

Analyzing The Impact Of Mining Equipment Electrification On Energy Security In Indonesia's Coal Mining Sector: A Strategic And Economic Assessment

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Abstract

Heavy equipment electrification offers significant potential to reduce the coal mining sector's dependence on diesel fuel. However, its feasibility hinges on production demands, energy costs, infrastructure readiness, and technology supply chains. This study evaluates the strategic and economic impacts of heavy equipment electrification on Indonesia's coal mining energy security. Using case studies, coal hauling was modeled using the electric SANY SYZ445C-8LRBEVR against diesel counterparts under a national baseline scenario (700 Mt/year production, 30 km haulage, and 40-tonne payload). A secondary comparison evaluated overburden transport using the hybrid SANY SRT100S against the conventional Komatsu HD785-7. At a 2.5-hour cycle time, annual energy demands reach 2.10 TWh for electric hauling versus 700 million liters of diesel, yielding estimated energy costs of USD 181.6 million and USD 1.146 billion, respectively. Sensitivity remains high toward cycle time, energy prices, payload, and utilization rates. For overburden transport, the hybrid SRT100S yields over 15% fuel savings. While electrification enhances energy security via diversification, national-level viability depends on grid reliability, charging infrastructure, local maintenance capabilities, and supply chain governance. A phased,

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duty-cycle-based adoption strategy supported by standard infrastructure and Total Cost of Ownership (TCO) evaluation is recommended.

Keywords: heavy equipment electrification; coal mining; energy security; hauling; overburden; electric vehicles.

INTRODUCTION

Coal mining represents a strategic sector within Indonesia's energy system and economy. Upstream mining operations demand substantial energy for drilling, excavation, loading, overburden removal, coal hauling, dewatering, and auxiliary activities. Concurrently, diesel fuel remains a primary energy source for heavy mobile equipment. This dynamic establishes a direct interplay among mining productivity, energy costs, and energy security.

In 2026, the government revised the governance framework for the Coal Mining Work Program and Budget (RKAB), underscoring the necessity to balance production output, market demand, commodity pricing, and reserve conservation. The Ministry of Energy and Mineral Resources (ESDM) reported national coal production at approximately 790 million tonnes in 2025, alongside production adjustment policies in 2026 intended to mitigate oversupply. For analytical purposes, this study adopts a baseline production figure of 700 million tonnes per year as an investigator-defined scenario, rather than a definitive assertion of approved national RKAB targets.

Heavy equipment electrification offers a viable pathway to reduce diesel consumption. Market observations from the Mining Expo 2025 indicate that five out of seven featured Chinese original equipment manufacturers (OEMs) showcased electric haul truck solutions. Furthermore, comparative analyses between electric and diesel vehicles highlight energy expenditure as a substantial component of total operating costs.

From a scientific standpoint, displacing diesel fuel does not inherently equate to enhanced energy security. Electrification effectively shifts a portion of energy demand from liquid fossil fuels to the power grid, introducing new operational dependencies on charging infrastructure, grid capacity, battery systems, power electronics, software integration, and after-sales support networks. Consequently, the impact of electrification must be evaluated as a structural shift in energy dependency rather than a straightforward reduction in fuel consumption.



RESEARCH METHODOLOGY

This study adopts a comparative techno-economic scenario-based analysis framework. Technical specifications for the vehicles evaluated were derived from three primary documents: market material on the Indonesia Truck Market, product brochure data for the SANY SYZ445C-8LRBEVR, and technical specifications for the SANY SRT100S hybrid. Baseline comparative parameters for the Komatsu HD785-7 were extracted from official manufacturer specifications published by Komatsu. All evaluations were conducted at the scenario level and are intended to serve as modeled analytical projections rather than empirical field measurements.

A. Selection of the Primary Approach

The primary focal point selected for this study is a comparative assessment of coal hauling using the SANY EV versus conventional diesel vehicles. The methodological rationale for this primary framework rests on four key factors: coal production volumes can be explicitly linked to total transported tonnage; a transport distance of 30 km serves as an explicit operational variable; energy requirements can be directly converted into electrical (kWh) and volumetric (L) metrics; and the resulting operational metrics can be systematically scaled to formulate national-level scenarios. Concurrently, the evaluation of the SANY SRT100S hybrid against the Komatsu HD785-7 is incorporated as a secondary case study to assess the techno-economic impacts of partial electrification within overburden handling operations.

B. National Scenario Assumptions

Table 1. Operational Parameters and Baseline Analytical Assumptions

Parameter	Value	Status / Rationale
Annual coal production (2026)	700 million tonnes/year	Research assumption
Stripping ratio	7 bcm/tonne of coal	Research assumption



Parameter	Value	Status / Rationale
Annual overburden volume	4.9 billion bcm/year	Calculated value
Overburden density for conversion	1.8 tonnes/bcm	Sensitivity assumption
Mass-equivalent overburden	8.82 billion tonnes/year	Calculated value
Coal hauling distance	30 km (one-way)	Research assumption
Normalized payload (EV vs. Diesel)	40 tonnes/trip	Conservative assumption
Hauling cycle time	2.0–3.0 hours	Sensitivity scenario
Operating calendar	365 days/year	Annualized baseline; non-operating days excluded

C. Energy Parameters for Coal Hauling

The SANY market presentation provides baseline energy consumption metrics comparing heavy-duty electric vehicles (EVs) and conventional diesel units. The model incorporates consumption rates of 48.1 \$kWh\$/hour for the EV variant and 16 \$L\$/hour for the diesel equivalent, yielding calculated hourly energy expenditures of USD 4.15/hour and USD 26.20/hour, respectively, based on source-defined fuel and electricity tariffs. Because these metrics are derived from vendor disclosures rather than direct empirical field measurements, all downstream analytical outcomes are framed as scenario-based estimates.





Figure 1. Performance and Energy Cost Comparison Between SANY EV and Conventional Diesel Vehicles



Figure 2. SANY SYZ445C-8LRBEVR Electric Dump Truck: Capacity and Key Features





Figure 3. Technical Specifications of the SANY SYZ445C-8LRBEVR

RESULTS AND DISCUSSION

A. Scale of Overburden Removal Requirements

Based on an annual coal production target of 700 million tonnes and a stripping ratio of 7 bcm/tonne, the total overburden volume to be moved is calculated at 4.9 billion bcm/year. Assuming a normalized loose/average overburden density of 1.8 tonnes/bcm, the equivalent mass movement reaches approximately 8.82 billion tonnes/year. This figure serves exclusively to demonstrate the macro-scale magnitude of material handling involved; site-specific density parameters must be substituted when applying this model to individual mining operations.

At a rated payload capacity of 91 tonnes per trip, the theoretical haulage demand equals approximately 96.9 million trips/year, whereas a higher payload capacity of 95 tonnes per trip yields approximately 92.8 million trips/year. This payload disparity illustrates that increasing vehicle capacity offers only a partial solution to operational productivity. Factors such as cycle time, mechanical availability, operational utilization, haul road conditions, loader-truck fleet matching, and queueing delays can substantially alter fleet size requirements in actual field conditions.

B. Case Study: SRT100S Hybrid versus Komatsu HD785-7

The attached product documentation for the SRT100S specifies a payload capacity of 95 tonnes, a gross vehicle weight (GVW) of 168 tonnes, a three-motor direct-drive system, a dual-engine range extender, and a regenerative electric braking system. According to the document, this setup yields reductions exceeding 15% in both maintenance expenses and fuel consumption compared to conventional mechanical-drive mining trucks.

For baseline comparison, official manufacturer specifications for the Komatsu HD785-7 list a rated payload capacity of 91 tonnes and an engine output of 1,200 HP.

- The SANY SRT100S is a 95-tonne payload hybrid mining truck designed for efficiency, durability, and high performance.
- It features a gearbox-free, three-motor direct drive system that reduces maintenance costs and fuel consumption by over 15% compared to conventional trucks.
- Engineered for extreme environments, the vehicle combines dual-engine range extenders with a high-capacity CATL battery to ensure consistent power.
- With a gross vehicle weight of 168 tonnes and advanced electric braking, the SRT100S offers a reliable, sustainable solution for modern mining operations.
- The SRT100S hybrid mining truck features a robust V-shaped steel body, a redundant hydraulic lifting system, and a certified FOPS/ROPS cabin designed for safety and comfort.

Figure 4. SANY SRT100S hybrid mining truck, payload 95 ton, dual-engine range extender dan regenerative electric braking.

- Its suspension system uses variable damping oil/gas cylinders for stability, while its braking system combines high-capacity wet discs with regenerative electric braking for reliability on steep descents.
- Powered by a dual-engine range extender and three-motor direct drive, the truck eliminates the need for a gearbox, significantly reducing maintenance costs while improving fuel efficiency by over 15% through energy recovery and optimal power coupling.

Figure 5. Detail sistem SRT100S: direct drive tiga motor dan energy recovery

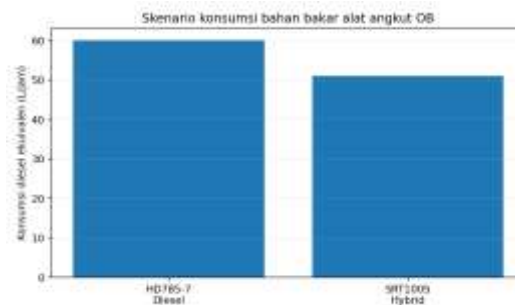


Figure 6. Diesel Consumption Scenarios

Assuming a conservative baseline diesel consumption rate of 60 L/hour for conventional units and a 15% efficiency gain for the hybrid variant, the equivalent fuel consumption for the SRT100S is estimated at 51 L/hour, yielding a net savings of 9 L/hour per unit. At an annual operational utilization of 5,000 hours/year, a single hybrid truck has the potential to displace approximately 45,000 liters of diesel annually. As an illustrative scenario applied across a fleet of 100 units, the cumulative reduction reaches approximately 4.5 million liters per year. These figures represent sensitivity scenario modeling to demonstrate order-of-magnitude impacts rather than a definitive national fleet projection.

C. Energy Security: Benefits and Risks

Table 2. Strategic Evaluation of Heavy Equipment Electrification Across Energy Security Dimensions

Dimension	Positive Impact of Electrification	Emerging Strategic Risks
Availability	Fuel diversification away from diesel toward electricity	Operational dependency on electricity grid supply and charging infrastructure
Affordability	Potential reduction in unit operational energy costs	Exposure to electricity tariffs, power demand charges, and substantial charging infrastructure CAPEX
Reliability	Integration of regenerative braking and fewer moving mechanical components in EV/hybrid architectures	Risk of operational downtime caused by charging bottlenecks, battery management system (BMS) faults, or power grid outages
Adaptability	Strategic flexibility to select pure EV, hybrid, or REEV configurations to match specific duty cycles	Susceptibility to vendor lock-in and required workforce upskilling for specialized technical competencies
Supply Chain	Opportunities to develop local charging infrastructure, assembly, and specialized maintenance industries	Import dependence for lithium-ion battery cells, power electronics, proprietary software, and OEM spare parts

Dimension	Positive Impact of Electrification	Emerging Strategic Risks
Environmental Resilience	Substantial reduction in direct point-source diesel combustion emissions at the mine site	Net lifecycle emission benefits remain contingent on the grid generation mix and battery supply chain sustainability

CONCLUSION

Under a production scenario of 700 million tonnes per year, a normalized payload of 40 tonnes, a 30 km one-way haulage distance, and a 2.5-hour cycle time, the model calculates approximately 17.5 million loaded trips annually. Based on source-case energy consumption parameters, the electric vehicle (EV) fleet requires an estimated 2.10 TWh per year, whereas equivalent diesel operations consume roughly 700 million liters of diesel annually. Applying source-case energy tariffs, annual energy costs are estimated at USD 181.6 million for EVs compared to USD 1.146 billion for diesel units. While these metrics indicate substantial economic potential, rigorous empirical validation against site-specific field data is required prior to informing capital investment decisions.

In overburden management, the SRT100S hybrid offers a 95-tonne payload capacity compared to 91 tonnes for the Komatsu HD785-7, with OEM product documentation citing fuel consumption reductions exceeding 15%. Assuming a conservative baseline consumption rate of 60 L/hour, a 15% efficiency gain corresponds to savings of 9 L/hour per unit. This secondary case demonstrates that hybridization presents a viable transitional pathway where full battery-electric deployment remains constrained by rigorous operational duty cycles.

Strategically, the electrification of heavy equipment can bolster mining energy security provided it mitigates petroleum dependence without introducing more critical operational vulnerabilities. Consequently, policy efficacy and operational viability must be evaluated across five core indicators: reduced petroleum exposure, energy affordability, grid supply reliability, technological adaptability, and supply-chain resilience.



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