Journal of Authentic Research
https://journal-center.litpam.com/index.php/jar/index

February 2026 Vol. 5, No. 1
e-ISSN: 2828-3724
pp. 333-346

Feasibility Analysis of PLN's Mining Electric Vehicle Implementation: A Techno-Economic Study of South Kalimantan Coal Mining and National Energy Policy Implications

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Received: December 2025; Revised: January 2026; Published: February 2026

Abstract

The mining sector is one of the largest contributors to carbon emissions in Indonesia, mainly due to the intensive use of diesel- and B40-fueled dump trucks in mining operations. The mandatory implementation of B40 starting January 1, 2025, is expected to reduce dependence on fuel imports and support the national target of achieving Net Zero Emission (NZE) by 2060; however, this policy also increases operational costs for mining companies because the price of B40 is higher than conventional diesel. In this context, the electrification of mining vehicles through the adoption of electric vehicle (EV) dump trucks emerges as a potential solution to simultaneously reduce operational costs and carbon emissions. This study aims to analyze the technical and economic feasibility of transitioning mining dump trucks from diesel/B40 to EV trucks. The research employs a descriptive quantitative method with a case study approach. Technical analysis is conducted to estimate electrical power requirements, fast-charging capacity based on the GB/T standard, and operating load profiles of EV trucks under mining conditions. Economic analysis involves a comparison of operating costs between diesel-based dump trucks and EV trucks, as well as an evaluation of key financial indicators, including Net Present Value (NPV), Internal Rate of Return (IRR), Benefit–Cost Ratio (B/C), and Payback Period. In addition, a strategic analysis is carried out to assess the broader implications of mining electrification for PLN's business strategy, cost efficiency for mining operators, and alignment with national energy transition objectives. Overall, this study is expected to contribute to policy formulation by providing evidence-based insights on the role of EV trucks in supporting cost-efficient, low-emission mining operations and accelerating Indonesia's transition toward a more sustainable and decarbonized energy system.

Keywords: Electric Vehicles, Charging Station, Partnership, Infrastructure, Business Scheme

How to Cite: Adi, T. W., & Prihasta, N. G. Feasibility Analysis of PLN's Mining Electric Vehicle Implementation: A Techno-Economic Study of South Kalimantan Coal Mining and National Energy Policy Implications. *Journal of Authentic Research*, 333-346. https://doi.org/10.36312/z44wt186

https://doi.org/10.36312/z44wt186

INTRODUCTION

The mining sector in Indonesia is a significant contributor to the national economy but also one of the largest sources of carbon emissions, primarily due to the intensive use of diesel-powered haul trucks in mining operations. These vehicles, while essential for transporting coal and other minerals, are responsible for substantial greenhouse gas (GHG) emissions, contributing to environmental degradation and climate change. According to data from the Indonesian Ministry of Energy and Mineral Resources (2025), the mining sector alone accounts for a large percentage of the country's total emissions. Consequently, Indonesia has committed to achieving a

Net Zero Emissions (NZE) target by 2060, with the mining sector being a key area of focus for reducing carbon footprints.

One of the most promising solutions to mitigate these emissions is the electrification of mining vehicles, particularly the adoption of Electric Vehicles (EVs). Battery Electric Vehicles (BEVs) have gained attention in the mining industry as a sustainable alternative to conventional diesel-powered vehicles. The adoption of BEVs can potentially reduce operational costs, improve air quality, and lower emissions in underground and surface mining operations (Hooli & Halim, 2025). As the global demand for cleaner energy sources grows, Indonesia's energy policy has also shifted toward enhancing the role of renewable energy in industrial operations. This aligns with the Indonesian government's broader goals of reducing dependence on fossil fuels and mitigating the environmental impact of coal mining.

The Indonesian government has recently mandated the use of B40 (a blend of 40% biodiesel and 60% diesel) in all mining operations, effective January 2025, aiming to reduce the country's reliance on imported fuels and help the national push for cleaner energy sources. However, this policy presents a challenge for mining companies, as the price of B40 is higher than conventional diesel, increasing operational costs (Wahyudi & Hermawan, 2025). As a result, the mining sector must explore alternative strategies to reduce costs while adhering to national environmental goals.

Electric mining vehicles, particularly EV dump trucks, emerge as a viable solution to this challenge. These vehicles are considered to be more efficient, cost-effective in the long term, and environmentally friendly when compared to their diesel or B40 counterparts. By eliminating the need for diesel fuel, EVs reduce the dependence on fossil fuels and contribute to the reduction of carbon emissions, thus supporting Indonesia's energy transition efforts and contributing to the broader global decarbonization agenda (Ghosh et al., 2024). However, large-scale implementation of electric mining vehicles requires the development of a robust charging infrastructure, effective integration with existing electrical grids, and careful planning regarding power supply and operational efficiency.

This study investigates the feasibility of implementing Electric Vehicles (EVs) in coal mining operations in South Kalimantan, focusing on the technical, economic, and policy implications of transitioning from diesel/B40 trucks to electric vehicles. The transition to electric mining vehicles is considered not only from the perspective of operational efficiency but also in terms of the broader impact on national energy policies. The growing demand for electricity from renewable sources, coupled with the transition to more sustainable and energy-efficient transportation systems, presents both opportunities and challenges for electricity providers such as PT PLN (Persero).

The use of Battery Electric Vehicles (BEVs) in the mining sector has shown significant promise in reducing the environmental impact of mining operations. A study by Hooli and Halim (2025) highlighted that BEVs, which operate on electricity rather than fossil fuels, have the potential to significantly lower GHG emissions, reduce harmful particulates, and minimize noise pollution compared to traditional diesel-powered vehicles. In underground mining, where ventilation and cooling are major operational concerns, BEVs help reduce the energy needed for these systems, thus improving overall energy efficiency. The high efficiency of electric motors—

approximately 90%—compared to the lower efficiency (around 30%) of diesel engines makes BEVs a compelling alternative for the mining industry (Mesa et al., 2025).

The implementation of BEVs in the mining sector is not without challenges. As pointed out by Wang et al. (2025), one of the primary obstacles is the need for substantial infrastructure development to support electric mining vehicles. Mining operations require robust and reliable charging infrastructure, including charging stations and power distribution networks capable of handling the increased electricity demand. The capital investment in this infrastructure is significant, and its cost-effectiveness depends heavily on the scale of the operation and the utilization rates of the charging stations.

The economic feasibility of transitioning to electric mining vehicles is a critical consideration for mining companies. While the upfront cost of purchasing electric vehicles is higher than that of conventional diesel vehicles, the operational savings over time, including reduced fuel costs, maintenance costs, and emissions-related penalties, can offset the initial investment. Several studies have demonstrated that while electric vehicles have a higher capital expenditure (capex), they offer lower operating costs (opex) due to cheaper electricity compared to diesel fuel (Wahyudi & Hermawan, 2025). The comparison of these cost components is essential in assessing the long-term financial viability of the transition to electric vehicles.

In a study by Ghosh et al. (2024), the decarbonization of mining operations was examined, comparing the operational costs and efficiency of diesel versus electric haul trucks. The findings indicated that, while electric trucks require substantial upfront investment, they provide a more cost-effective solution over time due to their lower fuel and maintenance costs. Additionally, the implementation of electric vehicles helps mining companies avoid rising fuel prices, particularly as Indonesia begins to implement policies like B40, which increase fuel costs (SolarIndustri.com, 2025).

Economic analysis for this study will utilize key financial indicators such as Net Present Value (NPV), Internal Rate of Return (IRR), Benefit-Cost Ratio (B/C), and Payback Period (PBP) to evaluate the economic viability of electric mining vehicles in comparison to their diesel and B40 counterparts. These metrics will help assess the overall cost-effectiveness of adopting electric vehicles in mining operations and provide insight into the potential return on investment (ROI).

The transition to electric vehicles in the mining sector has broader implications for national energy policy, particularly for PT PLN (Persero), the state-owned electricity provider. As mining operations transition to electric vehicles, the demand for electricity will increase, creating both opportunities and challenges for PLN. The integration of electric mining vehicles into the national grid requires careful planning to ensure that the electricity supply is sufficient, reliable, and cost-effective.

PT PLN is tasked with ensuring that the infrastructure and electricity supply are capable of meeting the growing demand from various sectors, including mining. According to the 2021-2030 General Electricity Supply Plan (RUPTL) developed by PLN, there is a concerted effort to increase electricity generation from renewable sources such as geothermal, hydro, and solar power. This aligns with Indonesia’s long-term energy transition goals, which include achieving Net Zero Emissions by 2060. The electrification of mining vehicles presents a significant opportunity for PLN to expand its market and contribute to the country’s decarbonization efforts by providing clean electricity for electric mining operations (Perusahaan Listrik Negara, 2025).

However, as noted by Mesa et al. (2025), the integration of electric vehicles into the national grid requires careful consideration of load management, charging infrastructure, and the operational patterns of mining vehicles. PLN must collaborate with mining companies to develop a strategy for upgrading the electrical infrastructure to support the increased load from electric vehicles without compromising the stability and reliability of the grid.

The electrification of mining vehicles presents a promising solution to reduce carbon emissions and operating costs in the mining sector, which is a key contributor to Indonesia's overall emissions. This study aims to assess the technical, economic, and policy feasibility of transitioning from diesel/B40-powered dump trucks to battery electric vehicles in coal mining operations in South Kalimantan. By evaluating the infrastructure needs, operational costs, and financial feasibility, this study will provide valuable insights into the role of electric vehicles in supporting sustainable and cost-effective mining operations. Additionally, the findings will inform policy decisions related to the energy transition and contribute to Indonesia's long-term goal of achieving Net Zero Emissions by 2060.

The adoption of electric mining vehicles, supported by appropriate charging infrastructure and optimized power system planning, offers significant potential to reduce the mining sector's carbon footprint while improving operational efficiency. However, successful implementation will require a coordinated effort between the mining sector, PT PLN, and the Indonesian government to ensure that the necessary infrastructure, policies, and financial mechanisms are in place to support the transition.

METHODS

This study employs a quantitative descriptive approach with a case study method to evaluate the technical, economic, and policy aspects of mining fleet electrification. The research focuses on the transition of coal mining dump truck operations from diesel/B40-fueled vehicles to battery electric vehicles integrated with the electricity system of PT PLN (Persero) at a coal mining site in South Kalimantan, Indonesia. Primary data were obtained through structured interviews with mine operators and PLN representatives regarding electrification plans, power demand projections, operational patterns, and cost assumptions, while secondary data were sourced from mine work plans and budgets, PLN technical documents, academic literature, industry reports, and official publications on electric vehicles and charging infrastructure. Technical analysis was conducted to determine vehicle energy demand based on travel distance, daily trip frequency, load characteristics, and energy efficiency, as well as to assess the required number and capacity of fast-charging stations compliant with the GB/T 360 kW standard, monthly operating hours, and the readiness of the PLN power system to accommodate increased electrical loads. Economic feasibility was evaluated by comparing the existing diesel/B40 system with the electric vehicle system using investment and operating cost components and assessing financial indicators including Net Present Value (NPV), Internal Rate of Return (IRR), Payback Period (PBP), and Benefit–Cost Ratio (B/C) over the project's economic lifetime. To ensure robustness of the results, sensitivity analysis was performed on key variables such as the number of vehicles, trip frequency, load capacity, number of charging stations, and vehicle energy efficiency, covering scenarios from realistic to highly optimistic conditions. Finally, a qualitative policy implication analysis was conducted to examine the impacts of mining electrification on PLN’s business strategy, cost efficiency for mining operators, and contributions to Indonesia’s national energy transition and Net Zero Emission 2060 target.

ANALYSIS

Mining Environment and Infrastructure Readiness

The object of this research is a large coal mining company operating in South Kalimantan, which is currently expanding its operations and implementing green mining initiatives, requiring increased electricity supply from PLN. The company has connected to the PLN grid and is finalizing a power purchase agreement for an additional 20–25 MVA, with plans to expand to 70–80 MVA, and has paid the initial connection fee.

Figure 1 Coal Mine Location

To support the operational transformation, the company will begin operating more than 100 electric mining trucks, increasing to 300–650 by the end of the forecast period. This electrification plan has a high level of implementation confidence, hovering around 80%, or optimistic.

Technical Aspect Analysis of Dump Truck Electrification

Figure 2. Mining Location and Dump Truck Transportation Route

Operational analysis shows that dump trucks used in coal transportation traverse a distribution route from the mining area to the port, where the material is finally delivered. This route also includes the Run of Mine (ROM) area, the initial processing area for raw mining materials. The estimated length of the route from the mining area to the port, including the ROM area, is approximately 50 kilometers in one direction.

Each dump truck performs eight transport cycles (trips) per day, with an average distance of 100 kilometers per cycle. Based on operational needs and energy consumption, each vehicle requires up to four battery charges per day. Therefore, to support the performance of a fleet of 100 electric dump trucks by early 2026, at least 20 to 25 Public Electric Vehicle Charging Stations (SPKLU) with a capacity of 360 kW with a dual-nozzle configuration are needed so that the charging process can run effectively and smoothly.

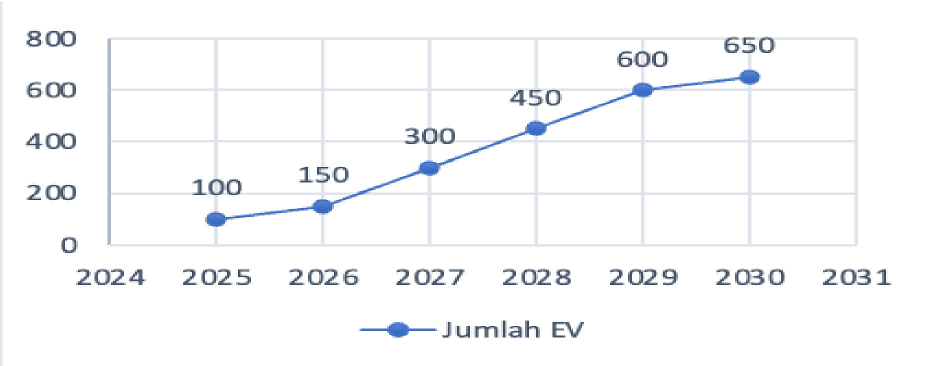

Figure 3. EV Implementation Plan in Coal Mine

The electric vehicle implementation graph in Figure 11 shows a consistent increase from 100 units in 2025 to 650 units in 2030, with a more accelerated growth rate in the period 2027 to 2029. This development illustrates a fleet electrification strategy that is planned systematically and progressively in line with the readiness of supporting infrastructure, especially charging facilities.

In addition, the projection data was obtained through direct confirmation with the coal mine management, thus reflecting the actual needs plan that has been considered in the context of implementing low-emission transportation technology to support the sustainable energy transition agenda.

SPESIFIKASI DUMP TRUCK EV		
	**Kapasitas Baterai**	352,08 kW
	Berat dump truk (kosong)	24,6 ton
	Berat dump truk (bermuatan)	70 ton
	Kapasitas pengangkutan	61 ton
	Konsumsi baterai	2,53 kWh/km
	Kecepatan (maks)	80 km/jam
	Kecepatan (dalam *mining area*)	45 km/jam

Figure 4. EV Dump Truck Specifications

The ideal location for SPKLU is at strategic points along the hauling route between the mining area and the port, taking into account the travel time of 2.2 hours per trip as well as the availability of space for power infrastructure and safety systems.

SPESIFIKASI CHARGING PILE		
	**Merk Charger**	XCMG
	Input	380 Vac
	Output	400~1000 Vdc
	Output current	500 A
	Power	360 kW
	Daya PLN	450 – 500 kVA
	Connector type	GB/T DC Charging Dual Nozzle
	Estimated Time Charging	0,7% per menit (dengan skala baterai 100%)

Picture 5. Charging Pile Specifications

The central zone of the hauling route is a prime candidate because it can reduce the unloaded distance to the charging facility, optimize the operating hours of the charging stations (87 JN per unit), and minimize potential charging queues. Centralized placement and/or distribution of charging stations into clusters could also be an option to accommodate the increasing number of dump trucks, up to hundreds of units, in the long term.

Energy and Electrical Power Requirements

Table 3 below presents a summary of the mine's operational conditions, which serve as the basis for calculating energy and power requirements to support the electrification of the haulage fleet. Information includes the mine's operating period, coal reserves up to the projected year, annual production capacity, and estimated daily mining volume based on the RKAB document approved by the Ministry of Energy and Mineral Resources.

RESOURCE BATUBARA	
Waktu operasi	**12 tahun (2025-2036)**
Cadangan Batubara Hingga 2036	**±743 Juta Ton**
Produksi per tahun	**±46,8 Juta Ton**
Penambangan per hari	**130.000 Ton**
Cadangan batubara: Nilai berdasarkan Rencana Kerja dan Anggaran Biaya (RKAB) milik perusahaan tambang yang telah disetujui oleh Kementerian Energi dan Sumber Daya Mineral (ESDM)	
JALUR TAMBANG	
Jarak perjalanan *dump truck* dari titik awal ke titik akhir.	**50 km**
Jarak 1 Ritase	**100 km**
Ritase: Satu siklus perjalanan pengiriman batubara dari satu titik awal ke titik akhir dan sebaliknya	

Figure 6. Coal Mining Resource and Route Data

The coal reserves owned by the mining company and have been approved in the Work Plan and Budget (RKAB) document by the Ministry of Energy and Mineral Resources (ESDM) reach ±743 million tons, with an operational plan lasting 12 years, namely from 2025 to 2036. The average annual production is projected at ±46.8 million tons, or equivalent to 130,000 tons per day. In supporting coal transportation activities, dump trucks will travel a route of 50 km from the starting point to the end point, so that one full transportation cycle (trip) includes a round trip of 100 km.

The information presented in Table 5 forms the basis for logistics planning and calculating energy requirements and supporting infrastructure in the implementation of battery-based electric vehicles (KBLBB) in mining areas.

Financial Feasibility Analysis of Fleet Electrification

This subchapter presents the operational assumptions and basic parameters used in the financial feasibility analysis of fleet electrification. The assumptions were obtained from primary data through interviews with mine managers and secondary data from literature and technical documents. The parameters presented, such as operating hours, number of shifts, fuel consumption, and electrical energy requirements, form the basis for calculating the operational costs and financial benefits of switching to electric dump trucks.

ASUMSI OPERASIONAL DUMP TRUCK		
Parameter	**Nilai**	**Sumber**
Jam Operasional	24 jam	Data Primer (wawancara dengan pengelola tambang)
Jumlah shift	2 shift	Data Primer (wawancara dengan pengelola tambang)
Konsumsi BBM	6 liter/km	Wahyudi, dan Hermawan, P. 2025
Konsumsi energi listrik	2,53 kWh/km	Datasheet EV XCMG Electric Dump Truck XGA3310E

Figure 7. Operational Assumptions for Dump Trucks

Figure 8 below presents a series of financial assumptions used as the basis for the economic feasibility analysis of mining fleet electrification. These assumptions cover capital expenditure (capex) components from both the mining company and the electricity provider, as well as annual operating costs (opex) relevant to calculating the costs and benefits of implementing electric vehicle technology. Parameter values were collected from a combination of primary data through interviews with mine managers and secondary data from official PLN reports, academic literature, and recent industry publications. Establishing these assumptions provides a consistent quantitative basis for calculating NPV, IRR, and Payback Period for the electrification scenarios studied.

ASUMSI FINANSIAL			
	Parameter	Nilai	Sumber
SISI PELANGGAN	Capex Tambang (Armada Dump Truck)	Rp19.843.218.000,-	Wahyudi, dan Hermawan, P. 2025
	Capex Tambang (SPKLU 360 kW)	Rp2.000.000.000,-	Data Primer (wawancara dengan pengelola tambang)
	Opex Armada Tambang (per km)	Rp2.672	Wahyudi, dan Hermawan, P. 2025; Permana et al. 2024
	Opex Armada Tambang (per tahun)	Rp300.000.000,-	Wahyudi, dan Hermawan, P. 2025; Permana et al. 2024
	Harga BBM	Rp21.450*	Solarindustri.com. 2025.
SISI PLN	Capex PLN (Transmisi)	Rp95.000.000.000,-	Perusahaan Listrik Negara (PLN). 2025
	Capex PLN (Gardu Induk)	Rp20.000.000.000,-	Perusahaan Listrik Negara (PLN). 2025
	Opex PLN (per tahun)	3% dari Capex	Perusahaan Listrik Negara (PLN). 2025
	Tarif Listrik I4 Tegangan Tinggi	Rp996,74	Perusahaan Listrik Negara (PLN). 2025
	Umur Proyek	11 tahun	Data Primer (wawancara dengan pengelola tambang)

Figure 8. Financial Assumptions of Calculation

In the financial feasibility analysis of fleet electrification, two main cost components are considered: investment costs (capex) and operational costs (opex). Investment costs encompass all initial capital expenditures required to support the transition to electric dump trucks, including EV fleet procurement, charging infrastructure development (SPKLU), and electricity network investments on the power supply side, such as transmission lines and substations.

Sensitivity and Scenario Analysis

To estimate the energy needs and capacity of electric vehicle charging infrastructure in the baseline scenario, a systematic quantitative approach is required through the use of mathematical formulas. These formulas serve to illustrate the relationship between the number of electric vehicles, daily operating characteristics, and the power supply capacity of the charging station infrastructure. By defining key parameters and their mathematical relationships, this analysis can provide a more measurable and objective understanding of electricity needs, charging capacity, and the utilization rate of charging station facilities in the context of mining operations.

Sensitivitas Efisiensi EV		
Skenario	Efisiensi EV (kWh/km)	Jam Nyala per bulan
Moderate Optimis	2,53	371
Realistis	2,27	333
Moderate-Pesimis	2,04	299
Pesimis	1,84	269
Sangat Pesimis	1,65	242
Base Case	1,49	218

Figure 9. Negative Gradual Sensitivity

Figure 9 illustrates the sensitivity of electric vehicle (EV) efficiency to monthly electricity usage hours in a mining fleet electrification scenario. It can be seen that the higher the energy consumption per kilometer (kWh/km)—reflecting the decreased

EV efficiency—the greater the electricity requirement that must be supplied through the SPKLU. For example, in the *Moderate Optimistic scenario* with an efficiency of 2.53 kWh/km, the electricity usage hours required reach 371 hours per month, while in the *Base Case scenario* with the best efficiency (1.49 kWh/km), the electricity usage hours required are only 218 hours per month.

Sensitivitas Variasi Muatan			Sensitivitas Jumlah Kendaraan		Sensitivitas Jumlah Truck & Jumlah SPKLU		
Skenario	Muatan (ton)	JN	∑ Kendaraan	JN	∑ Kendaraan (Unit)	∑ SPKLU	JN
Base Case	38	371	100	371	100	30	371
Moderate-Realistis	39	371	150	557	150	38	445
Realistis	40	371	300	1113	300	100	334
Moderate Optimis	41	371	450	1670	450	150	334
Optimis	42	371	600	2226	600	200	334
Sangat Optimis	44	371	650	2412	650	217	334

Figure 10. Positive Gradual Sensitivity

Figure 10 shows the results of a positive gradual sensitivity analysis for the parameters of the number of SPKLUs, trips, and a combination of both. An increase in the number of SPKLUs from 30 to 55 units is directly proportional to a decrease in operating hours (JN) from 371 to 202 hours per month. This indicates that the addition of electric charging infrastructure has a direct impact on the efficiency of electric vehicle operating time, which implies an increase in fleet utilization. On the trip side, increasing the number of trips from 6 to 12 trips per day also reduces operating hours, with a significant decrease from 371 to 278 hours. This means that increased vehicle productivity can be achieved without extending the operating duration, which is operationally beneficial.

	Sensitivitas Variasi Muatan dan Ritase			Sensitivitas Muatan, Jumlah Kendaraan & Jumlah SPKLU				Sensitivitas Ritase, Muatan, Jumlah Kendaraan & Jumlah SPKLU				
Skenario	Ritase	Muatan (ton)	JN	Muatan	∑ Kendaraan (Unit)	∑ SPKLU	JN	Ritase	Muatan (ton)	∑Kendaraan	∑ SPKLU	JN
Base Case	6	38	371	38	100	30	371	6	38	100	30	371
Moderate-Realistis	7	39	433	39	150	38	445	7	39	150	38	519
Realistis	8	40	495	40	300	75	445	8	40	300	75	594
Moderate Optimis	9	41	557	41	450	113	445	9	41	450	113	668
Optimis	10	42	618	42	600	150	445	10	42	600	150	742
Sangat Optimis	12	44	742	44	650	163	445	12	44	650	163	891

Figure 11 Positive Gradual Sensitivity

Table 23 presents the results of a multilevel sensitivity analysis that considers a combination of four main variables: itinerary, vehicle load, number of electric vehicles, and number of SPKLUs (Storage Stations), on monthly on-off hours (JN) as an indicator of the power system load. In general, the increasingly optimistic scenario (from *Base Case* to *Very Optimistic*) shows a significant improvement in all technical parameters, which directly impacts the increase in on-off hours from 371 hours to 891 hours per month. This indicates a positive correlation between the scale of electrification and the power load that must be supplied by PLN.

SENSITIVITAS	RATA RATA JN	PBP	NPV	IRR	B/C Ra
Variasi Muatan	371	5,00	84.579.123	23,7%	1,04
Variasi Jumlah Kendaraan	1.392	4,40	94.580.573	27,6%	1,04
Variasi Jumlah Kendaraan & Jumlah SPKLU	359	5,01	84.359.395	23,6%	1,04
Variasi Jumlah SPKLU	273	5,1	82.784.672	23,1%	1,04
Variasi Ritase	536	4,8	87.600.394	24,8%	1,04
Variasi Ritase & Jumlah SPKLU	302	5,1	83.315.683	23,3%	1,04
Variasi Efisiensi Electric Vehicle	289	5,1	83.077.644	23,2%	1,04
Variasi Ritase & Muatan	536	4,8	87.600.394	24,8%	1,04
Variasi Jumlah Muatan, Kendaraan & SPKLU	433	4,9	85.714.389	24,1%	1,04
Variasi Jumlah Ritase, Muatan, Kendaraan, SPKLU	631	4,7	89.339.913	25,4%	1,04

Figure 12. Results of NPV, IRR, PBP, B/C Ratio Analysis for Each Sensitivity

"Variation in Number of Vehicles" scenario showed the highest financial performance, with an NPV reaching IDR 94.58 billion and an IRR of 27.6% , as well as the fastest PBP of 4.4 years . However, this scenario recorded an average of 1,392 hours of operation per month , exceeding the maximum operational limit of the electric power system, which is 720 hours (24 hours × 30 days) . This reflects a mismatch between the growth in the number of fleets and the capacity of the SPKLU infrastructure which has not increased (remains at 30 units), thus creating potential overload and operational bottlenecks. Therefore, although financially very profitable, this scenario cannot be recommended technically.

On the other hand, the "Routes Variation" , "Routes and Loads Variation" , and the integrated scenario "Routes, Loads, Vehicles, and SPKLU Number Variations" show balanced results between technical and financial aspects. The three scenarios recorded operating hours between 536 and 631 hours , still within reasonable operational limits. In addition, all three recorded an NPV above IDR 87 billion with an IRR between 24.8% and 25.4% , and a consistent B/C Ratio of 1.04 . This indicates that increasing production through increasing the route and load , accompanied by the addition of supporting infrastructure (SPKLU and PLN power capacity), is an optimal and feasible strategy from both an electricity and investment perspective.

On the other hand, scenarios that result in extreme hours of operation (e.g., above 720 hours), such as "Vehicle Number Variation" and some combinations without infrastructure escalation, cannot be considered as realistic options. This demonstrates the importance of considering the technical limits of the power distribution system when planning fleet electrification, especially in the context of high-intensity mining operations .

RESULTS AND DISCUSSION

Calculation of Net Present Value (NPV), Internal Rate of Return (IRR), Payback Period (PBP)

The feasibility assessment of a mining fleet electrification project is determined not only by technical performance but also by the results of a financial analysis that reflects the efficiency and profitability of each implementation scenario. Figure 11 presents the results of a sensitivity analysis of various key variables, including the number of loads, itineraries, vehicles, SPKLUs, and electric vehicle efficiency. The evaluation was conducted using four main parameters: Net Present Value (NPV), Internal Rate of Return (IRR), Payback Period (PBP), and Benefit-Cost Ratio (B/C). This analysis aims to identify the most economically and technically feasible scenario to support the transition of mining operational vehicles to an electric power system.

Conclusions from Financial Analysis Results

The graph in Figure 36 presents a comparison of the analysis results across ten key sensitivity scenarios, representing variations from realistic to highly optimistic. Using a quantitative, simulation-based approach, this analysis aims to provide objective justification for investment decisions in mine electrification infrastructure, particularly in the context of utilizing electricity from PLN.

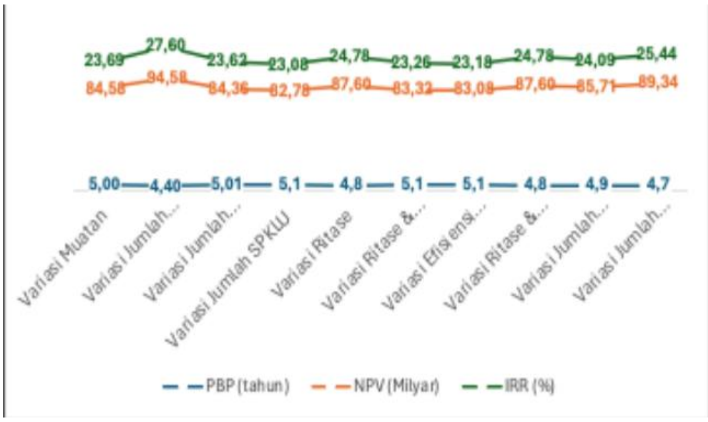

Figure 13. NPV, IRR, PBP Analysis Graph

The figure above presents a comparison of the financial performance of various sensitivity scenarios through three main indicators: NPV (in billions of rupiah), IRR (in percent), and PBP (in years). The results show that the scenario with varying vehicle numbers produces the highest NPV of Rp94.58 billion and the highest IRR of 27.6%, as well as the fastest PBP of 4.40 years. However, this scenario has an important caveat: the need for electricity on-time is very high because SPKLUs are not adjusted, remaining at only 30 units, which can lead to overutilization of the charging infrastructure, ultimately reducing operational feasibility.

On the other hand, the most balanced and feasible scenario based on the combination of feasibility indicators is:

1) Rhythm Variations
2) Trip & Load Variations
3) Variation in Number of Trips, Loads, Vehicles, SPKLU

These three scenarios show an NPV above IDR 87 billion, a competitive IRR in the range of 24.8%–25.4%, and a PBP of 4.7–4.8 years, with operating hours remaining reasonable and approaching the maximum operational limit of 720 hours per month. This demonstrates that increased production—both in terms of trip frequency and load capacity—can encourage the optimization of PLN's electricity utilization in an efficient and financially profitable manner.

Policy Implications for PLN and the Ministry of Energy and Mineral Resources (ESDM)

The results of the financial and sensitivity analyses indicate that mining fleet electrification has strong economic potential when supported by appropriate system design and infrastructure planning. For PT PLN (Persero), the identified feasible scenarios demonstrate an opportunity to increase electricity sales from the industrial sector through predictable and high-load demand profiles, particularly when electric vehicle charging operations approach optimal utilization levels. These findings suggest that PLN can strategically position mining electrification as a new anchor load, enabling better asset utilization, improved load factor, and more stable long-term revenue streams.

From the perspective of the Ministry of Energy and Mineral Resources (ESDM), the study provides empirical evidence to support the formulation of policies that encourage the transition of mining operational vehicles toward electrification. Policy instruments such as differentiated electricity tariffs for electric mining vehicles, fiscal incentives for charging infrastructure (SPKLU) deployment, and regulatory clarity on grid connection standards can significantly enhance project feasibility. Furthermore, aligning mining electrification programs with national energy transition targets—such as the reduction of diesel and B40 consumption, increased electricity demand from renewable sources, and the achievement of Net Zero Emission by 2060—will strengthen the role of the mining sector as a driver of Indonesia’s low-carbon energy transformation.

CONCLUSION

The results indicate that the project delivers strong technical and financial benefits, with an NPV of IDR 87.60 billion reflecting positive net economic value, an IRR of 24.78% exceeding the reference discount rate of 7.38% and signaling high profitability, and a Payback Period of 4.8 years that meets PLN’s medium-term investment feasibility threshold of less than five years. From a technical standpoint, operational constraints must be carefully managed, as SPKLU utilization exceeding 720 hours per month surpasses the maximum technical limit and may compromise long-term reliability and asset lifespan. These findings highlight that successful electrification cannot rely solely on favorable financial indicators but requires a collaborative business model between PLN and mining industry stakeholders to balance investment efficiency, system reliability, and operational continuity. As a concrete implementation pathway, the transition can be carried out in phases, starting with pilot-scale deployment of EV trucks and fast chargers, followed by gradual fleet expansion aligned with PLN network upgrades. Business schemes such as long-term electricity supply agreements, shared-investment models for charging infrastructure, and tariff incentives for high-utilization customers can further enhance project bankability and support sustainable mine electrification.

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