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National energy governance in the implementation of energy intensity, carbon emissions, and general energy fuel

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Abstract

This study aims to provide an understanding of national energy governance in the implementation of energy intensity, carbon emissions, and general energy fuel (coal and oil and gas minerals) in Indonesia. This study analyzes national energy governance in the implementation of energy intensity, carbon emissions, and general energy fuel (coal and oil and gas minerals).

The study was conducted using a qualitative descriptive research approach, focusing on transportation modes, in this case, as they generate carbon emissions during movement.

The study results indicate that the implementation of carbon emissions generated by transportation modes has a reciprocal impact on national energy governance in the implementation of energy intensity, carbon emissions, and general energy fuel (coal and oil and gas minerals) in Indonesia. Estimated CO2 emissions from transportation modes. Estimated CO2 emissions for a trip from Yogyakarta to Jakarta: by train, 7.43 kg CO2 is produced, by car, 27.12 kg CO2 is produced, and by airplane, 65.17 kg CO2 is produced. These carbon emissions results indicate that the lowest is the train mode. Transportation carbon emissions originate from general energy fuel sources (coal and oil and gas), specifically from the combustion of fuels (gasoline, diesel, aviation fuel). The relative energy intensity of cars compared to trains is about ≈ 3.6 times and the relative energy intensity of airplanes compared to trains is about ≈7.9 times. The relative carbon emission of cars compared to trains is about ≈ 3.6 × and the relative carbon emission of airplanes compared to trains is about ≈ 8.7 ×

These fuel sources are still entirely dependent on the oil and gas sector. Every increase in mobility means an increase in demand for petroleum. This demonstrates the need for energy governance policies that integrate the transportation and upstream mining sectors. The implementation of transportation modes in producing carbon emissions is inseparable from the use of energy intensity. The dynamics of energy intensity are directly proportional to the type of fuel and the efficiency of the engine system.

Keywords: National energy governance, energy intensity, carbon emissions, transportation modes, upstream energy sector

INTRODUCTION

National energy governance is crucial to analyze, linked to its upstream management, namely the general mining sector (minerals, coal, and oil and gas), which is the foundation of national energy. Dependence on fossil fuels results in a high carbon emission burden. Energy governance in the upstream sector needs to be directed to support energy efficiency in the downstream sector, one of which is transportation. Optimizing the energy supply chain, from exploration, production, to distribution, will reduce national energy intensity, ultimately resulting in lower carbon emissions. This study is based on a qualitative descriptive study with transportation as the object. Transportation is chosen because it is an activity that is always carried out by individuals. The results of the study will show the relationship between national energy governance and energy intensity, carbon emissions, and energy fuel (minerals, coal, oil, and gas). Daily transportation modes produce carbon emissions. In this case, PT Kereta Api Indonesia (Persero) has effectively calculated its carbon footprint for each train journey. This carbon footprint calculation is one of the company's sustainability performance targets (PT Kereta Api Indonesia (Persero), 2024).

Each mode of transportation produces different carbon emissions. For the same distance, if the type of fuel used is different, the engine is different, and the number of passengers is different, the carbon emissions produced will be different. The estimated CO2 emissions produced by train, car, and plane transportation modes are certainly very different. A trip from Yogyakarta to Jakarta, if using train services, will produce carbon emissions of 7.43 kg of CO2, if using a car will produce carbon emissions of 27.12 kg of CO2, and if using a plane will produce carbon emissions of 65.17 kg of CO2. This means that for one passenger who takes the train from Yogya to Jakarta, the journey is estimated to release 7.43 kilograms of CO2 gas. If using a car traveling alone with a private car from Yogyakarta to Jakarta, the vehicle will burn fuel equivalent to releasing 27.12 kilograms of CO2. Meanwhile, if using airplane mode, then one passenger seat on the plane for the Yogyakarta to Jakarta route produces 65.17 kilograms of CO2.

Of the three modes of transportation, trains can be said to have the lowest carbon emissions. The advantages of trains, including their larger passenger capacity and lower greenhouse gas emissions compared to other modes of transportation, make them a suitable choice for people who need public transportation while also supporting a healthy environment (PT Kereta Api Indonesia (Persero), 2024).

Considering the importance of understanding the implementation of national energy governance, carbon emissions, energy intensity, and general upstream mining (coal and oil and gas minerals) in everyday life, this paper is an exploratory paper. Based on the description above, the objectives of this study are: 1) Analyze national energy governance, 2) Identify components that play a greater role in changes in energy intensity in terms of transportation modes in Indonesia, 3) Analyze the implementation of carbon emissions in terms of transportation modes in Indonesia. 4) general upstream mining (coal and oil and gas minerals) that produce energy raw materials. The scope of this study is the Indonesian region with the object of transportation modes. The energy covered in this study includes all forms of final energy implemented in transportation modes. The findings of this study are expected to be the basis for governance analysis which is expected to be the basis for state policy in mitigating the risk of inefficiency, while contributing to the achievement of national energy targets. National energy targets are stated in the National Energy General Plan (RUEN).

LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

In response to global challenges, the Indonesian government established the 2024-2050 National Energy General Plan (RUEN) with a target of reducing energy intensity by 1% per year until 2030. Reducing energy intensity at the micro or company level can contribute to reducing energy intensity at the macro or national level (Suryaningsum et al., 2025). In this case, the general mining sector (coal and oil and gas minerals) was designated as a top priority due to its significant contribution to national energy consumption and its operational complexity. Data from the Handbook of Energy & Economic Statistics by the Ministry of Energy and Mineral Resources (ESDM) (2023) revealed that the energy intensity of this sector reached 0.28 BOE/million Rupiah, which in this case is 20% higher than the global standard (World Bank, 2022). This data confirms that structural transformation to reduce energy intensity in general mining companies is crucial to achieving the RUEN target.

A previous study by Kartiasih, F., Hartono, D., & Resosudarmo (2012) proved that 77% of the increase in national energy intensity stems from changes in economic activity without technical innovation. Final (secondary) energy is a form of transformation of primary energy that can be used after going through several processes, for example processes in oil refineries, LPG refineries, power plants, and city gas. Final energy can be directly used by economic actors, such as the industrial, transportation, household, commercial or service sectors, and other sectors. Final energy can be in the form of electrical energy, processed fuels (kerosene, diesel, premium, etc.), LPG, and other forms of processed energy (Yusgiantoro, 2000). Based on their availability, energy sources are divided into two, namely non-renewable fossil energy, such as petroleum, natural gas, coal, uranium, and so on; and renewable energy, such as geothermal, hydropower, solar power, wind power, and so on.

Furthermore, Pratiwi (2022), who analyzed the determinants of national energy intensity for the 2000-2020 period, revealed the complexity of macroeconomic factors such as FDI and energy prices. However, these studies have not yet addressed the governance aspects of energy intensity implementation at the corporate level, nor have they integrated lessons learned from other sectors such as office buildings (Suswitaningrum et al., 2022) and education (Faniama et al., 2024), which have successfully implemented energy audits and conservation. Energy intensity research that addresses the governance aspects of energy intensity implementation at the corporate level, particularly strategic decision-making mechanisms, budget allocation, and ESG (Environmental, Social, Governance) policy integration has been conducted by Suryaningsum et al., 2025. Suryaningsum et al. (2025), stated that in the ADRO corporation, there was an extreme fluctuation in ADRO's energy intensity (2019-2023) marked by a surge of 54% (2020) and 202% (2023) during expansion without technological innovation, as well as a decline of 61% (2021) and 60% (2022) post-infrastructure investment with consistent performance above the average of the Indonesian mining sector (0.28 BOE/million IDR).

This pattern reflects a critical reliance on aging infrastructure (more than 15 years old) and the lack of integration of long-term energy efficiency strategies, necessitating a sustained commitment to technical innovation and dedicated budget allocations in line with the 2024-2050 RUEN targets and ESG principles. Conceptually, the more efficient a sector's energy intensity, the lower its carbon emissions. However, without integrated and transparent governance, efficiency policies do not automatically result in significant emission reductions. A drastic improvement was seen in 2021-2022, with energy intensity dropping by 61% (2021) and 60% (2022) to reach a five-year low of 0.0013696 GJ/US$. This achievement, which coincided with a significant increase in revenue (US$3.993 billion in 2021 and US$8.102 billion in 2022), reinforces the findings (IESR, 2023b) regarding the effectiveness of equipment upgrades in reducing grid losses. However, its temporary nature as expressed (Hamdan et al., 2024) regarding the vulnerability of the reactive system, was proven when energy intensity jumped again by 202% to 0.0041319 GJ/US$ in 2023 even though income remained high (US$6.518 billion).

This performance regression is due to production expansion without technological innovation (ADRO, 2023) and reliance on aging infrastructure that affects 34% of Indonesian mining facilities (IESR, 2023b). The decline in energy intensity after infrastructure investment is in line with empirical evidence from the building sector. (Suswitaningrum et al., 2022) proves that replacing standard air conditioners with inverter air conditioners in office buildings can result in 30.6% energy savings with a payback period of 3.8 years, while replacing fluorescent lamps with LEDs saves 16.28% with a payback period of 4.4 years. A similar pattern is seen at PT Alamtri where technical investments in 2021-2022 succeeded in reducing energy intensity by 61-60%, confirming the effectiveness of equipment modernization. These findings underscore the urgency of an energy efficiency stabilization strategy at PT Adaro Alamtri according to the results of a study conducted by Suryaningsum et al. (2025). Regarding energy efficiency through the use of the latest technology, GRI Standard 302 (Global Reporting Initiative, 2021) makes a similar point. However, its implementation is hampered by a lack of alignment in national policies. The fact that only 30% of ASEAN mining companies consistently comply with the GRI 302 reporting standard is compounded by national grid losses that are 2.3 times higher than those in Malaysia (PLN, 2023).

A fundamental solution requires a three-pronged approach, encompassing infrastructure modernization through fiscal incentives for energy-efficient technologies and the integration of ESG into corporate governance. Without these systemic interventions, the 1% annual energy intensity reduction target set in the 2024-2050 National Energy and Mineral Resources Development Plan (RUEN) is at high risk of failing to achieve. Integration of technological innovation at every phase of production expansion, in line with recommendations (Wang & Wang, 2020), emphasizes the potential for a 15% energy intensity reduction through the adoption of high-standard machinery.

Data (World Bank, 2022) confirms that the energy intensity of the Indonesian mining sector (0.28 BOE/million IDR) remains 20% higher than the international average, with transmission losses reaching 8.2% (PLN, 2023). The root of the problem lies in the triad of inefficiency according to (Wang & Wang, 2020) reliance on aging infrastructure (more than 15 years old), a 40% higher cost disparity in diesel energy in remote areas, and commodity price volatility that erodes long-term investment capacity (Ministry of Energy and Mineral Resources (ESDM), 2023). These extreme fluctuations—where the company's energy intensity value was 20 times higher than the sector's minimum value in 2019—confirm the findings about the systemic inefficiency of the Indonesian mining sector. In terms of energy efficiency research, a comprehensive energy audit with techno-economic analysis as applied (Faniama et al, 2024) is needed.

Furthermore, the resulting policy recommendations, such as the integration of energy-efficient technologies and collaboration between the government and the private sector, can be adopted by policymakers in other countries to accelerate the achievement of Sustainable Development Goal (SDG) 7 on clean and affordable energy. Thus, this research contributes to the global discussion on a just and sustainable energy transition. RUEN has set a final energy efficiency target of 17% by 2025. However, a report by the Ministry of Energy and Mineral Resources (ESDM) (2023) shows that the decline in energy intensity has only reached 0.8% per year. The main causes are the dominance of fuel-based transportation and the low penetration of low-carbon mass transportation. Indonesia has a target of reducing energy intensity by 1% per year and has set a final energy efficiency target of 17% by 2025, this is in accordance with RUEN.

However, a 2023 report from the Ministry of Energy and Mineral Resources (ESDM) indicates that the decline in energy intensity has only reached 0.8% per year. The primary reasons for this 0.8% decline are the dominance of fuel-based transportation and the low penetration of low-carbon mass transportation.

The concept of energy intensity describes the amount of energy used to produce one unit of economic activity or mileage (MJ/pkm). The lower the energy intensity, the more efficient a transportation system is. According to data from the International Energy Agency (2021), rail has an energy efficiency of around 2.3 MJ/pkm, private cars around 3.9 MJ/pkm, and airplanes reach 8.7 MJ/pkm. Meanwhile, the upstream mining sector plays a crucial role in providing primary energy. Crude oil is processed into fuel and aviation fuel, while coal serves as an indirect energy source for electric trains. The close relationship between transportation and the upstream sector suggests that transportation efficiency can reduce pressure on fossil fuel exploitation.

This research contributes novelty by focusing its analysis on the governance aspects of energy intensity and carbon emissions implementation at the transportation mode level within the context of the general mining sector as an energy producer, which is still rarely researched in Indonesia. Previous studies such as (Wang & Wang, 2020) and (IESR, 2023a) have focused more on technical and macroeconomic factors, without addressing strategic decision-making mechanisms, budget allocation, and ESG policy integration within an energy governance framework. Recent research by (Hamdan et al., 2024) on real-time energy monitoring systems has also not linked them to corporate-level governance dynamics. Thus, this research fills a gap in the literature by linking micro-level corporate practices with macro-level regulatory pressures, and offers a holistic perspective on how energy governance can influence energy intensity performance in the context of the global energy transition.

This research starts from the assumption that national energy governance policy has a reciprocal conceptual influence on four main things that are highly correlated, namely energy intensity, carbon emissions, and general upstream mining (coal and oil and gas minerals) in Indonesia.

This study is based on the assumption that the National Energy General Plan (RUEN) policy has a conceptual influence on energy efficiency and carbon emission reduction efforts in Indonesia, particularly through regulating energy intensity in the transportation sector. This study uses a descriptive qualitative approach with policy analysis and secondary data sourced from reports from the Ministry of Energy and Mineral Resources, Statistics Indonesia (BPS), and related academic studies. The analysis results show that although the RUEN has emphasized energy transition and a target of reducing energy intensity by 1% per year, its implementation in the transportation sector still faces obstacles in cross-policy integration, green infrastructure financing, and the transition from fossil fuel-based transportation modes to low-carbon energy. This study recommends strengthening inter-agency coordination, green fiscal policy innovation, and more transparent monitoring of energy intensity in major transportation modes such as railways, land vehicles, and aviation.

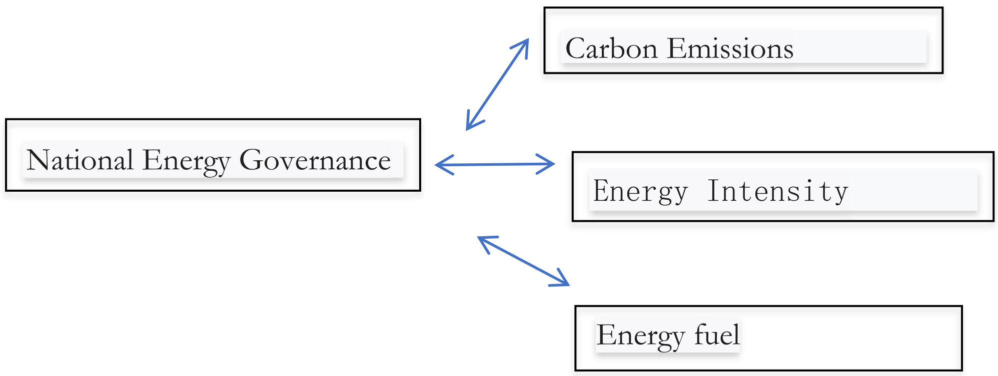

Figure 1. Conceptual Framework

RESEARCH METHOD

This study uses a descriptive qualitative approach with in-depth policy analysis. This study uses a literature review to explain national energy governance regarding energy intensity, carbon emissions, and fuel use. This research method is designed to answer the initial assumption related to the national energy policy has a reciprocal conceptual influence on three main things, namely national energy governance, energy intensity efficiency efforts, carbon emissions, and fuel use of transportation modes in Indonesia. The objects of observation are three types of transportation modes: trains, cars, and airplanes with a travel distance of Yogyakarta to Jakarta.

The discussion is conducted by analyzing the comparative use of energy intensity, carbon emissions, fuel used for trains, cars, and airplanes. Energy intensity is analyzed in depth regarding how much energy is used and how much rupiah value of costs is attached to the energy intensity of trains, cars, and airplanes with the travel distance from Yogyakarta to Jakarta. Carbon emissions are analyzed in depth regarding the impact of the amount of carbon dioxide released during the trip from Yogyakarta to Jakarta on trains, cars, and airplanes. Fuel is analyzed in depth regarding the rupiah value of costs attached to the energy intensity of trains, cars, and airplanes with the travel distance from Yogyakarta to Jakarta. National energy governance is analyzed in depth regarding how national policies cover energy intensity, carbon emissions, and fuel related to trains, cars, and airplanes.

The operational definition of energy intensity is the use of energy in an activity, used to measure its energy efficiency. It is usually calculated as the ratio of the amount of energy consumed to the economic output or unit of activity. In this study, energy intensity relates to energy use during the travel time from Yogyakarta to Jakarta. Each mode of transportation, train, car, and plane, uses/consumes energy. This study conducts an in-depth analysis of the impact of energy intensity. The operational definition of carbon emissions is the release of greenhouse gases, primarily carbon dioxide (CO2), into the Earth's atmosphere from train, car, and plane transportation activities between Yogyakarta and Jakarta. These carbon emissions will cause an increase in global temperature and global climate change because these gases trap solar heat. The operational definition of fuel is the energy source that powers the internal combustion engines of various modes of transportation, trains, cars, and planes, between Yogyakarta and Jakarta.

The carbon emissions research data is secondary data obtained from official sources, including Indonesian Railways (KAI), covering approximately 512 km of the Yogyakarta-Jakarta route, as planned for Taksaka 2025. Energy intensity was calculated from this carbon emissions data. The calculation uses a conversion: CO_2 → fuel → energy using common factors (IEA, IPCC), in this case gasoline/diesel: 2.31 kg CO_2 per liter and jet fuel: 2.53 kg CO_2 per liter. Energy per liter: ≈ 34.8 MJ (gasoline/diesel) and 34.4 MJ (jet fuel). Taksaka trains use diesel, cars use gasoline, and airplanes use jet fuel.

Energy data comes from secondary sources, including reports from the Ministry of Energy and Mineral Resources, Statistics Indonesia (BPS), and previous related academic studies. This carbon emissions, energy intensity, and fuel data will be analyzed in depth in light of national energy policy.

RESULTS AND DISCUSSION

Carbon Emissions, Energy Intensity, and Fuel (Coal & Gas) for Transportation Modes

Carbon emissions from official sources, including Indonesian Railways, for the approximately 512 km route from Yogyakarta to Jakarta (the Taksaka route in 2025), are estimated to produce 7.43 kg CO_2 for the 512 km journey by train, 27 kg CO_2 for cars, and 65.17 kg CO_2 for airplanes. This data is important because it is standardized per passenger for the Yogyakarta-Jakarta route (approximately 512 km). Table 1 shows the calculations used to determine the estimated energy intensity for the Taksaka train, car, and airplane modes.

Table 1. Energy Intensity Calculation for Taksaka Train, Car, and Airplane Mode of transport, Energy intensity, Carbon emissions, Fuel

Estimate/Mode of Transportation	Train	Car	Plane
CO_2 (kg/pax)	7.43	27.00	65.17
Conversion: CO_2 → fuel	Gasoline/diesel: 2.31 kg CO_2 per liter.	Gasoline/diesel: 2.31 kg CO_2 per liter.	Jet fuel: 2.53 kg CO_2 per liter.
Conversion: fuel→ energi	7.43 kg CO_2 ÷ 2.31 = 3.22 L	27 ÷ 2.31 = 11.7 L bensin ekv	65.17 ÷ 2,53 = 25.76 L jet fuel
Energy per liter depending on fuel	≈ 34.8 MJ (gasoline/diesel)	≈ 34.8 MJ (gasoline/diesel)	≈ 34.4 MJ (jet fuel).
Energy / passengers	3.22 × 34.8 = 112 MJ	11.7 × 34.8 = 407 MJ	25.76 × 34.4 = 887 MJ
Energy intensity per km, with a distance of 512	112 MJ ÷ 512 km = 0.22 MJ/pkm	407MJ÷ 512 km = 0.80 MJ/pkm	887MJ ÷ 512 km= 1.73 MJ/pkm
Intensity (MJ/pkm)	0.219 MJ/pkm	0.795 MJ/pkm	1.732 MJ/pkm

Note that this Energy Intensity calculation has limitations in using CO_2 to L conversion factors, with an average estimate of 2.31 and 2.53. These figures are general standards, but they can vary depending on fuel quality and calculation methods. This calculation assumes that all emissions listed on official KAI tickets are converted directly to the amount of fuel burned (a simple conversion). In reality, trains can run on electricity or diesel; for electric trains, the CO_2 footprint depends on the power plant. KAI may have incorporated these assumptions—so this conversion method is approximate. This calculation does not include non-CO_2 emissions, even though aircraft emissions (NOx, condensation effects) have an impact on the climate. This calculation uses rounded numbers.

Based on secondary data listed on the Taksaka ticket, KAI 2025 Yogyakarta–Jakarta route, it is known that carbon emissions per passenger for the three modes of transportation show very significant differences: the Taksaka train produces 7.43 kg CO_2, cars 27 kg CO_2, and airplanes 65.17 kg CO_2. To obtain energy intensity, CO_2 emissions are first converted into equivalent fuel volume using standard emission factors (2.31 kg CO_2/L for gasoline–diesel and 2.53 kg CO_2/L for aviation fuel), then multiplied by the energy value per liter of fuel. The conversion results show that train travel is equivalent to energy consumption of 111.93 MJ per passenger, cars 406.75 MJ, and airplanes 886.08 MJ. After dividing by the route distance of 512 km, the energy intensity obtained is 0.219 MJ/pkm for trains, 0.795 MJ/pkm for cars, and 1.732 MJ/pkm for planes.

These results demonstrate a pattern consistent with international literature on the energy efficiency of transportation modes: rail has the lowest energy intensity, followed by cars, while airplanes are the most energy-intensive mode. Quantitatively, cars require approximately 3.6 times more energy than trains, while airplanes require nearly 8 times more energy per passenger per kilometer than trains. This comparison confirms that transportation mode choice has significant environmental implications, particularly regarding energy consumption and carbon footprint. In the context of transportation and sustainability policy analysis, these findings strengthen the argument that increasing passenger load capacity, expanding the use of long-distance trains, and reducing reliance on high-energy-intensity modes are important strategies for reducing energy consumption in the transportation sector.

The analysis shows that rail transportation has the most efficient energy intensity and the lowest carbon emissions, as shown in the table below.

Table 2. Transport Mode, Energy Intensity, Carbon Emissions, Fuel

Estimation	Train	Car	Plane
Energy Intensity	0.219 MJ/pkm	0.795 MJ/pkm	1.732 MJ/pkm
Carbon Emissions Ygy - Jkt	7.43 kg CO_2	27.12 kg CO_2	65.17 kg CO2
Fuel Energy	Solar	petroleum	avtur
Relative Energy Intensity of the train	1x	≈ 3.6 ×	≈ 7.9 ×
Relative Carbon Emissions of the train	1x	≈ 3.6 ×	≈ 8.7 ×

Processed data (2025)

The results of energy estimation between transportation modes have different results. The relative energy intensity of cars compared to trains is about ≈3.6 times and the relative energy intensity of airplanes compared to trains is about ≈7.9 times. The relative carbon emission of cars compared to trains is about ≈ 3.6 × and the relative carbon emission of airplanes compared to trains is about ≈ 8.7 ×. The estimated energy intensity of trains (around 0,219 MJ/pkm) is much lower than private cars (0,795 MJ/pkm) and domestic planes (1,732 MJ/pkm). Observations on transportation modes show that trains, cars, and planes when traveling the Yogyakarta to Jakarta route and vice versa will produce different carbon emissions. This study refers to (PT Kereta Api Indonesia (Persero), 2024) stating that the main source of emissions for the Taksaka long-distance train comes from the use of Bio Solar

B35, which is a mixture of diesel from petroleum and biofuels (B35) such as palm oil, as fuel for its locomotives. This is a smart choice, because it is more environmentally friendly and efficient for long-distance travel than using pure fossil fuels. Fuel Type: Bio Solar B35, which is a mixture of diesel and biofuels. The mixture components are 65% diesel and 35% biofuel (FAME). The purpose of choosing this fuel is because it is efficient for long distances and as part of the government's program to reduce carbon emissions and reduce dependence on fossil fuels. In addition, its advantages are environmentally friendly with lower exhaust emissions, while maintaining the power and operational efficiency of the locomotive. Regarding future developments, PT KAI is also testing the use of Bio Solar B40 for future use, which is expected to be even better. In other types of high-speed trains, the Whoosh train fuel is electricity, not oil or diesel fuel like conventional trains. This train uses electricity that flows through cables above the rails to drive its engine. Main power: Electricity is the main power source that drives all operations of the Whoosh high-speed train.

Energy source: The electricity is transmitted from cables above the tracks connected to a pantograph (connecting device) on the roof of the train. Advantages: The use of electricity makes Whoosh more energy efficient and produces lower emissions, unlike trains that use fossil fuels. What about cars? Cars use a variety of fuels, including gasoline, diesel, and electric batteries. Why are their carbon emissions higher? Car engines burn gasoline/diesel directly. If a car carries four people, the carbon footprint per person will decrease (divided by four), but it is still usually higher than that of a train. Airplanes produce carbon emissions of 65.17 kg of CO2. This means that airplanes burn a very large amount of aviation fuel (avtur) during takeoff, flight, and landing. Emissions released directly into the atmosphere also have a stronger global warming effect. Environmental Impact: CO2 is one of the main greenhouse gases (GHGs) that cause climate change and global warming. The higher the emission rate, the greater its contribution to environmental problems, such as extreme weather, rising global temperatures, and melting polar ice. This data can be a consideration when choosing transportation. If you want to reduce environmental impact, trains are the best option for medium-distance routes like Yogyakarta-Jakarta. So, in essence, these figures represent an "environmental cost" that we don't pay with money, but rather with the health of our planet.

The analysis shows that although the National Energy and Mineral Resources Regulation (RUEN) emphasizes the energy transition and targets a 1% annual reduction in energy intensity, the RUEN sets a final energy efficiency target of 17% by 2025. However, the Ministry of Energy and Mineral Resources (ESDM) report (2023) shows that energy intensity reduction has only reached 0.8% per year. The main reasons for achieving only 0.8% reduction in energy intensity are the dominance of fuel-based transportation and the low penetration of low-carbon mass transportation. The significant spike of 54% in 2020 and 202% in 2023 strongly supports the finding that production expansion without technological innovation increases energy costs by up to 12%, a phenomenon consistent with a study (Wang & Wang, 2020) of 284 global mining companies. This pattern is clearly visible when in 2019, the company's energy intensity was recorded at 0.0056456 GJ/US$, still above the mining sector average (0.0027713 GJ/US$) then jumped 54% to 0.0087009 GJ/US$ (2020) along with a decrease in revenue to US$2.535 billion. This confirms the findings (Kartiasih, F., Hartono, D., & Resosudarmo, 2012) that a decline in production output without reducing energy consumption is an indicator of acute inefficiency. Challenges/obstacles facing national energy governance include the implementation of the National Energy Economic Plan (RUEN) in the transportation sector, including the need for more fiscal incentives for low-carbon energy, greater coordination between institutions, and more clean energy support infrastructure.

The research results show that the energy intensity of transportation in Indonesia remains dependent on fossil fuels sourced from the upstream mineral and coal and oil and gas sectors. The Taksaka rail mode of transportation has been shown to have the highest energy efficiency and lowest carbon emissions compared to private cars and airplanes on the

Yogyakarta-Jakarta route. This demonstrates the significant potential of rail transportation as the backbone of the national energy transition, especially when supported by grid electrification and a green energy mix.

The Relationship between National Energy Governance and Energy Intensity

National energy governance is the system of arrangements, policies, regulations, institutions, and coordination mechanisms that govern how energy is produced, distributed, consumed, and conserved at the national level. Energy intensity, on the other hand, is a measure of the efficiency of energy use in generating economic output (usually expressed as the amount of energy used per unit of GDP—for example, joules per rupiah or per dollar of GDP). The lower the energy intensity, the more efficient a country is in using energy to generate economic value.

a. The relationship between the two can be explained as a two-way cause-and-effect relationship.

Energy Governance significantly influences Energy Intensity. Good national energy governance will:

1) Promote energy efficiency through energy conservation policies, incentives for energy-saving technologies, and the implementation of efficiency standards in the industrial, transportation, and household sectors.
2) Develop renewable energy to increase energy source diversification and reduce dependence on fossil fuels.
3) Improve energy demand management (demand-side management) to make energy consumption more economical and efficient.
4) Restructure energy institutions and oversight to increase transparency and accountability.

a. As a result, national energy intensity decreased, indicating increased energy efficiency. Energy intensity has a reciprocal relationship with energy governance. Conversely, the level of national energy intensity can also be an indicator of the success of energy governance. If energy intensity remains high, it means energy governance is not yet optimal. If energy intensity decreases, this indicates that governance strategies are working well, energy-efficient investment is increasing, and economic sectors are becoming more energy-efficient.

b. Example in Indonesia

In the Indonesian context, this relationship is reflected in:

1) The National Energy General Plan (RUEN) and the Regional Energy Plan (RUED), which set a target of reducing energy intensity by ±1% per year.
2) Energy conservation policies in the industrial, building, and transportation sectors.
3) Increasing the share of new and renewable energy (EBT) to 23% by 2025.
4) These policies represent the implementation of national energy governance aimed at reducing national energy intensity and creating a sustainable energy system.

Conceptually, the more efficient a sector's energy intensity, the lower its carbon emissions. However, without integrated and transparent governance, efficiency policies do not automatically result in significant emission reductions. The National Energy and Mineral Resources Development Agency (RUEN) has set a final energy efficiency target of 17% by 2025. However, the 2023 ESDM report shows that energy intensity reduction has only reached 0.8% per year. The main causes are the dominance of fuel-based transportation and the low penetration of low-carbon mass transportation. In terms of Transportation Energy Intensity: Trains vs. Cars vs. Airplanes, analysis shows that rail transportation has the most efficient energy intensity (around 0.5–0.8 MJ/pkm), significantly lower than private cars (2.0–2.5 MJ/pkm) and domestic aircraft (2.7–3.0 MJ/pkm). This underscores the relevance of the modal shift policy initiated by RUEN. The main obstacles to implementing RUEN in the transportation sector include limited fiscal incentives for low-carbon energy, unsynchronized coordination between institutions, and a lack of supporting infrastructure for clean energy. It can be concluded that good national energy governance will reduce energy intensity through efficiency, conservation, and clean energy development. Conversely, trends in energy intensity reflect the quality of national energy governance.

CONCLUSION

It can be concluded that national energy governance plays a key role in the management of the upstream energy sector (minerba and oil and gas). Through sound policies and regulations, the government can ensure that energy exploration and production are efficient, transparent, environmentally friendly, and support the transition to sustainable energy. Strong energy governance in the upstream sector is a crucial foundation for national energy independence and security.

This research shows that national energy policy plays a conceptual and strategic role in reducing national energy intensity and carbon emissions, particularly in the transportation sector. However, its effectiveness still needs to be improved due to weak cross-sectoral energy governance and low implementation of green policies in the public transportation system. Institutional strengthening, harmonization of green fiscal policies, and monitoring of energy intensity based on open data are needed.

This research shows that rail has the lowest energy intensity and carbon emissions, followed by cars, and finally by airplanes. Meanwhile, the upstream mining sector plays a crucial role in primary energy supply. Crude oil is processed into fuel and aviation fuel (avtur), while coal serves as an indirect energy source for electric trains. The close relationship between transportation and the upstream sector suggests that transportation efficiency can reduce pressure on fossil fuel exploitation. The government can reduce energy intensity by optimizing electric and bioenergy-based mass transportation modes; providing energy efficiency incentives for state-owned enterprises (SOEs) and the private sector in the transportation and upstream industries; integrating national energy data, including transparent reporting of emissions and energy consumption; and supporting green technology research and innovation for the mineral, coal, and oil and gas sector during the transition phase.

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