Improving the Environmental Performance of a Copper Mine Site in Indonesia by Implementing Potential Greenhouse Gas Emissions Reduction Activities

By Joni Adiansyah

CHEMICAL ENGINEERING TRANSACTIONS
VOL. 72, 2019

A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.aidic.it/cet

Guest Editors: Jeng Shiun Lim, Azizul Azri Mustaffa, Nur Nabila Abdul Hamid, Jiří Jaromír Klemeš

ISBN 978-88-95608-69-3; **ISSN** 2283-9216

DOI: 10.3303/CET1972010

Improving the Environmental Performance of a Copper Mine Site in Indonesia by Implementing Potential Greenhouse Gas Emissions Reduction Activities

Joni S. Adiansyah

Department of Mine Engineering, Universitas Muhammadiyah Mataram, Indonesia
joni.adiansyah@ummat.ac.id

Indonesia has targeted 29 % Greenhouse gas (GHG) emissions reduction in 2030 and Industry is one of the big two contributors for GHG emissions. As an industry, mining is an energy-intensive industry, and reducing energy consumption is one of the strategies to improve mining environmental performance. The aim of this paper is to estimate the GHG emission reduction in a mining project through energy reduction initiatives. A copper mine in Indonesia with processing plant capacity of 120,000 t/d and operate 111 Caterpillar 793C Haul Truck was taken as a case study. This mine site has two sources of an electricity namely coal-fired power plant with 112 MW output and diesel power plant with 45 MW output. The analysis method for calculating CO_2 emission is using IPCC method where fuel consumption and emission factor are two main variables for GHG emissions. Business as usual scenario (TIER 1) showed that the average of diesel fuel consumption for fleets operation generated 294,006 t CO_2-eq/y. A coal-fired power plant with average coal consumption of 350 t/d/unit generated 1.15 Mt CO_2-eq/y and diesel power plant consumed 4.35 ML/y produced 11,632 t CO_2-eq/y. Two energy initiative programs were identified namely fuel conversion and used oil utilisation program. The initiative scenario focused on substituting, reducing and reusing of fossil fuels including coal, diesel fuel, and used oil. This scenario was estimated to contribute the carbon emission reduction (t CO_2-eq) of 258,381 annually. The involvement of mining industry in carbon emission reduction is not only helping Indonesia in achieving its GHG emissions reduction target but also increases mine site environmental performance and company image.

1. Introduction

Fossil fuel is the main energy source in Indonesia and contributed 95 % of the total Indonesian energy mix in 2015 (PP, 2017). Indonesia produced primary energy including coal, gas, and oil approximately 2.8 million Barrel Oil Equivalent (BOE) in 2015 and more than 50 percent were distributed for the international market. The National Energy Council of Indonesia recorded that the two biggest domestic energy consumers were transportation and industries including mining industry. These two sectors are projected to consume diesel fuel approximately 57 BL in 2025 as shown in Table 1 (USDA, 2016).

Table 1: Projection of diesel fuel consumption

Year	2018	2019	2020	2021	2022	2023	2024	2025
Diesel Total (in BL)	35	36	36	37	38	40	41	41
Transport	28	29	29	30	31	32	33	34
Industry	7	7	7	7	7	8	8	8

The utilisation of fossil fuel energy has increased the Carbon Footprint (CF) in various field including coffee harvester (Mantoam et al., 2017), water treatment plant (Samanaseh et al. 2017), coal tailings management (Adiansyah et al. 2017), iron and ore mining (Norgate and Haque, 2010). Norgate and Haque (2010) recorded that the loading and hauling activities were the highest CF for bauxite mine and the second largest CF for copper mine due to fossil fuels consumption. The two biggest mineral resources (metals) in Indonesia are copper and

Paper Received: 30 March 2018; Revised: 19 September 2018; Accepted: 14 December 2018
Please cite this article as: Adiansyah J.S., 2019, Improving the environmental performance of a copper mine site in indonesia by implementing potential greenhouse gas emissions reduction activities, Chemical Engineering Transactions, 72, 55-60
DOI:10.3303/CET1972010

gold with 4 Mt and 69 t production (USGS, 2016). These numbers are an obvious indicator of a copper mine contribution to the GHG emission in Indonesia. None of the current publicly available studies discuss the CF generated by copper mine site in Indonesia. The Government of Indonesia (GOI) has a target for GHG reduction in 2030 by 29 % and the mining industries should participate actively in the GHG reduction from their operations. The fossil fuels management is required to reduce the GHG emissions from a mining site. Some fossil fuels management that could be implemented at the mine site including fuel conversion and used oil utilisation.
This study is aimed to estimate the GHG emission reduction in a copper mine through energy reduction initiatives. Two scenarios were compared namely business as usual scenario, and energy reduction scenario.

2. Methods

The estimation of GHG emissions is carried out by using reference approach where fossil fuels consumption is used as a reference for calculating the total GHG emissions as shown in Figure 1.

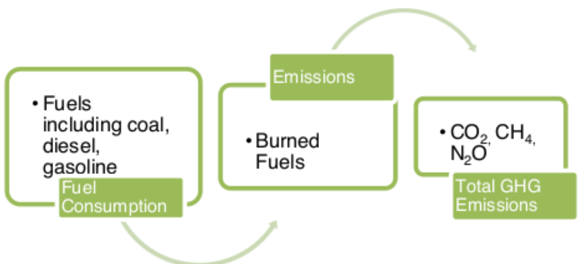

Figure 1: Reference approach for GHG emissions (KLH, 2012)

Due to the data availability, this study applies Tier 1 method where the emissions from all sources of combustion are estimated on the basis of the quantities of fuel combusted. In addition, the emissions from non-CO_2 gases are excluded because of its low carbon content (IPCC, 2006). The method applied determines the accuracy level of GHG calculation.
Based on the Intergovernmental Panel on Climate Change (IPCC) guideline that the GHG emissions are calculated by multiplying fuel consumption by the corresponding emission factor as presented in Eq(1).

$$Emissions_{GHG,\ fuel} = Fuel\ Consumption_{fuel} \times Emission\ Factor_{GHG,\ fuel} \quad (1)$$

Where: Emissions GHG, fuel is total of GHG emissions (kg CO_2-eq), Fuel Consumption fuel is the amount of fuel consumed (t or L), Emission Factor GHG, fuel is emission factor for the type of fuel (kg CO_2-eq/t or per L). The emission factors are adopted from Department for Environment, Food and Rural Affairs United Kingdom (DEFRA, 2017).
A copper mine located in the eastern part of Indonesia was taken as a case study to compare its emission before and after applying GHG reduction program. Two main initiatives were introduced, namely fuel conversion and used oil utilisation. Those two initiatives were implemented in the mining operation stages. Mining operations consist of mining, processing and supporting are determined as the boundary of the study as shown in Figure 2. Fossil fuels are classified as material input into the boundary and emissions are the output generated by mining operation stages. The emissions analyses will assist the Government of Indonesia (GOI) in preparing the strategy for reducing the CF from industrial sector particularly mining.

2.1 Limitations

In the mine site, GHG emissions are produced not only from fossil fuel utilisation but also from other activities including waste management, supply chain management. However, this study is focused on burned fuel activities due to public data available. These burned fuel activities are both from stationary and mobile equipment. The GHG emitted from fuel combustion are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). These three gasses have a different characteristic associated with its carbon content and emission factor. Fuel carbon content is the primary parameter for determining CO_2 emission factor while the emission factors of other two gasses depend on the combustion technology and operation condition (IPCC, 2006). This study excludes CH_4 and N_2O gas to reduce variability and uncertainty of analysis.

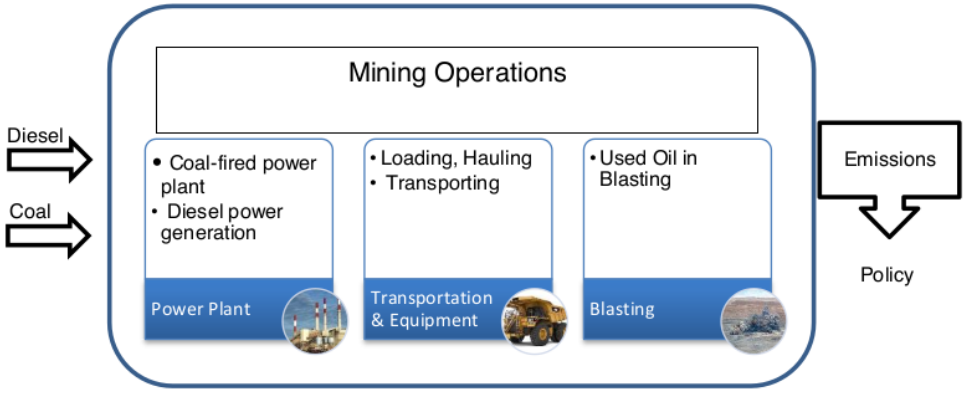

Figure 2: Boundary of the study

3. Results and discussion

In order to show the contribution of mining industry to the GHG emissions, a copper mine site in the eastern part of Indonesia was taken as a case study. In addition, The National Greenhouse Emissions Reporting System (NGERS) is used as a data reference. The operational boundary of the analysis is shown in Table 2 where direct emission (Scope 1) from fossil fuel usage is the main focus of this study. The scope 1 emissions were chosen due to two primary reasons as follows: the mine site generates it's own energy (electricity) and the emission sources are controlled internally. Two electricity sources used were coal-fired power plant and diesel power plant as detailed in Table 2.

Table 2: The operational boundaries of GHG emission

Scope	Activities	Description
Scope 1 Direct emissions	Coal utilisation for coal-fired power plant Diesel usage for diesel power plant	This mine site has two sources of an electricity namely coal-fired power plant with 112 MW output and diesel power plant with 45 MW output.
	Diesel and gasoline usage for the vehicle (heavy and light)	Loading and hauling are two major contributors for CF in mining operations. DEFRA (2017) guideline for company reporting is used as a reference for carbon emission factor.

The key technical parameters for evaluating GHG emissions of a copper mine are shown in Table 3. These parameters are divided into three categories: power generation, transportation and equipment, and blasting. Table 3 shows that transportation activity includes loading and hauling contributes 95 % of total diesel consumption. Three types of fleets that determine the fossil fuel usage for transportation and equipment are heavy equipment, light vehicles, buses, and operated machines.

Table 3: Technical parameters (PTNNT Report (2013))

Scenario	Business as Usual			Energy Reduction
	2010	2011	2012	
Power Generation:				
Diesel (ML)	5.71	5.30	5.60	-
Coal (Mt)	0.51	0.52	0.51	Substituting 20 % of coal with agricultural waste
Transport & Equipment (ML)	137.85	100.77	94.03	5 % fuel replacement
Blasting (ML)	0.07	0.07	0.08	Substituting 25 % diesel to used-oil

3.1 Business as usual scenario

The CF for business as usual scenario was calculated based on operations data from 2010 to 2012. Three types of fossil fuel usages were identified include electricity generation, fleets and machineries operation, and blasting activity as shown in Table 4. The carbon emissions of those activities were generated by diesel and coal consumption. The fluctuations of diesel and coal consumption as shown in Table 4 are strongly influenced by some operation variables including target production, and mine plan.

Table 4: Summary of carbon footprint from 2010 - 2012

Year Category	Emissions factor (DEFRA, 2017)	Unit	2010 t CO_2-eq	2011 t CO_2-eq	2012 t CO_2-eq
Scope 1					
Diesel for electricity	2.671	kg CO_2-eq/L	15,255.85	14,154.47	14,934.17
Diesel usage for fleet	2.671	kg CO_2-eq/L	364,936.57	260,857.43	256,226.62
Diesel usage for the operated machine	2.671	kg CO_2-eq/L	1,214.16	4,388.12	8,901.07
Gasoline usage for fleet	2.300	kg CO_2-eq/L	1,873.92	3,444.62	4,137.93
Coal for electricity	2,244.63	kg CO_2-eq/t	1,153,245.12	1,170,034.08	1,135,316.37
Diesel for blasting	2.671	kg CO_2-e/L	196.16	185.51	207.69

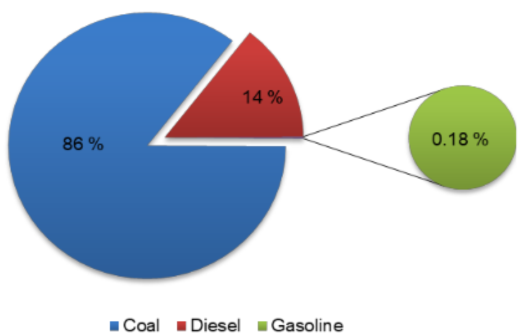

Figure 3: Percentage of fossil fuel usage

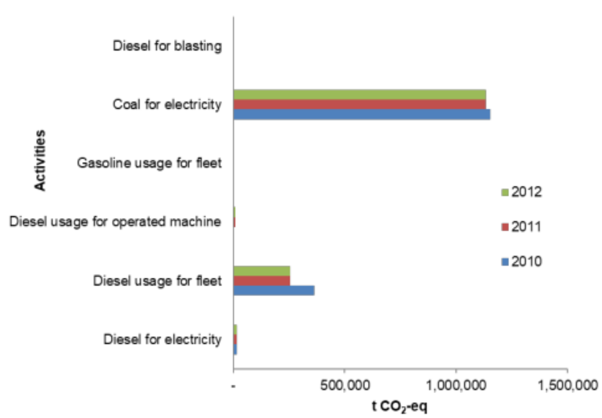

Figure 4: The Three-Year trend of total carbon emission from 2010 - 2012

The coal-fired power plant recorded the highest fossil fuel usage (86 %) as shown in Figure 3. Four boiler in the coal-fired power plant generated 120 MW of electricity for mine operations. It also noted that the coal consumption for electricity generation resulted in the highest amount of carbon emission annually as shown in Figure 4. The total carbon emission produced from coal-fired power plant ranged from 1.13 to 1.17 Mt CO_2-eq per year. The second contributor to carbon emission was the mining fleets operation include heavy vehicle and buses that generated around 0.3 Mt of CO_2-eq per year.

The business as usual scenario showed that coal-fired power plant and fleets operation as the two biggest environmental hot-spots of a copper mine. Management of these two activities is required to reduce annual carbon emission.

3.2 Energy reduction scenario

The energy reduction scenario focused on how to reduce the two biggest environmental hot-spots as mentioned in Section 3.1. These two spots were coal-fired power plant operation for coal utilisation and fleets operation for diesel consumption. Two strategies were proposed to reduce the carbon emission as shown in Table 3: substituting 20 % of coal with agricultural waste, and replacing 5 % of haul truck fuel with biodiesel from Jatropha and used cooking oil.

The quantity of coal, diesel, and substitute materials was calculated by considering its calorific values as described by Kumari et al. (2014). Emissions Factor (EF) shown in Table 5 indicated that substitute materials include agricultural waste, and biodiesel have lower emission factors compared to the fossil fuels.

Table 5: Carbon reduction

Scenario	Quantity	Unit	Emissions factor (DEFRA, 2017)	Unit	CF (t CO_2-eq/y)	Total Carbon reduction (t CO_2-eq/y)
#1. Coal reduction (20 %)						
Coal	104,251.80	t	2,244.63	kg CO_2-eq/t	234,006.82	-
Agricultural waste	19,744.66	t	77.7645	kg CO_2-eq/t	1,535.43	232,471.38
#2. Diesel fuel reduction (5 %)						
Diesel	4,881,438.35	L	2.671	kg CO_2-eq/L	13,042.87	-
Jatropha	4,497,102.17	L	0.02001	kg CO_2-eq/L	89.99	12,952.88
Used cooking oil	4,284,875.75	L	0.02001	kg CO_2-eq/L	85.74	12,957.13

The first energy reduction scenario that substituting 20 % of coal with agricultural waste in the coal-fired power plant showed the total carbon emission reduction reached 232,471 t CO_2-eq per year. This value was derived from the subtraction of CF generated from coal consumption with CF generated from 20 % of agricultural waste burned.

The second scenario was replacing 5 % of diesel fuel with biodiesel. One of the reasons for choosing this scenario is better performance of biodiesel in terms of lubricating and cetane rating. Total carbon reductions generated by the second scenario were 12,952 t CO_2-eq per year and 12,957 t CO_2-eq per year for Jatropha and used cooking oil.

Those both scenarios create an opportunity for mining to participate actively in the climate action particularly emission reduction part. The mining involvement could accelerate the achievement of Indonesian emission reduction target. However, the effective implementation of those scenarios depends on the continuity supply of raw material or final product i.e. supply of agricultural waste to coal-fired power plant, and volume of bio-diesel fuel produced.

4. Conclusions

Indonesia has huge minerals deposit where copper is recorded as the biggest reserve. The copper mines in Indonesia are managed and operated by private companies (multi-national companies) with total production approximately 4 Mt. The consequence of those total production is energy demand for copper production. The energy demand is linear with the production target. On the other word, the higher production target the higher energy is required. Therefore, the copper mine carbon emissions are closely related with the mine production target.

The role of mining industry in carbon emission reduction is significant due to its high energy consumption including coal and diesel fuel consumption. The utilisation of these two fossil fuels contributes to the CF of a mine site. Carbon emission analysis of a copper mine site shows that 86 % of CF is contributed by coal utilisation in the coal-fired power plant. Coal consumption reduction initiative is proposed to reduce the carbon emission by substitute 20 % of coal with agricultural waste. Another initiative is reducing 5 % of diesel fuel used for fleets operation. These two initiatives contribute to the total reduction of carbon emission of 258,381.40 t CO_2-eq annually. The emissions generated by transportation activity for supplying the raw material or final product to the mine site is beyond the scope of this study.

The CF estimation will assist the GOI for preparing the strategy (policy) to achieve 29 % carbon emission reduction by 2030. The policy would contribute to the achievement of Indonesian Sustainable Development Goals (SDGs) particularly climate action goal. The of stakeholders including mining company is essential to conserve the environmental quality and performance in Indonesia. The carbon reduction strategy should be also analysed from an economic perspective because capital is required for implementing those strategies. By considering environmental and economic aspects, the sustainability of the program can be maintained properly. The company image would be obtained by a mine site that correlate to the social license to operate.

Acknowledgments

The author would like to acknowledge the Directorate General of Research and Development Ministry of Research, Technology and Higher Education Republic of Indonesia for providing the author with an international conference grant. The author would also to thank some friends for their voluntary review and providing some data that used in this study.

References

Adiansyah J.S., Haque N., Rosano M., Biswas W., 2017, Application of a life cycle assessment to compare environmental performance in coal mine tailings management, Journal of Environmental Management, 199, 181-191.

DEFRA, 2017, UK Government GHG Conversion Factors for Company Reporting, DEFRA Publishing, London, UK.

IPCC, 2006, IPCC Guidelines for National Greenhouse Gas Inventories <ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_2_Ch2_Stationary_Combustion.pdf> accessed 12.05. 2018.

KLH, 2012, Pedoman Penyelenggaraan Inventarisasi Gas Rumah Kaca Nasional: Kegiatan Pengadaan dan Pengunaan Energi, KLH Publishing, Jakarta, Indonesia (in Indonesian).

Kumari R., Nirmala N., Caroline J.C., Dawn S.S., 2014, Calorific Value Measurements and Optimization of Waste Cooking Oil Bio-Diesel, National Journal on Chembiosis, 5, 17-21.

Mantoam E.J., Romenelli T.L., Gimenez L.M., Milan M., 2017, Energy Demand and Greenhouse Gases Emissions in the Life Cycle of Coffee Harvesters, Chemical Engineering Transactions, 58, 175-180.

Norgate T., Haque N., 2010, Energy and Greenhouse Gas Impacts of Mining and Mineral Processing Operations, Journal of Cleaner Production, 18, 266-274.

PP, 2017, Presidential Regulation of Indonesia Number 22/2017: National Energy Plan, Secretary Cabinet Publishing, Jakarta, Indonesia.

PTNNT, 2013, PTNNT Report: Identification of Potential Carbon Projects at PT. Newmont Nusa Tenggara, Indonesia, CER Publishing, Jakarta, Indonesia.

Samanaseh V., Noor Z.Z., Hassan C.H., Sabeen A.H., 2017, Water-Energy-Nexus in Water Supply: A Case Study on Greenhouse Gases Emissions Trends of a Water Utility Company in Johor, Malaysia, Chemical Engineering Transaction, 56, 1711-1716.

USDA, 2016, Indonesia Biofuel Annual, Global Agricultural Information Network Publishing, Jakarta, Indonesia.

USGS, 2016, Minerals Year Book: Indonesia (Advance Release), US Geological Survey Publishing Office, Virginia, USA.

Improving the Environmental Performance of a Copper Mine Site in Indonesia by Implementing Potential Greenhouse Gas Emissions Reduction Activities

ORIGINALITY REPORT

7%

SIMILARITY INDEX

PRIMARY SOURCES

1	estudogeral.sib.uc.pt Internet	22 words — 1%
2	pro.poli.usp.br Internet	18 words — 1%
3	www.baltic-pipe.eu Internet	17 words — 1%
4	jurnal.ugm.ac.id Internet	16 words — 1%
5	cyberleninka.org Internet	14 words — < 1%
6	documents.coastal.ca.gov Internet	13 words — < 1%
7	www.econjournals.com Internet	12 words — < 1%
8	www.amb.cat Internet	10 words — < 1%
9	link.springer.com Internet	10 words — < 1%
10	Min Tang, Shi Yong Zhang, Li Ping Wang. "An Analysis of Simulation System of CO₂	9 words — < 1%

Emission and Emission Reduction Paths in Chongqing's Electric Power Industry", Applied Mechanics and Materials, 2014
Crossref

---

11 Zabihian, Farshid, and Alan S. Fung. "Greenhouse Gas Emissions Calculation Methodology in Thermal Power Plants: Case Study of Iran and Comparison With Canada", ASME 2008 Power Conference, 2008.
Crossref
9 words — < 1%

---

12 J S Adiansyah, K Payadi, Alpiana, D Rahmawati. "Evaluation of loading and hauling technology for improving andesite mine performance", IOP Conference Series: Materials Science and Engineering, 2018
Crossref
9 words — < 1%

---

13 manualzz.com
Internet
8 words — < 1%

---

14 Dechasiri, Phongpiti, Weerin Wangjiraniran, and Achariya Suriyawong. "A Study on Energy-Related GHG Scenario of Thailands Textile Industry", Advanced Materials Research, 2013.
Crossref
8 words — < 1%

---

15 biblio.ugent.be
Internet
8 words — < 1%

---

16 Lean and Cleaner Production, 2013.
Crossref
7 words — < 1%

---

17 Chooi Mei Mah, Takeshi Fujiwara, Chin Siong Ho. "Life cycle assessment and life cycle costing toward eco-efficiency concrete waste management in Malaysia", Journal of Cleaner Production, 2018
Crossref
6 words — < 1%

---

18 Juliana Segura-Salazar, Francisco Mariano Lima, Luís Marcelo Tavares. "Life Cycle Assessment in the minerals industry: Current practice, harmonization efforts, and potential improvement through the integration with process simulation", Journal of Cleaner Production, 2019
6 words — < 1%

Crossref

EXCLUDE QUOTES	OFF	EXCLUDE MATCHES	OFF
EXCLUDE BIBLIOGRAPHY	ON		