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Greenhouse gas emissions assessment of the Orezone Bombore SA gold mine in Burkina Faso (West Africa)

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Abstract

This study aims to assess greenhouse gas (GHG) emissions from the Orezone Bomboré SA gold mine in Burkina Faso, with a particular focus on Scope 1 (direct emissions) and Scope 2 (indirect emissions from purchased electricity) as defined by the Greenhouse Gas Protocol. The assessment aligns with the company's sustainable development strategy and cost-reduction objectives.

The methodological approach is based on the 2013 Global Warming Potential (GWP) over a 100-year horizon from the Intergovernmental Panel on Climate Change to quantify and analyze emission sources.

The results indicate that the mine generates both direct and indirect GHG emissions. Direct emissions (Scope 1) arise mainly from diesel generators, light and heavy mining equipment, and blasting activities, while indirect emissions (Scope 2) are primarily linked to electricity consumption supplied by SONABEL. Additional contributions include fugitive emissions from refrigerant leakage in air conditioning systems.

The total annual GHG emissions were estimated at 215,349.50 tCO_2e. Electricity consumption represents the largest share (141,120.66 tCO_2e), followed by generators (70,960.07 tCO_2e), mining equipment (2,951.29 tCO_2e), air conditioning systems (201.09 tCO_2e), and blasting operations (116.38 tCO_2e).

Based on these findings, several mitigation strategies are proposed, including reducing reliance on grid electricity through the deployment of a hybrid solar–battery power system, implementing preventive maintenance to improve fuel efficiency, promoting eco-driving practices, and encouraging low-carbon mobility options such as public transport and active transportation.

Overall, this study provides a comprehensive emissions baseline and practical pathways to support the decarbonization of mining operations in Burkina Faso.

Keywords: Greenhouse gases; Orezone; GHG Protocol; Assessment; Strategy

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1. Introduction

Mining operations have an impact on biodiversity and the environment at several scales: local, regional, and global [1]. The global impact is primarily linked to greenhouse gas (GHG) emissions, which contribute to climate change. The first World Climate Conference in 1979 highlighted the problems associated with climate change [2]. This conference concluded that anthropogenic carbon dioxide emissions could have a long-term effect on the climate, leading to the creation of the World Meteorological Organization's (WMO) global climate program, the World Climate Research Program, and the Intergovernmental Panel on Climate Change (IPCC), which received the Nobel Peace Prize in 2007 [3]. The scientific literature has extensively documented the environmental impact of mining activity in several regions of the world, including Canada, Australia, and South Africa. In Canada, emissions from the mining sector increased by 75 megatons of CO_2 equivalent (Mt CO_2e) between 2005 and 2023 [4]. This research highlights the indirect and direct emissions of mining activities. Greenhouse gas emissions are generated by several sectors, including energy, agriculture, transportation, buildings, and industry. The industrial sector, particularly mining, is a significant source of emissions. The main sources in this sector are the combustion of fossil fuels for machinery and heavy vehicles, electricity consumption from non-renewable sources, the transportation of materials and personnel, ore processing and transformation, and deforestation related to mine development.

Since the early 2000s, gold has become Burkina Faso's leading export [5]. This rapid growth has been accompanied by increased environmental pressure, notably through increased energy consumption, deforestation around mining sites, and the production of waste and unquantified atmospheric emissions. The mining sector in Burkina Faso plays a central role in the country's economy. In 2023, it represented 14.8% of GDP, more than 75% of exports and more than 20% of public revenue with significant impacts, including excessive pollution of water resources by highly toxic products such as mercury and cyanide [6]. Burkina Faso has ratified the United Nations Framework Convention on Climate Change (UNFCCC), the Kyoto Protocol, and the Paris Agreement as a sign of its commitment to contributing to the Convention's ultimate goal of stabilizing greenhouse gas concentrations in the atmosphere at a level that prevents dangerous anthropogenic interference with the climate system [7].

It is within the framework of its shared commitments that Burkina Faso has pledged to keep the rise in the average global temperature well below 2°C and to pursue efforts to limit it to 1.5°C above pre-industrial levels, in accordance with the Paris Agreement. Several strategies are currently being developed or implemented in Burkina Faso, including the Nationally Determined Contribution (NDC) 2021-2025, the National Ecovillage Development Strategy 2018-2027, the National Adaptation Plan (NAP), the National REDD+ Strategy, and, in the longer term, Burkina Faso's 2050 vision for low-carbon and climate-resilient development [8].

Mining uses enormous amounts of energy in the form of electricity and fuel for machinery. This is why a study by the Coalition for Eco-Efficient Comminution (CEEC) highlights the considerable energy consumption of two areas in the mining industry: the mining fleet running on diesel (46%) and the comminution process (25%). Added to this is the concentration of greenhouse gases in the atmosphere in the form of CH_4 emissions, a gas resulting from blasting, mineral processing plants, and many other sources [9]. Thus, emissions from mining cannot be ignored, as they contribute significantly to global warming. Orezone Bombore SA, a major player in the Burkinabe mining sector, must integrate this dimension into its environmental management.

2. Materials and methods

The methodology used is based on the GHG Protocol Corporate Standard, internationally recognized for accounting for organizations' greenhouse gas emissions [10]. It relies on several specific standards, including:

- The Corporate Standard for organizations
- The Project Protocol for emissions reduction projects
- The Product Standard for product lifecycle assessment
- The Scope 3 Standard for a detailed analysis of indirect emissions

The strength of this methodology lies in its flexibility and widespread adoption, making it a common framework for international companies and investors. This framework enables a rigorous, transparent, and comparable approach. Unlike ISO 14064, which focuses more on quality requirements for carbon accounting, the GHG Protocol offers detailed guidelines. The Chinese methodology GB/T 32150 is partly based on the GHG Protocol but has several distinctive features, such as a particular focus on the energy-intensive industrial sectors that characterize the Chinese economy, calculation methods adapted to the Chinese energy mix, and integration with other Chinese climate change mitigation policies [11]. The IPCC publishes regularly updated guidelines for conducting greenhouse gas (GHG) emissions inventories. The work of this organization serves as a reference for many sectors and global stakeholders in conducting GHG assessments. However, they recommend adapting emission factors and calculation methods to the specific characteristics of each country. The latest AR6 report, in three volumes—Volume 1 (August 2021), Volume 2 (February 2022), and Volume 3 (April 2022)—contains the main sections discussed in the context of the energy transition and its impacts, according to the IPCC Working Group III report published in 2021 and 2023 [12, 13]. To take all these fundamental principles into account, it is necessary to base the methodology on the 2006 IPCC guidelines and standardized GHG accounting tools [14].

An emission factor is the ratio between the quantity of air pollutants or greenhouse gases emitted by a good, service, or activity and the unit quantity of that activity or service. The emission factors presented in table 1 allow us to convert different input data (electricity produced in kWh, fuel in liters, explosives in tons) into greenhouse gas emissions in CO_2e. Emissions of different GHGs are expressed in CO_2e (CO_2 equivalent) to allow for comparison. Different gases do not have the same impact on the environment; to standardize them, we use a benchmark: the Global Warming Potential (GWP). Multiplying the emission factors by the GWP of the gas in question gives the total GHG that gas in CO_2 equivalent per activity (Eq.1).

$$CO_2 = EF \times AD$$

Where: EF = Emission Factor; AD = Activity Data **Eq.1**

$Emissions = \Sigma\ (AD_i \times EF_i)$

Table 1 Global warming potential of the different gases considered in the study

Greenhouse gases		GWP_{100}	Lifespan in the atmosphere (years)
Carbon dioxide	CO_2	1	100
Methane	CH_4	30	12 ± 3
Nitrous oxide	N_2O	265	120
Hydrofluorocarbons	HCF	138 to 12 400	-
Sulfur hexafluoride	SF_6	23500	3200
Perfluorocarbons (PFCs)	PFC	6 630 à 12 200	-

Source : IPCC, 2013 [15]

Several websites have been created with carbon footprint calculation models for businesses, such as the ADEME GHG Assessment, Datagir, DitchCarbon, and the GHG Protocol [16]. In Burkina Faso, there is no single, universal tool, but rather several tools adapted to different needs. The international carbon accounting methodology, the GHG Protocol, is the basis for this categorization, which is also used in the ISO 14064 standard and the Carbon Disclosure Project (CDP) methodology internationally [17]. The calculation of GHG emissions is based on the careful conversion of activity data collected in different sectors into energy values. From these energy values, the specific GHG emission fractions for the activity in question is calculated. To ensure quality control of the accounting, a manual calculation is performed using the formulas listed below for the different activities.

The emission factor is a very important element in carbon emission assessment and requires particular attention in our study. Indeed, this factor is the greatest source of uncertainty in carbon emission assessment due to the multiplicity of parameters involved in calculating its value and the heterogeneity of their nature.

2.1. Calculation of direct emissions

This concerns direct emissions from stationary combustion sources, including fuel consumption in generators, emissions from mobile combustion sources such as heavy equipment, light equipment, and finally, emissions related to mining blasting.

The calculation of emissions from stationary and mobile sources considers activity data and emission factors. For the calculation of emissions from generator sets, the data to be collected concerns the types of hydrocarbons used and the monthly quantities consumed by the generator sets. The generator sets in Orezone operate on LFO (low-carbon fuel).

The gases emitted are CO_2, CH_4, and N_2O. Total emissions is equal to the carbon intensity produced in Burkina Faso during the inventory period multiplied by the sum of the collected activity data.

2.2. Calculation of indirect emissions

For indirect emissions, this refers to Scope 2 in the study, which represents emissions corresponding to the consumption of final energy where the greenhouse gases are not emitted at the point of consumption, but at the point of production. Indirect emissions related to the electricity purchased by Orezone for the production site and its headquarters located in Ouagadougou is assessed. The calculation of indirect emissions is made according to Eq.2 done as follows:

***Emissions (kg CO_2 eq.) = electrical energy consumed (kWh) x electricity emission factor (kg CO_2 eq./kWh)* Eq.2**

2.3. Calculation of fugitive emissions

The calculations of fugitive emissions in our study follow the surface area approach inspired by the ADEME methodological guide. Air conditioning and refrigeration equipment uses refrigerants based on fluorinated gases, which are known for their significant impact on global warming. This is why the amendments to the Montreal Protocol in London in 1990 and in Copenhagen in 1992 aimed to control and completely eliminate the use of chlorofluorocarbons [18].

3. Results and discussion

3.1. Identification of Emission-Generating Activities

Orezone mining company primarily generates two types of emissions: direct and indirect. Direct emissions come from generators, light and heavy equipment, and blasting, while indirect emissions come from purchased energy (not produced on-site). Other emissions should not be overlooked, particularly fugitive emissions from leaks of refrigerants used in air conditioning systems. Regarding direct emissions (Scope 1), Orezone Bombore SA (OBSA) mine's power supply relies on a fleet of ten generators. This fleet is managed by two separate entities; eight generators are supplied by African Power Services (APS). These are CAT 3516 B units, with an apparent power of 2,350 kVA and an actual electrical capacity of 1.2 MW each. Each unit has 16 cylinders. Two other units belong directly to OBSA. These units are PROGEN brand, each with a power output of 3.5 MW and equipped with a 20-cylinder EMD engine. These units operate alternately; when there is a problem with the electrical grid, the CAT 3516 B units automatically take over according to the plant's demand. If demand increases, one of the PROGEN units starts up as backup, necessarily reducing the need for the CAT 3516 units. Orezone mine has three main lines requiring power generation with these generators: the plant's power requirement is between 130 MW and 140 MW, a line encompassing MSA-TSF-OCR-CAMP (between 12 MW and 14 MW), and the power plant itself (1.5 MW to 3 MW). The annual energy consumption requirement for generator sets for 2024 is estimated at 16,606.02 MWh and is shown in figure 1:

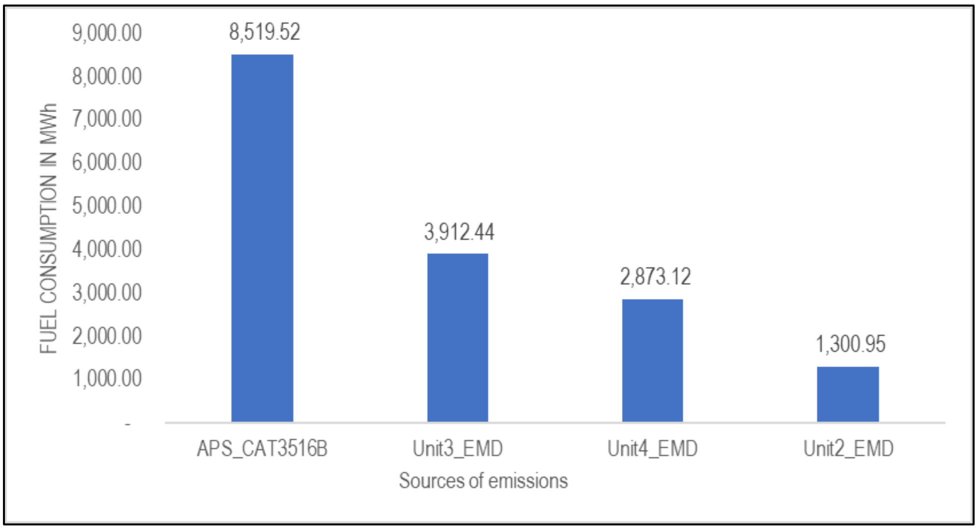

Figure 1 2024 Fuel Consumption of Generator Sets (*Source: Compiled from Orezone data*)

The 1,787 items of light and heavy equipment are comprised of 50.08% light equipment and 48.01% heavy equipment. Detailed information on each of these two equipment categories is provided in table 2.

Table 2 Light and heavy equipment of the Orezone mine

Orezone Equipment	**Number**	**Percentage (%)**
Unknown Equipment	34	1.90
NOT SPECIFIED	34	1.90
Light Equipment	895	50.08
DELIVERY TRUCK	9	0.50
AMBULANCE	7	0.39
BUS	21	1.18
DELIVERY TRUCK	1	0.06
EMERGENCY CAR	13	0.73
LIGHT VEHICLE	794	44.43
LIGHTNING PLANT	37	2.07
MINI BUS	13	0.73
Heavy equipment	858	48.01
BACKHOE	6	0.34
CHRUSHER	31	1.73
COMPRESSOR	40	2.24
CRANE TRUCK	41	2.29
DISPATCH	134	7.50
DRILLING MACHINE	21	1.18
DUMP TRUCK	2	0.11
DUST SUPPRESSOR	2	0.11
EXCAVATOR	18	1.01
FIRE TRUCK	6	0.34
FORKLIFT	40	2.24
Fuel Service Truck	13	0.73
FUEL TANK	4	0.22
FUEL TRUCK	4	0.22
GENERATOR	250	13.99
HANDLING EQUIPEMENT	13	0.73
HIGHT VEHICLE	13	0.73
LOADER	39	2.18
MIXER	10	0.56
PUMP	2	0.11
SERVICE TRUCK	4	0.22
TEMPORAIRE	45	2.52

TRACTOR	2	0.11
WATER PUMP	74	4.14
WATER TRUCK	23	1.29
WELDING MACHINE	21	1.18
Total	1787	100

Blasting is also included in emissions accounting, and the type used is an emulsion composed of 94% saturated ammonium nitrate solution and 6% fuel oil. This mixture produces ammonium nitrate fuel oil (ANFO), which is used in addition to boosters and surface relays for rock blasting at Orezone. Electricity Map (EM) is a platform that provides real-time data on the carbon intensity of electricity in different regions of the world, considering the current energy mix. This approach is particularly relevant in regions where the share of variable renewable energies (wind, solar) is significant. The carbon emission factor of electricity produced in Burkina Faso was 577 g of CO_2/kWh. The annual electricity consumption requirement is estimated at 37,372.232 MWh during the year 2024. This quantity comes from SONABEL with an average monthly consumption of 3,114.35 MWh. The breakdown by air conditioner type and their characteristics is shown in table 3.

Table 3 Types of Air conditioners used in Orezone

Types of Air conditioners	Gas	Number	Average power (kW)	Percentage
Nasco	R410 A	50	2.4	10.89
Alliance	R410 A	127	2.4	27.67
Sharp	R22	40	3.52	8.71
	R410 A	186	2.4	40.52
Samsung	R22	24	3.2	5.23
LG	R410 A	15	2.4	3.27
Roch	R410 A	3	2.4	0.65
Whirlpool	R410 A	3	1.4	0.65
Airwell	R410 A	4	2.4	0.87
Boreal	R410 A	3	2,4	0.65
Ideal Sense	R410 A	1	2.4	0.22
Decakila	R410 A	1	2.4	0.22
Solstar	R410 A	1	2.4	0.22
Midea	R32	1	2.6	0.22
Total		459		100

Source: Compiled from a census of all air conditioners in the camp, November 2025

Regarding air conditioners, the Sharp and Alliance brands are the most prevalent. Indeed, of the 459 air conditioners, 226 are Sharp, representing 49.24% (40.52% for R410A and 8.71% for R22), followed by the Alliance R410A brand with 27.67%.

The total emission is 4442.44 metric tons of CO_2 equivalent (tCO_2e) for the generator sets, 5444.04 tCO_2e for the equipment which is lower than that of the generator sets.

For the year 2024, the total quantity is 988 metric tons of ammonia used, equivalent to 988,000,000 g of CO_2. Regarding emissions from air conditioners, the Sharp and Alliance brands recorded the highest values, with 86,017,932 kg CO_2e

and 58,732,674 kg CO_2e respectively. All air conditioners combined emitted a total of 201,096,428 kg CO_2, equivalent to 201,096 teCO_2 (with 42.77% for the Sharp brand and 29.21% for the Alliance brand).

This study on the assessment of greenhouse gas emissions from Orezone Bombore SA gold mine in Burkina Faso analyzed and quantified the mine's emission-generating activities. Strategies were also formulated to enable the company to significantly reduce its greenhouse gas emissions while optimizing its gold production. The results indicate that Orezone's mining activity poses a risk to the environment due to its emissions. Indeed, the mining company Orezone primarily generates two types of emissions: direct emissions (from generators, light and heavy equipment, and blasting) and indirect emissions. In addition, there are fugitive emissions from leaks of refrigerants used in air conditioning systems. Our results are similar to those obtained by the EITI study (2014), which shows that greenhouse gases are generated by various emission sources, the most significant being electricity generation, accounting for 60.5% of all emissions. These results also corroborate those of Tibrewal (2016), which concluded that mining and technological advancements are accompanied by a whirlwind of environmental hazards that pose a serious threat to humanity and nature [19].

In terms of energy production and transportation, Orezone's activities confirm the findings of the study conducted on greenhouse gas emissions from all countries worldwide where 53.8 billion tons of greenhouse gases were released into the atmosphere by human activities [20] and include electricity and heat production, industry, transportation, agriculture, buildings, and waste [21]. In Burkina Faso sectors producing the most greenhouse gases are agri-food, textiles, mining and quarrying, construction and public works and electricity production.

As mentioned by Bandpey (2024), the mining industry will generate 5.7 gigatonnes of CO_2 equivalent of greenhouse gas emissions by 2050 [22]. The GlobalData platform estimates that the mining industry contributes between 4 and 7% to global greenhouse gas emissions [23]. The quantity of CO_2 emissions at OBSA mine is been estimated to 215349.50tCO_2e in 2024 with 141120.66tCO_2e for electricity consumption by SONABEL, 70960.07tCO_2e for generators, 2951288.628tCO_2e for light and heavy equipment, 201.09tCO2e for air conditioners and 116.38tCO_2e for blasting.

4. Conclusion

This research on the assessment of greenhouse gas emissions from Orezone Bombore SA gold mine in Burkina Faso aimed to evaluate the GHG emissions of Orezone Bombore SA mine, focusing on scopes 1 and 2 of the GHG Protocol, in response to Orezone's sustainable development policy. The study involved identifying emission-generating activities, quantifying these emissions through simple calculations. The results indicate that the mining company Orezone primarily generates two types of emissions: direct and indirect emissions. Direct emissions come from generators, light and heavy equipment, and blasting, while indirect emissions come from purchased energy (not produced on-site). Other emissions should not be overlooked, particularly fugitive emissions from refrigerant leaks in air conditioning systems. For year 2024, CO_2 emissions totaled 215,349.50 tCO_2e.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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