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Optimizing the Use of Sany EV Units to Reduce Greenhouse Gas Emissions in the Hauling Area at PT Antareja Mahada Makmur's Mifa Bersaudara Site for the Period January–June 2026

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Abstract

Hauling activities in the mining industry are among the operational activities that consume significant amounts of energy and contribute substantially to greenhouse gas (GHG) emissions. The use of diesel-powered hauling units results in fossil fuel consumption and carbon dioxide (CO_2) emissions generated through the combustion process. This study aimed to analyze the effectiveness of SANY electric vehicle (EV) units as an effort to reduce fuel consumption, GHG emissions, and operational hauling costs at PT Antareja Mahada Makmur (PT AMM), Mifa Bersaudara Site. The study employed a case study design with a quantitative comparative approach by comparing three diesel-powered hauling units and three SANY EV units during the January–June 2026 period. The analyzed parameters included fuel consumption, estimated CO_2-equivalent (CO_2e) emissions, and operational costs.The results showed that the implementation of three SANY EV units had the potential to replace 241,230 liters of diesel fuel consumption and reduce emissions by 646.50 tons of CO_2e. Economically, the use of SANY EV units generated operational cost savings of IDR 8.21 billion, equivalent to approximately 79%, compared with diesel-powered units during the same period. These findings demonstrated that optimizing the use of SANY EV units could be an effective strategy to support operational decarbonization, cost efficiency, and the implementation of green mining practices at PT AMM. This achievement indicated the feasibility of hauling electrification, with a projection that the addition of ten SANY EV units could potentially reduce diesel fuel consumption by 804,100 liters, decrease emissions by 2,155 tons of CO_2e, and generate operational cost savings of IDR 27.37 billion.

PENDAHULUAN

Climate change is one of the most pressing environmental challenges of the twenty-first century, driven primarily by the continued release of anthropogenic greenhouse gases (GHGs) into the atmosphere. The Intergovernmental Panel on Climate Change (IPCC) confirmed that human activities have unequivocally caused global warming, with global surface temperatures already reaching approximately 1.1°C above pre-industrial levels. The IPCC further warned that limiting warming to 1.5°C requires deep and sustained emission reductions across all economic sectors (IPCC, 2023). The international community has responded through the 2030 Agenda for Sustainable Development, in which Goal 13 explicitly calls for urgent action to combat climate change (United Nations, 2015). Consequently, energy-intensive industries, including mining, face increasing pressure to align their operations with global decarbonization pathways.

The mining industry, although a comparatively smaller direct contributor to global GHG emissions than sectors such as power generation and road transportation, still accounts for an estimated 4–7% of

global GHG emissions when Scope 1 and Scope 2 activities are considered (Tokac et al., 2025). A substantial proportion of these emissions originates from mobile heavy equipment, particularly diesel-powered haul trucks used to transport ore, coal, and overburden. Globally, off-road mining haul trucks are estimated to generate approximately 174 megatonnes of CO_2-equivalent emissions annually (IDTechEx, 2024a), while diesel combustion in haul fleets reportedly contributes 30–50% of a typical mine site's direct Scope 1 emissions (ABB, 2025). These figures indicate that hauling represents one of the largest and most feasible opportunities for emission reduction within the mining value chain.

Hauling, referring to the continuous transportation of mined materials from the extraction area to processing or disposal locations, is consistently identified as one of the most energy-intensive activities in open-pit mining operations, with operating cycles that may extend up to 20 hours per day (Rocky Mountain Institute, 2019). Diesel-fueled hauling units consume large volumes of fossil fuels and release carbon dioxide (CO_2), nitrogen oxides (NOx), sulfur oxides (SOx), and diesel particulate matter (DPM) into the operational environment (Mining Magazine Australia, 2023). Beyond contributing to corporate carbon footprints, these emissions also pose occupational health risks. Diesel exhaust is recognized as a carcinogen, and prolonged exposure to diesel particulate matter has been associated with respiratory diseases, cardiovascular disorders, and increased lung cancer risks among mine workers (Menendez-Cabo & Garcia-Gonzalez, 2025). Therefore, regulatory agencies such as the United States Mine Safety and Health Administration and the Occupational Safety and Health Administration have established occupational exposure limits for diesel particulate matter (MSHA, n.d.; OSHA, 2021).

At the national level, Indonesia has established an increasingly ambitious climate policy trajectory. Under its Enhanced Nationally Determined Contribution (NDC), Indonesia targets GHG emission reductions of 31.89% through domestic efforts and 43.20% with international support by 2030, alongside a long-term commitment to achieving Net Zero Emissions (NZE) by 2060 or earlier (Kementerian Koordinator Bidang Perekonomian Republik Indonesia, 2025). This commitment was further strengthened through Indonesia's Second Nationally Determined Contribution, submitted ahead of COP30, which sets an intermediate emission reduction target of 1.258–1.489 gigatonnes of CO_2-equivalent by 2035 (Kementerian Lingkungan Hidup Republik Indonesia, 2025). However, analysts have noted that current policy trajectories remain insufficient to fully align Indonesia with the Paris Agreement targets and have called for stronger sectoral actions, including within energy-intensive industries such as mining (Institute for Essential Services Reform, 2023).

The mining sector plays a crucial role in supporting this national agenda. Peraturan Menteri Energi dan Sumber Daya Mineral Nomor 26 Tahun 2018 requires mining companies to implement good mining practices and environmentally responsible operations, building upon Indonesia's green mining initiatives that were formally introduced more than a decade ago (Kementerian Energi dan Sumber Daya Mineral Republik Indonesia, 2018). The Ministry of Energy and Mineral Resources has continued to encourage mining holding companies and contractors to commit to decarbonizing their operations as part of the national energy transition agenda (Kementerian Energi dan Sumber Daya Mineral Republik Indonesia, 2021). Furthermore, national planning institutions emphasize that translating NDC commitments into sector-specific and measurable actions, including fleet electrification, is essential for maintaining the competitiveness of Indonesia's coal mining industry amid increasing environmental, social, and governance (ESG) expectations from investors and international buyers (Badan Perencanaan

Pembangunan Nasional & Global Green Growth Institute, 2018; Institute for Essential Services Reform, 2023).

Within this context, mine haulage electrification has emerged as one of the most promising near-term decarbonization pathways for the mining industry. The adoption of this technology has accelerated at both vehicle and infrastructure levels. Original equipment manufacturers have advanced the commercial development of battery-electric haul trucks. ABB and Hitachi Construction Machinery, for example, have conducted trials of the world's first fully battery-electric haul truck at the Kansanshi copper-gold mine in Zambia (Sustainability Magazine, 2025). Mining company Fortescue has also committed to a multibillion-dollar investment in battery-electric haul trucks to eliminate Scope 1 and Scope 2 terrestrial emissions from its Pilbara operations by 2030 (Electrek, 2026). In addition, trolley-assist systems, fast-charging technologies, and battery-swapping systems are being developed to overcome duty-cycle and operational availability limitations (Nyobolt, 2025; ABB, 2026). This development reflects a broader technological trend, as the International Energy Agency (IEA) has reported continued global growth in electric vehicle adoption across passenger, commercial, and specialized heavy-duty segments, with electrification increasingly recognized as a key component of global industrial decarbonization strategies (IEA, 2024). These technological advancements are also being adapted for off-road applications, including the SANY EV units implemented at PT AMM (IDTechEx, 2024a).

The adoption of electric hauling technology is driven not only by environmental considerations but also by increasingly favorable total cost of ownership (TCO) outcomes. Comparative TCO analyses of 150-tonne diesel and lithium iron phosphate battery-electric haul trucks indicate that electrification can reduce the cost per tonne of material transported by up to 65% when fuel and maintenance savings are considered (SRK Consulting, 2024). Independent market analyses have also estimated savings of nearly USD 2.5 million per electrified haul truck, with payback periods for additional capital investment occurring within approximately three years (IDTechEx, 2024b; MINING.com, 2024). Similar evidence from the heavy commercial vehicle sector in emerging markets, including India, indicates that battery-electric trucks can achieve cost parity with diesel-powered alternatives when electricity tariffs, incentives, and utilization rates are considered (Rajagopal et al., 2024). However, simulation-based haulage studies highlight that realized economic benefits remain highly dependent on site-specific duty cycles, climate conditions, and charging infrastructure availability because diesel units can be refueled within minutes, whereas electric units may require several hours for recharging (Tokac et al., 2025).

Despite their advantages, battery-electric vehicles are not entirely emission-free when assessed through a life-cycle perspective. Life cycle assessment (LCA) studies conducted based on ISO 14040:2006 principles indicate that although battery-electric vehicles eliminate tailpipe emissions during operation, lithium-ion battery production and the carbon intensity of electricity generation contribute to their overall environmental footprint. Battery manufacturing alone has been estimated to generate approximately 105 kg of CO_2-equivalent per kilowatt-hour of battery capacity (Zhang et al., 2023). Nevertheless, cradle-to-grave assessments consistently demonstrate that battery-electric vehicles provide substantial net GHG reductions compared with diesel-powered alternatives throughout their operational lifetime, with further improvements expected as electricity systems become increasingly decarbonized (European Parliament, Directorate-General for Internal Policies, 2023). These findings reinforce the importance of internationally recognized accounting frameworks, such as ISO 14064-1:2018, in evaluating the actual emission-reduction potential of electrification programs.

PT Antareja Mahada Makmur (PT AMM), a mining contractor operating at the Mifa Bersaudara coal site in West Aceh Regency, Aceh Province, has positioned itself within this broader green mining transition. As a contractor responsible for overburden removal and coal transportation activities, PT AMM's hauling fleet represents one of its most fuel-intensive and emission-intensive operational assets. Internal operational evaluations indicate that a single diesel-powered hauling unit at the site consumed up to 14,835 liters of fuel during one month of operation. This condition illustrates the extent of fossil fuel dependence and the associated cost and emission exposure under a conventional operating model.

In response to these challenges and in line with its sustainability commitments, PT AMM has begun deploying SANY electric vehicle (EV) units within its hauling fleet as an initial step toward operational electrification. Unlike diesel-powered units, SANY EV haul trucks are powered directly by electricity, eliminating tailpipe emissions during operation and reducing dependence on diesel logistics, which in remote regions such as West Aceh may contribute to additional supply-chain emissions and cost fluctuations (Rocky Mountain Institute, 2019). This initiative reflects the broader transition occurring within the global mining industry, where original equipment manufacturer (OEM) and mining company partnerships are increasingly advancing battery-electric haul trucks from pilot projects toward fleet-scale implementation (Mining Magazine Australia, 2023).

Despite the growing body of international literature on the feasibility, economic performance, and life-cycle emissions of electric haul trucks, empirical studies quantifying the operational, financial, and emission outcomes of electric haul truck adoption specifically within Indonesian coal mining operations remain limited. Much of the existing evidence originates from large-scale iron ore, copper, or logistics operations in Australia, Africa, Europe, and North America (SRK Consulting, 2024; Sustainability Magazine, 2025; Electrek, 2026), where duty cycles, electricity infrastructure, and regulatory conditions differ substantially from those of Indonesian contract mining sites. Site-level comparative data on fuel displacement, CO_2e emission reductions, and cost savings resulting from EV adoption at active Indonesian hauling operations, which are essential for supporting investment decisions by contractors such as PT AMM and strengthening national NDC and green mining reporting, have not been sufficiently documented in the published literature.

This study addressed this gap by examining the initial implementation of SANY EV units within PT AMM's hauling operations at the Mifa Bersaudara site. Specifically, this research aimed to analyze the effects of SANY EV utilization on greenhouse gas emission reductions and hauling operational cost efficiency at PT AMM during the January–June 2026 period by comparing EV units with comparable diesel-powered hauling units operating under equivalent duty cycles. By quantifying fuel displacement, estimated CO_2e emission reductions, and operational cost differences using internationally recognized GHG accounting principles (ISO 14064-1:2018) and emission factors informed by life cycle assessment approaches, this study provided an empirically grounded case reference to support PT AMM's fleet electrification roadmap, contribute to the growing evidence base on green mining practices in Indonesia, and support the national decarbonization agenda outlined in Indonesia's NDC and Net Zero Emission 2060 commitments (Kementerian Koordinator Bidang Perekonomian Republik Indonesia, 2025; Kementerian Lingkungan Hidup dan Kehutanan Republik Indonesia, 2024). Theoretically, this study contributed to the literature on mining electrification and operational decarbonization within the Indonesian context, where empirical evidence on electric haul truck adoption remains limited. Practically, it provided data-driven insights for PT AMM's investment decisions and fleet planning, comparative

benchmarks for other mining contractors considering similar transitions, and empirical evidence for policymakers in developing sectoral emission-reduction strategies aligned with national climate targets.

METHOD

The research used a case study method with a quantitative comparative approach. The analysis was conducted by comparing diesel-fueled hauling units with SANY Electric Vehicle (EV) units used in hauling activities.

LocationResearch

The research was conducted in the operational area of PT Antareja Mahada Makmur Site Mifa Bersaudara located in West Aceh Regency, Aceh Province

Collection Data

Data Which used in study includes:

1. Data consumption material burn diesel unit.
2. Data need energy unit EV SANY.
3. Data cost operational energy.
4. Data activity hauling.
5. Data literature factor emission gas House glass.

Data analysis

Analysis done through stages as follows:

1. Identification condition existing activity hauling.
2. Comparison consumption energy between unit diesel and EV.
3. Analysis cost energy operations .
4. Analysis potential subtraction emission gas House glass.
5. Evaluation efficiency operational.
6. Compilation recommendation development electrification fleet hauling.

The analysis was carried out by comparing fuel consumption, emissions, and operational costs between three unit diesel And three unit EV SANY. Estimate emission CO_2e counted based on The diesel fuel consumption and emission factor used in the analysis are 2.68 kg CO_2e/liter. The calculation is carried out using the equation:

$$\text{Emission } CO_2e = \text{Material Consumption Burn} \times \text{Emission Factor}$$

Cost efficiency is calculated based on the difference in operating costs of SANY's diesel unit and EV unit against the operating costs of the diesel unit.

RESULT AND DISCUSSION

Condition Existing Operational Hauling

Hauling activities at PT AMM are still dominated by the use of diesel-powered units. material burn fossil in a way continously cause height cost operational and greenhouse gas emissions.

Operational data shows that one of the diesel hauling units had a fuel consumption of 14,835 liters during the period of March 2026. The high fuel consumption indicates that size contribution activity hauling to energy use fossil company.

Implementation Unit EV SANY

As an effort to reduce emissions, PT AMM implemented one SANY EV unit in its activities.

hauling. Unit This use energy electricity as source power main so that does not produce direct exhaust emissions during operation.

SANY's EV implementation is the first step in electrifying its hauling fleet, supporting the company's green mining and operational decarbonization programs.

Figure 1. SANY Electric Vehicle Unit at PT AMM Mifa Bersaudara Site

Source: PT Antareja Mahada Makmur Internal Documentation (2026)

The evaluation results show that the use of SANY Evs provides significant energy cost efficiency compared to conventional diesel units.

Table 1. Comparison of Operational Parameters Between Diesel Unit and SANY EV Unit

Parameter	Diesel Eng	EV
Cycle Time (minutes)	62 min	62 min
Consumption/Cycle	31.57 L	104.4 kW
Consumption/Hr	30.55 L	101.0 kW
Price (Fuel or Electricity)	18,000 /L	1,143.67 kW/Hr
Cost/Hr	IDR 549,987 /Hr	IDR 115,548 /Hr
EWH/day	18 Hr	18 Hr
EWH/year	6300 Hr	6300 Hr
Cost/year	**IDR 3,464.G18,710**	**IDR 727.G4G.644**
% Reduction Cost/year	**7G%**	
Cost/5 year	**IDR 17,324,5G3,548**	**IDR 3.63G.748.221**
Cost Reduction per 5 Yr	**IDR**	**13,684,845,327**

Source: PT Antareja Mahada Makmur Operational Data (2026)

Based on the analysis results, the use of one SANY EV unit can generate energy operational cost savings of 79% or equivalent to IDR 13,684,845,327 over a five-year operational period.

Impact To Environment

The use of SANY EVs makes a positive contribution to reducing greenhouse gas emissions by reducing the use of diesel fuel in hauling activities.

Impact environment Which obtained among others:

1. Subtraction consumption material burn fossil.
2. Decline emission gas House glass.
3. Decline emission particulates and gas throw away vehicle.
4. Improvement quality air operational area.

5. Support to program Green Mining PT AMM.

From a sustainability perspective, SANY's EV deployment also supports the company's goal of reducing its operational carbon footprint and improving environmental performance.

Comparison Usage 3 unit Diesel And 3 Unit Ev Sany

Table 2. Comparison of Fuel Consumption and CO_2e Emissions Between 3 Diesel Units and 3

Parameter	3 Unit Diesel (PM56407, PM56410, PM56414)	3 Unit EV SANY (PE55801, PE55802, PE55803)
Fuel Consumption	**40,205 Liter**	**0 Liter**
Factor Emission	**2.68 kg CO_2e/L**	-
Estimate Emission CO_2	**107.74G,40 kg CO_2e (107.75 ton CO_2e)**	**0 kg CO_2e**

Source: PT Antareja Mahada Makmur Operational Data (processed, 2026).

Table 3. Summary of Fuel Displacement, Emission Reduction, and Cost Savings from 3 SANY EV

Parameter	Mark	Unit
Amount EV Unit SANY	3	Unit
Fuel Diesel Which Replaced	241,230	Liter
Decline Emission CO_2e	646.5	Ton CO_2e
Cost Operational Diesel	Rp10,394,756,130	IDR
Cost Operational EV	Rp2,183,848,932	IDR
Estimated Cost Savings	Rp8,210,907,198	IDR

Source: PT Antareja Mahada Makmur Operational Data (processed, 2026).

Based on fuel consumption during the operational period, the three diesel units (PM56407, PM56410, and PM56414) consumed a total of 40,205 liters of diesel fuel, resulting in estimated emissions of 107,749.40 kg CO_2e or 107.75 tons CO_2e. In contrast, the three SANY EV units (PE55801, PE55802, and PE55803) did not use diesel fuel and therefore did not produce any emissions. emission gas throw away direct (tailpipe emission) during operational. With Thus, the implementation of three SANY EV units has the potential to reduce greenhouse gas emissions by up to 107.75 tons of CO_2e in an equivalent operational period.

Potential Development Program

Successful implementation of one EV unit SANY This demonstrates the feasibility of electric vehicle technology for mining hauling activities. PT AMM has planned to expand the program by gradually adding 10 SANY EV units as part of the company's operational decarbonization roadmap.

Table 4. Projection Benefit Implementation 10 Unit EV SANY

Parameter	10 Unit Diesel	10 Unit EV SANY	Improvement
Amount Unit	10 Unit	10 Unit	-
Fuel Consumption	**804.100 Liter**	**0 Liter**	**100%**
Emission CO_2e	**2.155 ton CO_2e**	**0 ton CO_2e**	**100%**
Cost Operational	**Rp34.64G.187.100**	**Rp7.27G.4G6.440**	**Economical Rp27.36G.6G0.660 ***

Source: PT Antareja Mahada Makmur Operational Data (projected, processed, 2026)

The implementation of three SANY EV units demonstrated success in reducing fuel consumption, CO_2e emissions, and operating costs. Based on these results, expanding to ten SANY EV units is projected to reduce diesel consumption by up to 804,100 liters. pressing emission around 2.155 ton CO_2e, as well as produce potential efficiency cost operational of Rp27.37 billion in the equivalent operational period.

CONCLUSION

The use of SANY EV units in PT Antareja Mahada Makmur's hauling activities has demonstrated significant environmental and economic benefits. The implementation of one SANY EV unit achieved approximately 79% energy cost efficiency compared with conventional diesel-powered units, with potential savings of IDR 13.68 billion over five years of operation. In addition to providing economic advantages, the use of SANY EV units has the potential to reduce fossil fuel consumption and greenhouse gas (GHG) emissions, thereby supporting the implementation of green mining practices and corporate sustainability targets. The success of this initiative demonstrates that hauling fleet electrification can serve as an effective strategy to support decarbonization efforts in the mining sector.

Based on these findings, several recommendations are proposed. For PT AMM management, it is recommended to accelerate the expansion of SANY EV deployment from the current pilot phase toward fleet-scale implementation, as projected in the ten-unit scenario, while simultaneously developing supporting infrastructure, including fast-charging facilities and battery maintenance systems, to ensure operational reliability and maximize long-term cost efficiency. For other mining contractors, this study provides a benchmark demonstrating that electrification is technically feasible and economically viable under Indonesian mining conditions. Similar feasibility assessments are encouraged to be conducted based on each contractor's specific operational characteristics and requirements. For policymakers, particularly the Ministry of Energy and Mineral Resources and the Ministry of Environment, it is recommended to strengthen regulatory support for mining fleet electrification through mechanisms such as tax incentives, accelerated depreciation schemes, and preferential electricity tariffs for mining operations adopting electric hauling technologies. In addition, standardized emission reporting guidelines aligned with ISO 14064-1:2018 should be developed to support national emission reduction monitoring under the NDC framework. Future researchers are encouraged to extend the observation period to evaluate long-term battery degradation and maintenance performance, incorporate life cycle assessment (LCA) approaches that account for battery manufacturing and electricity grid emissions, and expand research coverage to multiple mining sites or commodities to improve the generalizability of findings regarding electric haul truck adoption in Indonesia.

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