, and thus maintain positive public relations.

Additionally, examining the carbon management strategies of gold mining companies reveals the potential for using clean energy in traditional heavy industries. It also shows how technological advancements and other emission reduction measures can impact company performance (World Gold Council, 2021) [21]. Since gold mining companies have long faced pressure from social environmental organisations and the government's strict environmental policies, they are actively seeking emission reduction measures and environmentally friendly technologies. By implementing these carbon management strategies, gold mining companies will significantly reduce carbon emissions and environmental impact and achieve greater environmental protection and economic benefits. Analyzing the carbon management practices of gold mining companies provides deeper insights into the strategies, challenges, and opportunities associated with achieving net-zero emissions and effective carbon management (Sustainable Minerals Institute, 2020) [16]. Besides, as the sustainable development becomes mainstream, it offers valuable insights and inspiration for traditional heavy industry enterprises seeking innovation.

5 St Barbara Overview

This paper uses Santa Barbara Co., Ltd. as a case study to conduct both qualitative and quantitative research on its carbon management strategy and performance (St Barbara Limited, 2019) [11]. St Barbara is a gold mining company with a global presence, currently operating projects in Australia, Canada and Papua New Guinea (PNG). The company started in Western Australia and was first registered and listed under the name Endeavor Oil in 1969. St Barbara initially focused on mineral exploration, but in the early 2000s it shifted its focus to gold production. The company has expanded and adjusted its scope and scale of its operations through the acquisition and sale of different asset allocations. Today, St Barbara is a global gold mining company with multiple operating projects in three countries and more than 2,200 employees worldwide (St Barbara Limited, 2021) [12].

Currently, St Barbara's main operating businesses include Leonora, Atlantic Operations and Simberi Operations. In 2022, St Barbara's turnover exceeded US$680 million with a gross profit over US$265 million. The company not only operates multiple gold mining projects, but also actively engages in exploration activities to discover new gold resources and mining opportunities. It is worth mentioning that, unlike traditional gold mining projects, Simberi Operations plans to extend the service life of the mine by at least 10 years by increasing sulfide processing capacity, while actively integrating into the local community, creating sustainable business opportunities for the local area.

However, St Barbara also meets many issues and challenges related to climate change, such as carbon emissions taxes and the impact of natural disasters on business operations. But the most important issue is energy efficiency, with the 2022 St Barbara Sustainability Report stating that gold mining may require more ventilation equipment and energy-intensive processing. This means that companies require more energy to conduct their mining activities, leading to increased greenhouse gas emissions and exacerbating the risk of climate change.

6 Sustainability Commitments

In response to the growing emphasis on sustainable development across various sectors, St Barbara, a traditional heavy industry enterprise, has made clear commitments and set goals for emission reduction. The St Barbara 2022 Sustainability Report outlines these future objectives (St Barbara Limited, 2022) [14].

First, the company aims to improve its Scope 1 and Scope 2 emissions efficiency (tons of gold/CO2e) by 18.6% by 2030 relative to 2013, achieving an emissions intensity of 0.45 tons of CO2e per ounce of gold. Increased efficiency will lead to reduced GHGs emissions. Secondly, St Barbara aims to be carbon neutral by 2050. These targets are guided by the Science-Based Targets Initiative (SBTI) and the United Nations, aligning the United Nations-approved absolute emissions reduction target for Australia in 2020, which mandates a 27% reduction by 2030 relative to 2005 (an annual decrease of 1.1%). The reasons for St Barbara's commitment to carbon management, as detailed in their annual and sustainability reports, include the critical importance of energy to gold producers, cost efficiency control, and the expectations of stakeholders.

St Barbara clearly recognizes that gold mining uses significant amounts of energy and their carbon intensity is likely to increase without proactive carbon management measures. While causing damage to the environment, it will also cause companies to face policy issues and potential legal disputes. Improving energy efficiency is therefore crucial for St Barbara, as it ensures the company's long-term sustainability.

By committing to and implementing effective carbon management measures, St Barbara can effectively reduce operating costs and improve operational efficiency, thereby increasing profitability and return on investment. At the same time, more resources can be allocated to other areas of the company, such as research and development or marketing.

From the perspective of internal stakeholders, with the development of environmental protection, the company's management, employees and shareholders are paying

more attention to sustainable development performance. St Barbara's commitment to carbon management can improve employee satisfaction and loyalty, attract and retain talented individuals, and enhance the company's internal cohesion and innovation capabilities. External stakeholders such as customers, communities and governments also prioritize sustainable development performance. Through carbon management commitments, it enhances its brand image and market competitiveness, attracting more customers and investments.

7 St Barbara Carbon Management Strategy

7.1 Emissions Estimates

7.1.1 Scope 1.

According to the International Standard Classification, Scope 1 carbon emissions arise from GHGs emissions generated by facilities directly operated by the company. As reported in St Barbara's 2022 and 2019 corporate sustainability reports, GHGs emissions from fiscal years 2017 to 2019 were recorded only in two countries: Australia and Papua New Guinea (PNG). Carbon emissions from corporate operations in Canada have also been included since 2020. The chart below (Fig. 1) shows St Barbara's Scope 1 absolute GHGs emissions in Australia, PNG and Canada from 2017 to 2022 (St Barbara Limited, 2022) [15].

The chart shows that between 2017 and 2019, CO2e released by companies in Australia has stabilized at around 64 kt, rising to 80kt from 2020, and reaching 95kt in 2022. On the contrary, the CO2e emitted by companies in PNG was stable at 77kt before 2020, rose to 82kt in 2020 (St Barbara Limited, 2021) [13], and then fell sharply, to only 38kt in 2022. The company's carbon emissions in Canada are only 12-15kt.

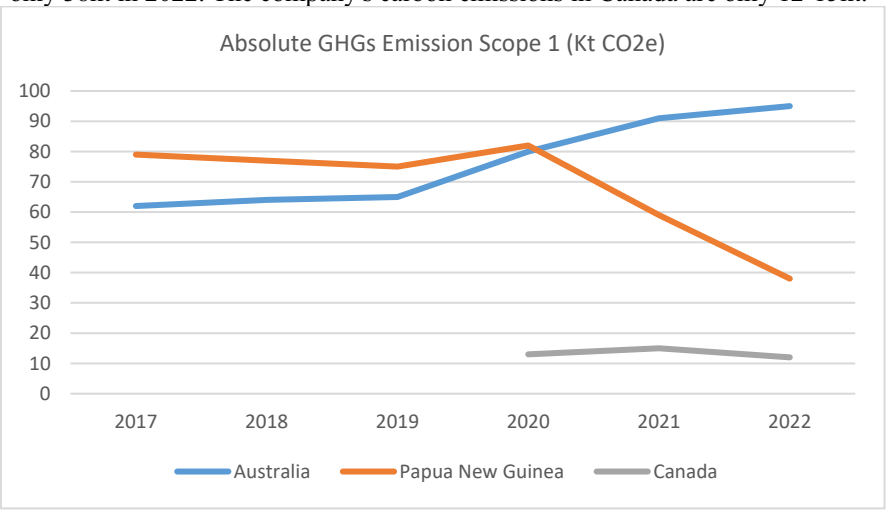

Fig. 1. Absolute GHGs Emission Scope 1 (Kt CO2e)

7.1.2 Scope 2.

Scope 2 refers to the GHGs gas emissions generated by companies purchasing and using electricity, heat and steam (Fig. 2). According to St Barbara's 2022 and 2019 Corporate Sustainability Reports, the company reported Scope 2 GHGs gas emissions of 1kt in Australia from 2017 to 2022, and zero emissions in PNG during the same period. In Canada, the reported Scope 2 GHGs emissions were 44kt in 2020, 46kt in 2021, and 47kt in 2022.

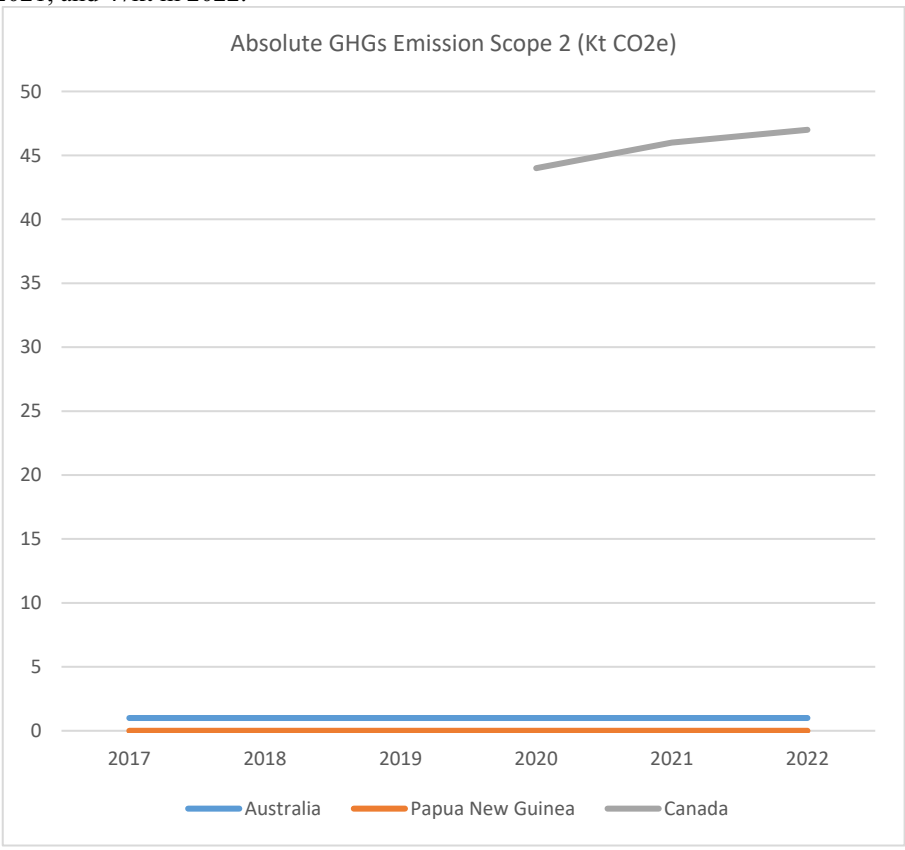

Fig. 2. Absolute GHGs Emission Scope 2 (Kt CO2e)

7.1.3 Total Emissions (Scope 1 + Scope 2).

Judging from the total GHGs emissions (Fig. 3), St Barbara's global emissions remained stable at around 141kt from 2017 to 2019. Due to the addition of Canadian business, it increased to 220kt in 2020 and then dropped to 194kt in 2022.

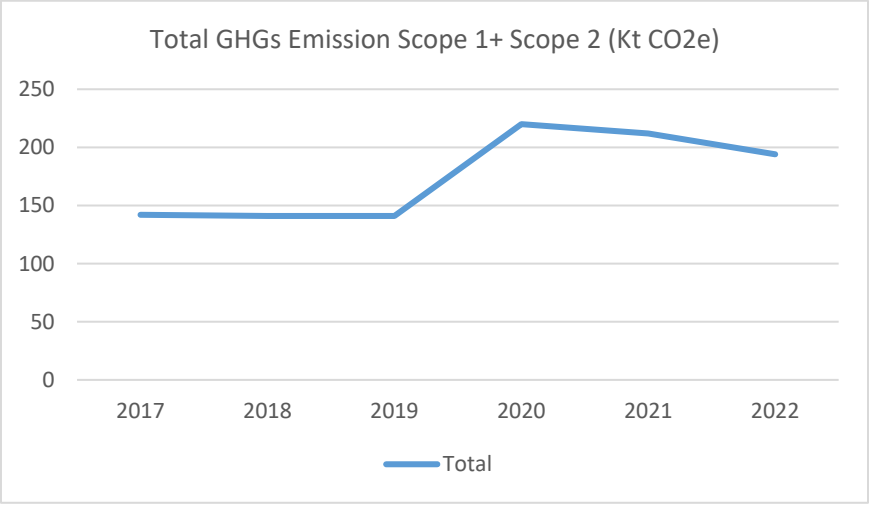

Fig. 3. Total GHGs Emission Scope 1+ Scope 2 (Kt CO2e)

7.1.4 Scope 3.

Scope 3 refers to other indirect emissions generated by corporate activities, most of which originate from the corporate value chain. Based on the St Barbara 2022 sustainability report, Scope 3 carbon emissions for each region in 2021 and 2022 are reported (Fig. 4). The total Scope 3 emissions in 2021 were 481kt and 2022 were 436kt. Notably, the Scope 3 emissions are more than twice the combined total of Scope 1 and Scope 2 emissions.

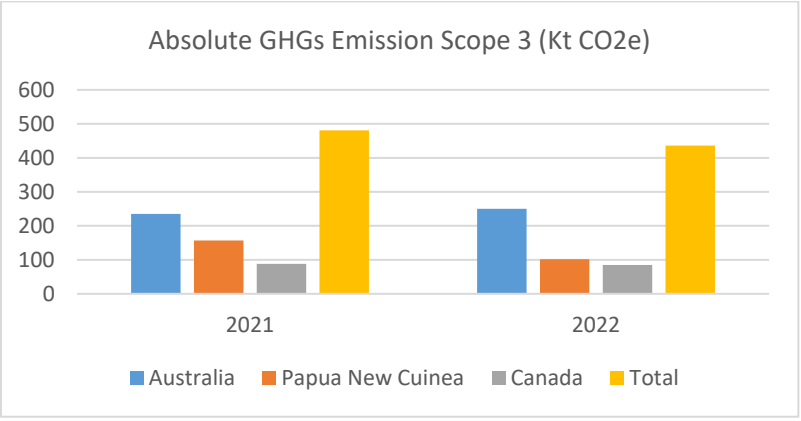

Fig. 4. Absolute GHGs Emission Scope 3 (Kt CO2e)

7.1.5 Revenue.

The figure below (Fig. 5) shows St Barbara's revenue (US$1,000/ton) corresponding to each ton of CO2e from 2017 to 2022. In 2020, revenue per ton of CO2e emissions decreased by nearly $850. Combined with the analysis of the above data, St Barbara's

carbon emissions have increased significantly since 2020, while its performance has decreased considerably.

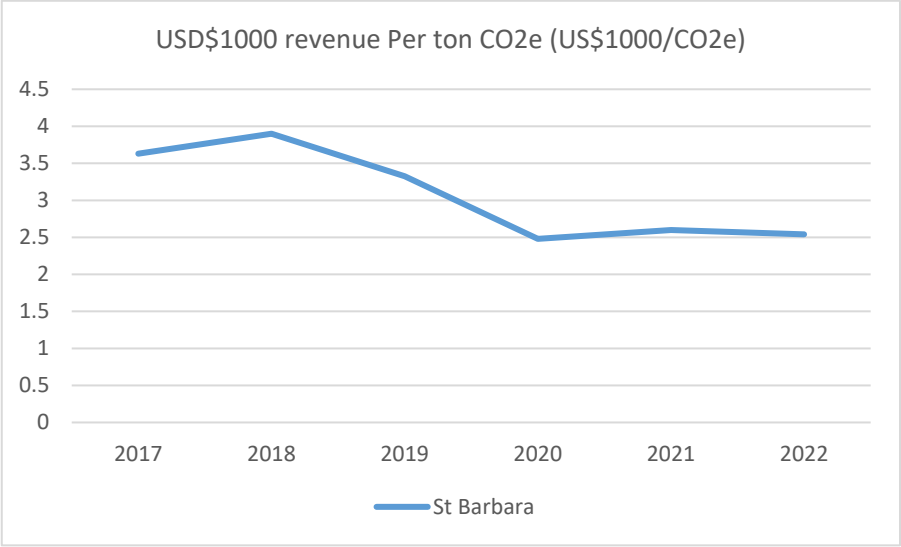

Fig. 5. USD$1000 revenue Per ton CO2e (US$1000/CO2e)

7.2 Emissions Reductions

Combined with St Barbara's 2019 to 2022 sustainability report and content analysis of the annual report, St Barbara identifies the importance of carbon management. In addition, three main carbon emission reduction methods are proposed: Ropecon transportation, Deep-sea tailings placement (DSTP), and wetland restoration related to gold mining. These methods of reducing carbon emissions play an important role in corporate sustainability strategies. Below is an analysis and summary of their effectiveness, feasibility and cost.

7.2.1 Ropecon.

In its sustainability report, St Barbara highlighted the use of Ropecon, a conveyor belt system, at its Simberi Operation to replace trucks transporting materials. This measure can save more than 4,000 tons of CO2e emissions. Compared with ordinary diesel trucks, Ropecon's carbon emissions are significantly lower, helping companies achieve environmental protection and emission reduction goals. From a feasibility perspective, the Ropecon conveyor belt system is a mature technology capable of operating in various terrains and environmental conditions, making it suitable for long-distance material transportation (Doppelmayr Transport Technology, 2023) [1]. And the system can continuously transport materials, greatly improving the efficiency and reliability of material transportation.

The Ropecon project is used in Simberi Operation because of St Barbara's environmental commitment and relevant regulatory requirements. This project is crucial in

helping the company achieve its goal of carbon neutrality in 2050. Additionally, by fulfilling its corporate social responsibility, the company can enhance its reputation among customers.

From a cost perspective, the construction of the Rocepcon system requires a large initial investment cost. However, by reducing fuel consumption and improving transportation efficiency, Ropecon systems can help companies achieve long-term operating cost savings.

7.2.2 Deep-Sea Tailings Placement (DSTP).

St Barbara's sustainability report mentions its efforts in Simberi Operation, which includes monitoring underwater activity and participating in projects such as coral propagation and mangrove planting. The implementation and monitoring technology of DSTP is relatively mature, ensuring the safety and effectiveness of DSTP and mitigating the adverse effects on the marine environment. From a project effectiveness perspective, monitoring underwater activities and participating in coral propagation and mangrove planting allows companies to protect marine ecosystems and reduce the impact of carbon emissions effectively. Consequently, the company achieved a significant reduction in carbon emissions, from 26,000 tons to 18,000 tons. Diesel usage has also been reduced from 9 million liters to 6 million liters.

This project is important to St Barbara as it supports businesses in achieving their sustainability goals. In addition, this not only helps the company's own development, but also meets the regulatory requirements of relevant organisations. From a cost perspective, DSTP, coral propagation and mangrove planting all require large initial investments, including the purchase of equipment and technology and staff training (Rinkevich, 2014) [9]. However, these projects can help companies improve their market image and attractiveness, reduce regulatory pressure, and thereby achieve long-term and stable economic and social benefits.

7.2.3 Wetland Restoration.

St Barbara's sustainability report mentions a research project on the restoration of wetlands associated with gold mining, applied to their Atlantic Operations. Similar to the previously mentioned planting projects, wetland restoration technology is relatively mature and can effectively restore and rebuild wetlands, reducing the impact of carbon emissions on the ecosystem (Moreno-Mateos et al., 2012) [6]. As a result, companies in the region have reduced carbon emissions from 14 to 11 kt, while diesel usage has remained at 4 million liters. The cost model of this project is similar to that of the red coral propagation project, which requires a large initial investment to purchase equipment and technology, train employees, etc. This supports St Barbara's sustainable development goals and ensures long-term returns.

8 Performance Evaluation of Carbon Management

St Barbara has repeatedly emphasized carbon management strategies, monitoring measures, and statistical results in its sustainability and annual reports. Three indicators are crucial in evaluating the performance of carbon management efforts: Absolute GHGs Emissions, the amount of gold produced per ton of CO2e emissions, and the revenue corresponding to each ton of CO2e emissions.

The report indicates that St Barbara's carbon emissions rose significantly in 2020, likely due to the addition of it Canadian operations. It is noteworthy that while carbon emissions have increased significantly, the revenue and gold produced per ton of CO2e emissions have declined. This suggests a significant decrease in enterprise productivity in 2020 and an increase in other operating costs. From the perspective of the external environment, this carbon management problem may be caused by the Covid-19 pandemic, which disrupted the global supply chain. Increased energy and labor prices have resulted in additional operating costs for companies, thereby reducing productivity and the amount of gold produced per ton of CO2 emissions.

8.1 Comparison of Similar Companies

Newcrest Mining Limited is a mineral development company headquartered in Australia, also engaged in gold mining like St Barbara (Newcrest Mining Limited, 2021) [7]. The difference is that Newcrest's business scale is larger than St Barbara's. Newcrest's revenue in 2022 was USD 4207 million, compared to St Barbara's USD 680 million (Newcrest Mining Limited, 2022) [8]. The corresponding carbon emission indicator of Newcrest is also larger than that of St Barbara. In 2022, the total carbon emissions of Newcrest Scope 1 and Scope 2 exceeded 2240 kt, which is 11.5 times that of St Barbara. The emissions of Newcrest Scope 3 were 741kt, which is greater than St Barbara's 436kt. In terms of carbon management performance, Newcrest produced only 1.1 ounces of gold per ton of CO2e emitted in 2022, while St Barbara produced 1.44 ounces per ton of CO2e. Regarding revenue, Newcrest generated USD 1,800 per ton of CO2e emitted, whereas St Barbara generated USD 2,540 per ton. This data supports the effectiveness of St Barbara's carbon management strategies, despite its smaller size compared to Newcrest.

8.2 Estimate Credibility

It is worth noting that in most respects, the carbon emission estimates in St Barbara's sustainability report are highly reliable, as it takes into account all aspects of the company's organisational activities and operations in different regions. However, Scope 2 data is still unconvincing. The emissions of 1,000 tons in Australia over six years and zero carbon emissions in PNG during the same period are very different from the carbon emissions of about 45,000 tons of Canadian operations in 2020. Therefore, the estimated data need to be further verified and the data source needs to be further explained to ensure the accuracy and authenticity of the estimate.

8.3 Carbon Management Effectiveness

The carbon emission indicators in St Barbara's sustainability report play a crucial role in corporate carbon management. Firstly, these indicators help the company make objective decisions that align with organizational interests by identifying carbon emission sources and potential opportunities for reduction. Secondly, carbon emission indicators are also helpful for corporate compliance, which helps companies meet relevant environmental protection policies and regulations. This is particularly important for large multinational companies like St Barbara, which must navigate the environmental policies of different countries. In addition, carbon management data can help St Barbara attract a large amount of investment, especially from investors who focus on environmental protection and sustainable development. The company's commitment to sustainable development is particularly important. Finally, carbon management estimates contribute to risk management. By understanding and monitoring emissions data, companies can identify and manage potential risks related to climate change (Sullivan and Gouldson, 2017) [17].

9 Conclusions

Overall, St Barbara's sustainability report accurately estimates carbon management in different categories and measures different indicators. While the carbon emissions data for Scope 2 in Australia and PNG require further verification and clarification, most other carbon emission estimates are highly reliable. St Barbara's carbon emissions remained stable from 2017 to 2019, but rose in 2020 due to increased Canadian operations and the impact of Covid-19, which had a negative impact on the business's capacity, spending and management.

St Barbara attaches great importance to carbon management. In its report, it mentioned three different projects to reduce carbon emissions: the use of Ropecon for transporting materials, coral and mangrove planting, and wetland restoration projects. All three initiatives have a positive impact on corporate carbon management. Despite their different implementation locations, they share a common trait: a high initial investment aimed at achieving long-term stable economic and social benefits. Compared with larger enterprises like Newcrest Mining Limited, St Barbara, though smaller in scale and revenue, has demonstrated higher carbon management effectiveness and a more proactive carbon management strategy. Carbon management is important to St Barbara in attracting investment, meeting policy, pursuing potential opportunities and managing risk.

Although this report provides a comprehensive analysis of St Barbara's carbon management performance, it has limitations. This analysis covers corporate data from 2017 to 2022, providing an incomplete view of long-term trends. In addition, comparing St Barbara with only one similar company limits the industry environment analysis. Therefore, this report only analyzes St Barbara's carbon management performance and serves as a reference for other organisations.

To further promote net zero and sustainable development for traditional heavy industrial enterprises like St Barbara, here are three suggestions to improve carbon management performance. First, implement more clean or renewable energy, such as solar and wind energy projects, to reduce dependence on fossil fuels (Jacobson et al., 2017) [4]. Secondly, enforce stricter monitoring and management of carbon emissions, as the public scrutinizes the environmental performance of traditional heavy industries more closely than ordinary enterprises. Finally, strengthen employee training on environmental protection to ensure employees understand and participate in the company's carbon management. By implementing the above recommendations, St Barbara can further improve its carbon management performance and achieve its environmental protection and sustainable development goals, while also helping to enhance its market share and social image.

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