

TRANSPORT CO₂ EMISSIONS IN INDONESIA BEFORE AND AFTER THE EMISSIONS-BASED LUXURY GOODS SALES TAX (PPnBM) ON MOTOR VEHICLES

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Abstract

The emissions-based luxury goods sales tax (PPnBM) on motor vehicles, effective 16 October 2021 under Government Regulation No. 74 of 2021, was designed as an instrument for decarbonising Indonesian transport, yet whether it has played a role in transport emission patterns since its introduction is unknown. This study uses a quantitative descriptive analysis of official annual data for 2013–2025. A series of CO₂ emissions from transport-sector gasoline and diesel is built from fuel volumes in the Handbook of Energy & Economic Statistics of Indonesia and IPCC default emission factors, decomposed using the Logarithmic Mean Divisia Index (LMDI), and complemented by an upper-bound calculation of the PPnBM contribution through battery electric vehicle (BEV) sales. Emissions did not fall: they averaged 140.9 Mt CO₂ in 2022–2025, 2.0% above 2019, although GDP grew by 24.0% over 2019–2025. The decomposition shows that in 2019–2025 economic growth added 29.9 Mt, while the offsetting factors were biodiesel blending (–14.5 Mt) and the decline in fuel use per unit of GDP (–12.4 Mt). This decline in fuel intensity is not new and has in fact slowed, from 1.7% a year in 2013–2019 to 1.3% a year in 2021–2025. Even if all 175,309 BEVs sold in 2020–2025 were attributed to PPnBM, the emission savings would be at most 0.4–0.8 Mt, less than 0.6% of 2025 emissions. Post-policy restraint in emissions is therefore explained mainly by biodiesel blending and a pre-existing efficiency trend, not by PPnBM. The paper also specifies the data needed for future policy monitoring: monthly fuel sales, registrations by emission class, and CO₂ per kilometre of new vehicles.

Keywords: transport CO₂ emissions; luxury goods sales tax (PPnBM); fuel consumption; biodiesel; LMDI decomposition; Indonesia

INTRODUCTION

Decarbonising land transport is one of the hardest tests of Indonesia's climate commitments. The transport sector accounted for 28% of energy-sector emissions in 2018, and its emissions are projected to grow by 53% by 2030 relative to 2015 (IESR, 2023). At the same time, the 2022 Enhanced Nationally Determined Contribution (ENDC) raised the 2030 emission reduction target to 31.89% unconditionally and 43.20% with international support, relative to a business as usual scenario (Republic of Indonesia, 2022). The widening gap between a rising emissions trajectory and increasingly ambitious targets places policies that shape vehicle choice at the centre of the mitigation agenda. One of the most explicit policy responses is the reform of the Luxury Goods Sales Tax (Pajak Penjualan atas Barang Mewah, PPnBM) on motor vehicles. Government Regulation (Peraturan Pemerintah, PP) No. 73 of 2019 changed the PPnBM tax base from engine capacity, drive system, and body type to fuel consumption and CO₂ emissions per kilometre (Government of Indonesia, 2019), and PP No. 74 of 2021 revised the rates, including those for battery electric vehicles (BEV), fuel cell electric vehicles (FCEV), hybrids (HEV), and plug-in hybrids (PHEV) (Government of Indonesia, 2021). Through this reform, PPnBM no longer merely taxes luxury but sends a price signal that differentiates vehicles by their carbon footprint. The scheme took effect on 16 October 2021. Its introduction, however, did not take place under clean conditions: the government-borne (ditanggung pemerintah, DTP) PPnBM incentive for certain vehicle types was extended until December 2021 (Ministry of Finance of the Republic of Indonesia, 2021). As a result, two fiscal instruments with different logics operated in the same market at almost the same time. International evidence gives reason for optimism, but also for caution. CO₂-based vehicle taxes in Norway and Ireland have been shown to shift new car sales towards lower emissions (Ciccone, 2018; O'Riordan et al., 2023). Large emission reductions, however, generally result from policy mixes that include price instruments, not from vehicle taxes alone (Koch et al., 2022; Stechemesser et al., 2024). The same literature also

shows that vehicle taxes work through new vehicles, so that their impact on fleet emissions accumulates gradually as the fleet is renewed. In Indonesia, studies of PPnBM have so far focused on business perceptions and the economic multiplier effects of the DTP incentive (Nugraheni & Cahyonowati, 2023; Wahyudi, 2026). The question of emissions, which is precisely the main rationale for the reform, remains unaddressed.

This gap is closely related to the nature of the data and of the policy itself. Official transport GHG statistics are published annually and in aggregate, without a consistent quarterly breakdown. PPnBM took effect nationwide on a single date, and its introduction coincided with the COVID-19 pandemic, a major expansion of biodiesel blending, and a shift in the types of fuel sold, each of which could move emissions far more strongly than a tax on new vehicles. In this context, what is needed first is a clear picture of what actually happened to emissions, fuel composition, and vehicle sales around the time the policy took effect. Without such a picture, claims that PPnBM has succeeded in reducing emissions, or that it has failed, are equally at risk of being unfounded.

This article addresses that need through a descriptive analysis directed at one central question: can the pattern of transport CO₂ emissions after the emissions-based PPnBM took effect be explained by the policy, or by other factors? To answer it, the article examines four issues in turn. First, how CO₂ emissions from transport-sector gasoline and diesel evolved over 2013–2025, and how 2022–2025, the first four full calendar years after the policy took effect, compare with 2019 and earlier years. Second, how CO₂ emissions relative to GDP and population changed over the same period. Third, which changes in fuel composition occurred concurrently and how large their influence on observed emissions is. Fourth, which factors explain the change in emissions in the post-policy period, and how much room there is, at most, for a contribution from PPnBM.

The article makes three contributions. First, it presents a transparent and replicable annual series of CO₂ emissions from transport-sector gasoline and diesel for 2013–2025, constructed from official fuel statistics. Second, it decomposes the change in emissions before and after the policy into the contributions of economic activity, fuel intensity, fuel mix, and biodiesel blending using LMDI decomposition, so that the causes of restrained emissions can be shown quantitatively. Third, it calculates an upper bound on the PPnBM contribution through BEV sales under deliberately generous assumptions, and specifies the data needed for future policy monitoring. To the authors' knowledge, no previous study has decomposed fuel-based transport CO₂ emissions in Indonesia in relation to the timing of the emissions-based PPnBM. The article argues that the restraint in Indonesia's transport emissions in 2022–2025 is explained mainly by biodiesel blending and an efficiency trend that predates the policy, while the maximum room for a PPnBM contribution is below 1 Mt CO₂.

LITERATURE REVIEW

Emissions-based vehicle taxes have been evaluated using vehicle-specific data. Norway's 2007 registration tax reform reduced the market share of high-emission vehicles by about 12 percentage points in the first year, raised the diesel share by about 20 points, and cut the average CO₂ intensity of new vehicles by about 7.5 g/km (Ciccone, 2018). Without Ireland's 2008 reform, the emission intensity of new cars would have been 9% higher in 2018, with cumulative savings of 1.2 Mt CO₂ over 2008–2018 (O'Riordan *et al.*, 2023). Across countries, ten interventions reduced road CO₂ emissions in the European Union by 8–26%, with the most successful mixes combining carbon or fuel taxes with green vehicle incentives (Koch *et al.*, 2022), and 63 of some 1,500 climate policies in 41 countries achieved large reductions (Stechemesser *et al.*, 2024). Vehicle taxes thus work by shifting new vehicle sales rather than by changing the existing fleet. Their effect on overall fleet emissions accumulates gradually, and its magnitude depends on complementary policies such as fuel prices and electric vehicle incentives.

Indonesia's official GHG data are published annually for the aggregate energy sector, without a consistent quarterly breakdown for transport. Fuel statistics provide a more direct measure of activity: the Ministry of Energy and Mineral Resources publishes annual consumption of each fuel type by sector, and CO₂ emissions can be estimated from fuel volumes using default emission factors (Eggleston *et al.*, 2006). This fuel-based approach is standard for CO₂ because the CO₂ released during combustion depends almost entirely on the carbon content of the fuel burned. Its limitation is that national energy statistics derive consumption from supply-side sales data (MEMR, 2024) and that the transport sector is broadly defined.

PPnBM changes the relative prices of vehicles according to their emission intensity. These price changes are expected to shift the composition of new vehicle sales and, as the fleet is renewed, gradually reduce the emission intensity of the fleet (Ciccone, 2018; O'Riordan *et al.*, 2023). This effect may, however, be offset by other mechanisms, such as technological shifts, rebound effects, and other policies operating at the same time. Fleet-level fuel use is therefore an outcome that is distant from the policy mechanism and responds to it slowly. During 2013–2025, this outcome was also affected by other policies unrelated to PPnBM. For example, Indonesian fuel statistics

record a minimum 30% biodiesel blending mandate for diesel since 2020 (MEMR, 2024), and the biodiesel share of BioGasoil reached about 40% in 2025 (MEMR, 2026). The data used here also show that lower-octane RON 88 gasoline was gradually replaced by RON 90 over the period. Descriptive analysis has a distinct role in the study of emissions policy. Before the impact of a policy can be assessed, it is first necessary to know how the relevant outcomes move, on what scale, and which factors drive them. Cross-country studies of climate policy, for instance, start from observing patterns and breaks in emission series before linking them to specific policies (Koch et al., 2022; Stechemesser et al., 2024). One of the most widely used descriptive tools for this purpose is index decomposition analysis, in particular the Logarithmic Mean Divisia Index (LMDI) method, which decomposes a change in emissions into the contributions of its component factors without leaving a residual (Ang, 2005, 2015). Within this framework, this article documents patterns in emissions, emission intensity, fuel composition, and electric vehicle sales around the time PPnBM took effect, decomposes the change in emissions into its component factors, and interprets the results with the help of the literature on vehicle tax mechanisms.

METHODS

Research Design

This study uses a quantitative descriptive analysis of official annual data for 2013–2025 (13 observations). The analysis focuses on comparing levels, growth rates, and composition across periods, complemented by triangulation with electric vehicle sales data. The years are grouped into three reference periods: 2013–2019 (pre-pandemic baseline), 2020–2021 (pandemic and recovery; the policy took effect on 16 October 2021, so 2021 is largely pre-policy), and 2022–2025 (the first four full calendar years after the policy). The year 2019 serves as the base for all indices because it is the last year unaffected by the pandemic.

Data and Variables

All energy and macroeconomic inputs come from the Handbook of Energy & Economic Statistics of Indonesia (HEESI) published by the Ministry of Energy and Mineral Resources, which compiles fuel statistics from the Directorate General of Oil and Gas and macroeconomic data from BPS-Statistics Indonesia. Data for 2013–2014 are taken from HEESI 2023 (MEMR, 2024), while data for 2015–2025 are taken from the latest edition, HEESI 2025 (MEMR, 2026), which also contains revised GDP and population figures for several years. Transport fuel volumes for 2015–2023 are identical in both editions, so splicing the two editions does not change the emission estimates for those years. Table 1 lists the variables. Transport fuel volumes were transcribed from Table 5.4.1, and the components for each year were checked against the published totals (the largest discrepancy is 2 kL, reflecting rounding in the source). Since 2025, HEESI has used actual reports from the Downstream Oil and Gas Regulatory Agency to allocate fuel consumption across sectors (MEMR, 2026). The 2025 figures may therefore contain a small series break, although among the fuel types used in this study a notable change occurs only for MDF, whose share is very small.

Table 1. Variables and data sources

Variable	Definition	Unit	Source
Transport fuel volume	Consumption by fuel type in the transport sector (gasoline RON 88/90/92/95+; gasoil CN 48/51/53; MDF; BioGasoil)	kL	HEESI 2023 & 2025, Table 5.4.1
Biodiesel share (s_t)	Biodiesel energy divided by the energy of the BioGasoil blend, all sectors	%	HEESI 2023 & 2025, Table 3.3
GDP	Gross domestic product at constant 2010 prices	IDR billion	HEESI 2023 & 2025, Table 1.2 (BPS)
Population	Mid-year population	Thousand people	HEESI 2023 & 2025, Table 1.4 (BPS)
CO ₂ emissions (E_t)	Estimated CO ₂ from transport-sector gasoline and fossil diesel (Equation 1)	Mt CO ₂	This study
CO ₂ intensity	E_t divided by GDP	t CO ₂ per IDR billion	This study

Emission Estimation

Emissions are estimated as fuel volume multiplied by a CO₂ emission factor per litre. Gasoline covers RON 88, 90, 92, and 95 and above. Diesel covers gasoil (CN 48, 51, and 53), medium distillate fuel (MDF), and the fossil part of BioGasoil, a blend of gasoil and biodiesel. CO₂ from biodiesel is treated as biogenic and is not counted, following IPCC practice (Eggleston et al., 2006). Jet fuel (avtur), fuel oil, kerosene, and aviation gasoline are excluded, so the series is a proxy for land transport rather than for the sector as a whole. Emissions in year t are

$$E_t = V_t^g \cdot EF^g + (V_t^d + V_t^b(1 - s_t)) \cdot EF^d \quad (1)$$

where V_t^g is gasoline volume, V_t^d conventional diesel volume, V_t^b BioGasoil volume (all in kL), s_t the biodiesel share of BioGasoil, and EF^g and EF^d the emission factors in kg CO₂ per litre. The factors are 2.27 for gasoline (69,300 kg CO₂/TJ $\times$ 44.3 TJ/Gg $\times$ 0.74 kg/L) and 2.68 for diesel (74,100 kg CO₂/TJ $\times$ 43.0 TJ/Gg $\times$ 0.84 kg/L). Emission factors and net calorific values are IPCC (2006) defaults, while densities are typical values. The biodiesel share is taken from economy-wide energy data in HEESI Table 3.3 and applied to transport as an assumption.

Descriptive Measures

Results are summarised as annual levels, year-on-year changes, indices with 2019 = 100, CO₂ intensity (emissions divided by GDP at constant 2010 prices), CO₂ per capita, and the average annual growth rate between two years,

$$g = (X_{\text{end}} / X_{\text{start}})^{1/n} - 1 \quad (2)$$

where n is the number of years between them. Three checks test the estimates: (a) each emission factor is varied by $\pm 5\%$; (b) BioGasoil is counted entirely as fossil diesel, as an upper bound; and (c) the biodiesel share is held at its 2019 level while actual volumes are retained, an accounting scenario that isolates the effect of blending on estimated emissions. As a plausibility check, jet fuel is added to the estimate for comparison with the published transport total. All results are presented as descriptive statistics, in line with the study's aim of mapping the patterns and magnitudes of change.

Decomposition of the Change in Emissions

To identify the factors that explain the change in emissions, the difference in emissions between two years is decomposed using additive LMDI decomposition (Ang, 2005, 2015). Emissions are written as the identity

$$E = \sum_i Y \cdot (F/Y) \cdot (F_i/F) \cdot (E_i/F_i) \quad (3)$$

where i is the fuel type (gasoline and diesel), Y is GDP at constant 2010 prices, F is the total volume of gasoline and diesel (including all BioGasoil), F_i/F is the volume share of each fuel, and E_i/F_i is fossil emissions per litre. For gasoline, E_i/F_i is constant; for diesel, it falls as the biodiesel share rises. The change in emissions ΔE is then split into four effects: economic activity (change in Y), fuel intensity (change in F/Y), fuel mix (change in F_i/F), and biodiesel blending (change in E_i/F_i). Each effect is calculated as $\sum_i L[E_i(T), E_i(0)] \cdot \ln[x_i(T)/x_i(0)]$, where $L(a, b) = (a - b)/(\ln a - \ln b)$, x is the relevant factor, and 0 and T are the start and end years; the four effects sum exactly to ΔE . The fuel intensity effect captures everything that changes fuel use per unit of output, including vehicle efficiency, modal shift, economic structure, fuel prices, and any effect of PPnBM on the efficiency of gasoline and diesel vehicles. It therefore provides a reasonable descriptive test: if PPnBM accelerated fleet efficiency, the intensity effect should grow larger after 2021.

Upper Bound on the PPnBM Contribution

The contribution of PPnBM through electric vehicles is measured as an upper bound rather than a point estimate. All BEVs sold in 2020–2025 are assumed to have been caused by PPnBM, each is assumed to replace one gasoline car operating for the whole of 2025, and each replaced car is assumed to consume 1,000, 1,500, or 2,000 litres of gasoline per year. These assumptions are deliberately generous, so that the result overstates rather than understates the true contribution: some BEVs would have been bought without incentives, some were only sold at the end of 2025, and the replaced vehicles tend to be more efficient than average (Xing et al., 2021). Savings are calculated as the number of units $\times$ fuel use per unit $\times$ the gasoline emission factor (2.27 kg CO₂ per litre).

RESULTS AND DISCUSSION

Emission Levels and Trends

The constructed emission series reveals one clear pattern: the largest shock of the past thirteen years came from the pandemic, not from vehicle fiscal policy. Estimated CO₂ from transport-sector gasoline and diesel rose from 123.8 Mt in 2013 to 138.2 Mt in 2019, an average of 1.8% per year (Table 2, Figure 1). Emissions then fell sharply by 13.6% to 119.3 Mt in 2020, recovered to 128.8 Mt in 2021, and then levelled off at 140.6 Mt (2022), 140.3 Mt (2023), 142.9 Mt (2024), and 139.9 Mt (2025). The 2022–2025 average (140.9 Mt) is 2.0% above 2019 and 11.2% above the 2013–2019 average (126.8 Mt).

In other words, during the first four full calendar years after the emissions-based PPnBM took effect, aggregate emissions did not fall below their pre-pandemic level; they returned to trend and then flattened. Their growth slowed sharply, from 1.8% per year in 2013–2019 to 0.2% per year in 2019–2025, while the economy still grew by 3.7% per year (Table 3). The slowdown is visible for both fuel types. Gasoline volume grew by only 0.6% per year and gasoline emissions did not increase between 2024 and 2025 (83.2 Mt), while fossil diesel volume fell by 0.4% per year. The flattening of gasoline emissions in 2024–2025 does coincide with the surge in electric car sales, but also with a shift towards higher-octane gasoline and the change in sectoral allocation methods in 2025, so it cannot yet be read as an effect of electric vehicles. As for the slowdown in diesel, as explained below, it is largely an accounting effect of biodiesel blending. Vehicle taxes themselves work through new vehicles, so their impact on fleet emissions accumulates gradually as the fleet is renewed (Ciccone, 2018; O’Riordan et al., 2023).

The series also shows how sensitive recorded emissions are to energy policies outside the vehicle sector. The fall in 2016 (–7.1%) and the recovery in 2017 (+7.9%) came almost entirely from fossil diesel: its recorded volume fell by 21% in 2016 when the biodiesel share rose from 6.5% to 24.8%, and then rose by 15% when the share returned to 17.8% (Figure 3b). This episode is an early warning that movements in fuel-based emissions can be driven by fuel composition rather than by changes in driving behaviour or fleet composition. This finding is central to the discussion of fuel composition below.

Table 2. Estimated CO₂ emissions from transport-sector gasoline and diesel and related indicators, 2013–2025

Year	Gasoline (Mt)	Fossil diesel (Mt)	Total (Mt)	Annual change (%)	Index (2019 = 100)	GDP index (2019 = 100)	Intensity (t CO ₂ per IDR billion)	Biodiesel share (%)
2013	67.3	56.5	123.8	–	89.6	74.5	15.18	10.1
2014	68.2	53.8	122.0	–1.5	88.3	78.2	14.25	16.4
2015	69.7	55.5	125.3	+2.7	90.7	82.0	13.95	6.5
2016	72.7	43.7	116.4	–7.1	84.2	86.2	12.34	24.8
2017	75.4	50.2	125.6	+7.9	90.9	90.5	12.67	17.8
2018	77.6	58.5	136.2	+8.4	98.5	95.2	13.06	18.7
2019	80.3	57.9	138.2	+1.5	100.0	100.0	12.62	21.6
2020	70.3	49.0	119.3	–13.6	86.4	97.9	11.13	30.4
2021	74.6	54.1	128.8	+7.9	93.2	101.6	11.58	31.1
2022	81.3	59.2	140.6	+9.2	101.7	107.0	12.00	31.2
2023	81.8	58.5	140.3	–0.2	101.5	112.4	11.40	34.9
2024	83.2	59.7	142.9	+1.9	103.4	118.0	11.06	36.2
2025	83.2	56.7	139.9	–2.1	101.3	124.0	10.30	40.9

Note. Mt = million tonnes of CO₂; annual change = change relative to the previous year; intensity = t CO₂ per IDR billion of GDP at constant 2010 prices; fossil diesel excludes the biodiesel part of BioGasoil. Source: authors’ calculations based on MEMR (2024, 2026).

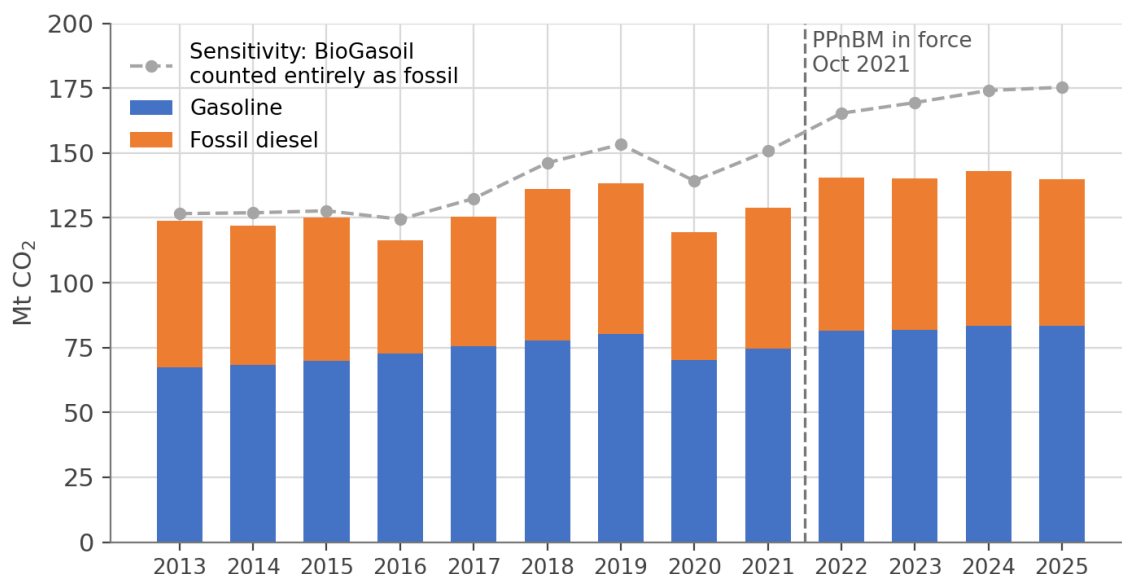


Figure 1. Estimated CO₂ emissions from transport-sector gasoline and diesel, 2013–2025 (Mt CO₂); the dotted line shows the sensitivity case in which BioGasoil is counted entirely as fossil diesel

Emissions Relative to GDP and Population

Comparing emissions with economic output gives a picture that looks more encouraging, but is also more prone to misinterpretation. Between 2019 and 2025, GDP grew by 24.0% while estimated emissions grew by only 1.3%, so emissions per unit of GDP fell by 18.4% and emissions per capita fell by 4.6% (Figure 2). On average, intensity fell by 3.3% per year in 2019–2025, slightly faster than the 3.0% per year of 2013–2019 (Table 3). Read in isolation, this could be taken as a sign of accelerated decoupling of emissions from economic growth after the policy took effect. That acceleration, however, stems almost entirely from biodiesel accounting. If the biodiesel share is held at its 2019 level, intensity falls by only 1.5% per year in 2019–2025, half the pre-pandemic rate (Table 3, Figure 2).

The annual trajectory was also shaped more by the pandemic and biodiesel blending than by vehicle policy. In 2020, emissions fell by 13.6% while GDP fell by only 2.1%, leaving intensity 11.8% below 2019. The gap narrowed to 8.2% in 2021 and 4.9% in 2022 as mobility recovered, and then widened again to 9.6% in 2023, 12.4% in 2024, and 18.4% in 2025. Each widening since 2023 coincided with an increase in the biodiesel share, from 31.2% in 2022 to 34.9%, 36.2%, and 40.9% (Table 2), not with a vehicle policy milestone. The acceleration in the decline of intensity seen in the data therefore cannot be linked to the timing of PPnBM. This pattern is consistent with cross-country evidence that large reductions in transport emissions are rarely achieved by a single instrument and generally result from policy mixes that include price instruments (Koch et al., 2022; Stechemesser et al., 2024).

Table 3. Average annual growth rates before and after 2019 (% per year)

Indicator	2013–2019	2019–2025
CO ₂ emissions (land fuel proxy)	+1.8	+0.2
GDP (constant 2010 prices)	+5.0	+3.7
CO ₂ intensity (per unit of GDP)	–3.0	–3.3
CO ₂ intensity, biodiesel share fixed at 2019	–	–1.5
Gasoline volume	+3.0	+0.6
Fossil diesel volume	+0.4	–0.4

Source: authors' calculations based on MEMR (2024, 2026). Growth rates are compound annual rates between the end years shown.

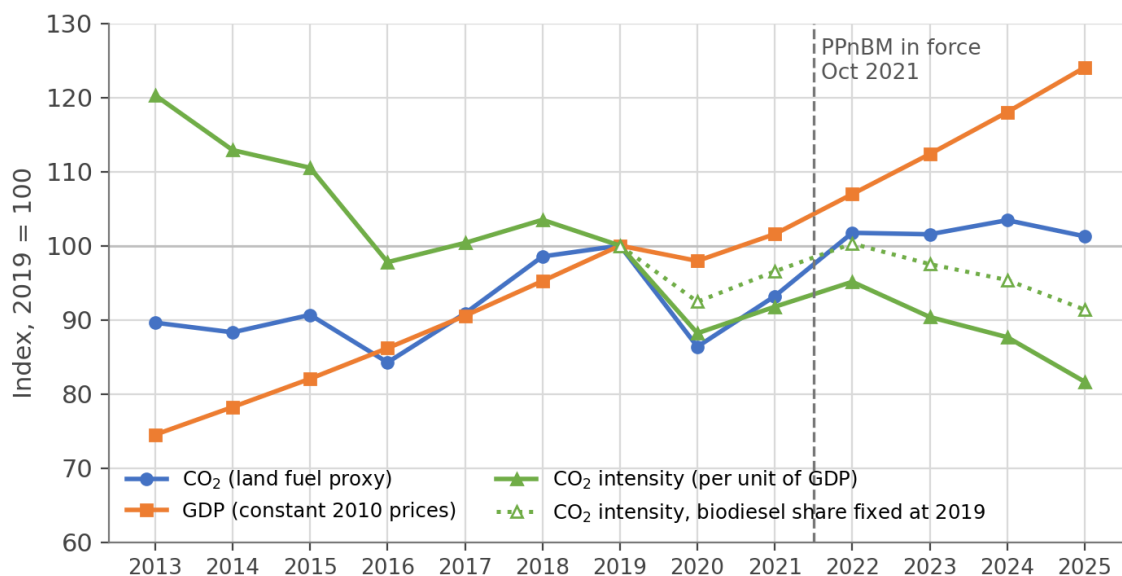


Figure 2. Estimated CO₂ emissions, GDP, and CO₂ intensity, 2013–2025 (index, 2019 = 100); the dotted line shows intensity with the biodiesel share held at its 2019 level

Fuel Composition and Biodiesel Blending

Beneath the aggregate figures, fuel composition changed far more dramatically than total emissions (Figure 3). For gasoline, RON 88 shrank from 96.6% of volume in 2013 to 32.1% in 2019 and had almost disappeared by 2022, replaced mainly by RON 90, which reached 83.9% of volume in 2023. The share of RON 92 and above was relatively stable at between 13% and 20% during 2016–2024, and then rose to 23.1% in 2025. These shifts between gasoline grades changed the structure of the fuel market but did not alter the CO₂ estimates, because all gasoline grades are treated with the same emission factor (Eggleston et al., 2006). The decisive change occurred in diesel: the biodiesel share of BioGasoil rose from 21.6% in 2019 to 30.4% in 2020, 34.9% in 2023, and 40.9% in 2025.

Because CO₂ from biodiesel is treated as biogenic, every increase in the blending share mechanically reduces recorded fossil emissions, and the size of this effect exceeds every other change in the data. Holding the biodiesel share at its 2019 level while retaining actual volumes, emissions would be 148.2 Mt in 2022, 151.4 Mt in 2023, 155.5 Mt in 2024, and 156.6 Mt in 2025, that is, 7.6, 11.1, 12.6, and 16.7 Mt higher, respectively, than the estimates in Table 2. The 2025 difference alone is almost ten times the entire 2019–2025 increase in emissions of only 1.7 Mt. If BioGasoil is counted entirely as fossil diesel, estimated emissions rise by 14.3% between 2019 and 2025, not by 1.3% (Table 4). In other words, the expansion of the biodiesel mandate, an energy policy wholly unrelated to vehicle taxation, is the largest driver of change in recorded emissions in the post-policy period.

These findings should be read with two caveats. First, a decline in recorded fossil emissions is not identical to a decline in net GHG emissions. The inventory convention that treats biodiesel CO₂ as neutral at the point of combustion does not account for emissions from land-use change for its feedstock, which can reduce or even eliminate the climate benefit of biofuels (Searchinger et al., 2008). Second, the conclusion is robust to technical assumptions. Varying each emission factor by $\pm 5\%$ yields a 2019–2025 change of between +1.11% and +1.40%, compared with +1.26% in the baseline estimate, and widening the test range to $\pm 10\%$ yields a range of only +0.97% to +1.54%. Because HEESI does not publish a transport-specific biodiesel share, the economy-wide share is applied as an assumption (Table 1). If the actual transport share differed systematically by ± 5 percentage points in all years, the 2019–2025 change would shift to between +0.67% and +1.81%, still far smaller than the effect of biodiesel accounting itself (+13.32%). Full calculations are available in the “Uji Sensitivitas” (sensitivity tests) sheet of the supplementary workbook.

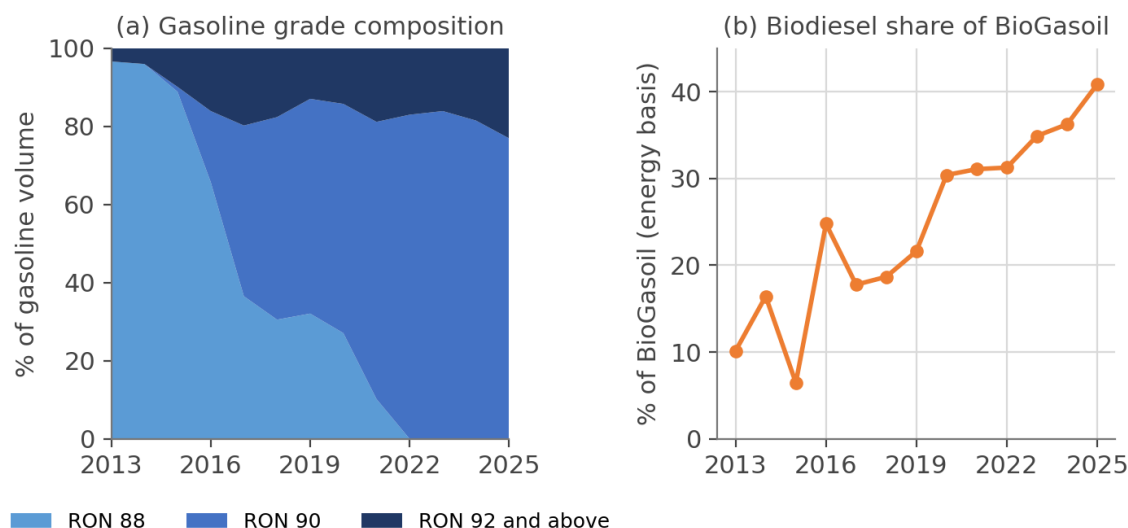


Figure 3. Fuel composition, 2013–2025: (a) gasoline volume by grade and (b) biodiesel share of BioGasoil

Table 4. Sensitivity of the estimated change in emissions to assumptions (% change relative to 2019)

Scenario	2019 to 2023	2019 to 2025
Baseline estimate	+1.53	+1.26
Emission factors $\pm 5\%$ (each fuel)	+1.50 to +1.55	+1.11 to +1.40
BioGasoil counted entirely as fossil diesel	+10.49	+14.33
Biodiesel share held at 2019 level	+9.54	+13.32

Source: authors' calculations based on MEMR (2024, 2026) and Eggleston et al. (2006).

Plausibility Check

As a plausibility check, the estimate is compared with the official inventory. Adding jet fuel to the 2019 estimate yields 150.9 Mt CO₂, 4.4% below the 157.8 MtCO₂e reported for the transport sector in Indonesia's Third Biennial Update Report (BUR), as cited in T20 Indonesia (2022). Because the official figure is expressed in CO₂ equivalent and includes gases other than CO₂, a small negative gap of this size is expected. The estimate is therefore of a plausible magnitude, although it is not intended to replace the official inventory.

Electric Vehicle Sales and Policy Chronology

If the emissions-based PPnBM works as designed, its first footprint should appear not in fleet fuel data but in the composition of new vehicle sales (Ciccone, 2018; Klier & Linn, 2015). The emission series is therefore complemented with wholesales data on new car sales (factory-to-dealer shipments) compiled by the Association of Indonesian Automotive Industries (Gaikindo), in particular battery electric vehicles (BEV), the segment with the lowest PPnBM burden under PP No. 74 of 2021 (Government of Indonesia, 2021). These data come from outside HEESI and are not used in the emission estimates in Table 2; their role is descriptive triangulation. Figure 4 sets BEV sales and their share of total car sales against the chronology of the main fiscal instruments.

BEV sales surged after the policy took effect: from zero in 2019, 125 units in 2020, and 687 units in 2021 to 10,327 units in 2022, 17,051 units in 2023, 43,188 units in 2024, and 103,931 units in 2025 (Bisnis Indonesia, 2025; Databoks, n.d.; Tempo, 2026b). In 2025, BEVs accounted for 12.9% of the 803,687 cars sold nationally (Tempo, 2026a, 2026b). A surge of this size is easily read as a policy success, but two considerations limit that interpretation. First, relative to the fleet, the change is still small. Cumulative BEV sales in 2020–2025 (175,309 units) are equivalent to 3.4% of total new car sales over the same period (5,142,481 units), and more than half of them were sold in 2025 alone. Because PPnBM affects only new vehicles, while fuel data reflect the entire fleet, including the motorcycles that dominate mobility in many Indonesian cities (Guerra, 2019), a shift of this size cannot yet be clearly visible in aggregate emissions for 2022–2025. The effect of vehicle taxes on fleet emissions accumulates as the fleet is renewed and can be slowed by responses in the used car market (Jacobsen & van Benthem, 2015; O'Riordan et al., 2023).

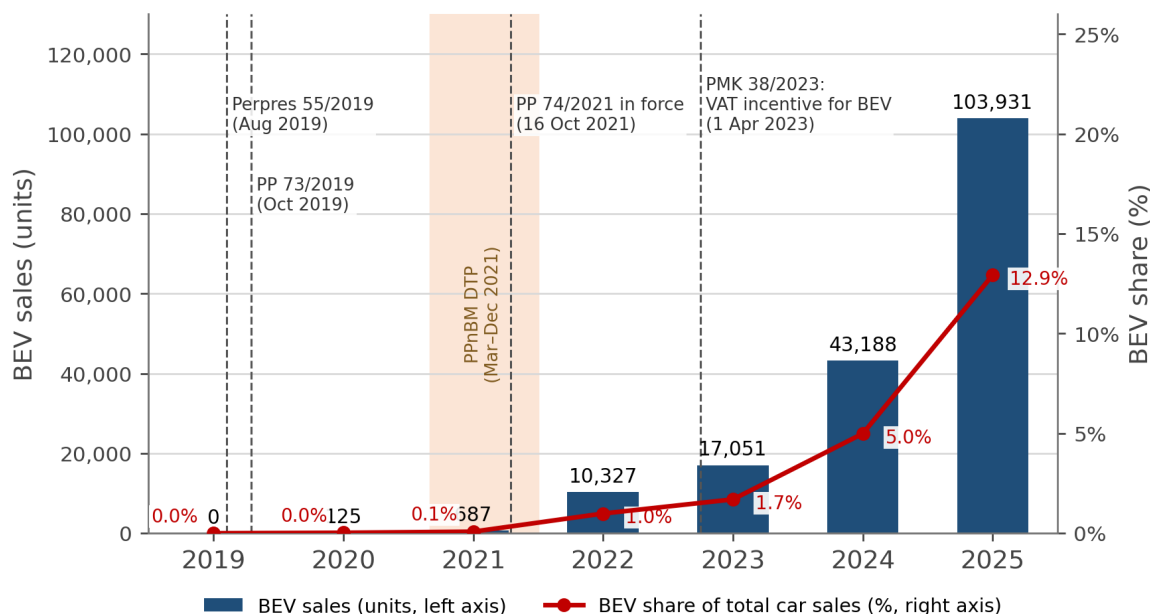


Figure 4. Battery electric vehicle (BEV) wholesales and their share of total car sales, 2019–2025, with the chronology of fiscal instruments (dashed lines mark the dates instruments took effect; the shaded area marks the PPnBM DTP incentive period)

Source: Gaikindo, as cited in *Bisnis Indonesia* (2025), *Databoks* (n.d.), and *Tempo* (2026a, 2026b), processed by the authors.

Second, the timing of the surge does not line up neatly with a single instrument. The increase in 2022 occurred after PP No. 74 of 2021 took effect, but also coincided with the entry of locally assembled BEV models and the announcement of planned electric vehicle subsidies (*Bisnis Indonesia*, 2025). The next surge coincided with the government-borne VAT incentive for BEVs with a local content requirement (tingkat komponen dalam negeri, TKDN) of at least 40% from 1 April 2023 (Ministry of Finance of the Republic of Indonesia, 2023). The largest surge, in 2025, occurred as more brands and new models entered the market at prices competing directly with low-end conventional cars (*Tempo*, 2026b). This stepwise pattern indicates that BEV adoption responds simultaneously to a stack of incentives, to model availability and prices, and to infrastructure readiness, not to PPnBM alone. The international literature does find that financial incentives increase electric vehicle adoption, but with moderate effects once the technology diffusion trend is controlled for (Münzel et al., 2019), while in Indonesia infrastructure readiness and the supporting ecosystem remain constraints (Maghfiroh et al., 2021).

Even if all BEV sales were attributed to PPnBM, their emission benefit could not be equated with the number of units sold. Each BEV replaces a vehicle that would otherwise have been bought, and the replaced vehicles tend to be relatively fuel-efficient already. In the United States, ignoring this overstates the emission benefit of electric vehicles by 39%, and about 70% of tax credit recipients would have bought an electric vehicle without the incentive (Xing et al., 2021). The French bonus/malus experience even shows that a vehicle tax scheme encouraging purchases of low-emission classes can increase total emissions by increasing the number of vehicles bought (D'Haultfœuille et al., 2014), while more efficient vehicles can encourage more intensive use through the rebound effect (Gillingham et al., 2016). The net benefit of BEVs also depends on the carbon intensity of the electricity that charges them (Knobloch et al., 2020), which is not captured in this fuel-based series. Vehicle sales data therefore reinforce the article's argument: the shift in new vehicle composition has begun and strengthened in 2025, but in cumulative terms it remains small relative to the fleet, overlaps with other incentives, and is too far removed from fleet emission outcomes to be reflected in annual fuel data.

Decomposition: What Held Emissions Back?

The LMDI decomposition answers the article's central question directly (Table 5, Figure 5). During 2019–2025, economic growth added 29.9 Mt to emissions. This increase was almost entirely offset by two factors: biodiesel blending (–14.5 Mt) and the decline in fuel use per unit of GDP (–12.4 Mt). The shift in the mix between gasoline and diesel contributed only –1.3 Mt, leaving a net change in emissions of +1.7 Mt. For comparison, in 2013–2019

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economic growth added 38.5 Mt, while fuel intensity and biodiesel held back 13.6 Mt and 10.5 Mt respectively, so that emissions still rose by 14.4 Mt.

Table 5. LMDI decomposition of the change in CO₂ emissions, 2013–2019 and 2019–2025 (Mt CO₂)

Factor	2013–2019	2019–2025
Economic activity (GDP)	+38.5	+29.9
Fuel intensity per unit of GDP	–13.6	–12.4
Gasoline–diesel mix	+0.0	–1.3
Biodiesel blending	–10.5	–14.5
Net change in emissions	+14.4	+1.7

Source: authors' calculations based on MEMR (2024, 2026), following Ang (2005, 2015). Both periods are six years long, so the figures can be compared directly.

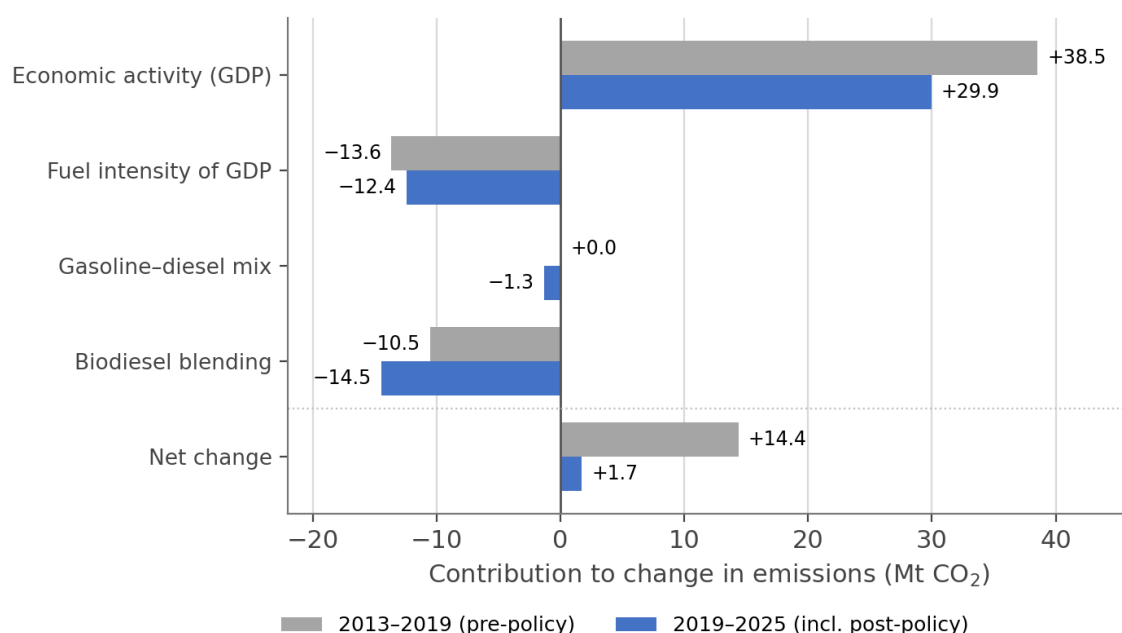


Figure 5. Contribution of each factor to the change in CO₂ emissions, 2013–2019 and 2019–2025 (LMDI decomposition, Mt CO₂)

Two findings stand out from this comparison. First, the offsetting factor that grew after 2019 is biodiesel, not efficiency. The biodiesel effect rose from –10.5 Mt to –14.5 Mt, or from –1.75 to –2.41 Mt per year, as the blending share rose towards 40%. Second, the fuel intensity effect shows no acceleration. It in fact shrank slightly, from –13.6 Mt (–2.27 Mt per year) in 2013–2019 to –12.4 Mt (–2.07 Mt per year) in 2019–2025. Fuel use per unit of GDP fell by 1.7% per year before the policy, 1.5% per year in 2019–2025, and only 1.3% per year in 2021–2025, a period lying entirely after the emissions-based PPnBM took effect. Because the intensity effect captures all efficiency channels, including the shift towards more efficient gasoline and diesel vehicles that PPnBM targets, this slowdown indicates that the policy's effect, if any, has not been large enough to change the pre-existing efficiency trend.

How Much Room Is There for PPnBM?

The upper-bound calculation clarifies this scale. Under deliberately generous assumptions, namely that all 175,309 BEVs sold in 2020–2025 were caused by PPnBM and each replaced a gasoline car operating for the whole of 2025, emission savings in 2025 amount to only about 0.40 Mt if each replaced car consumed 1,000 litres of gasoline per year, 0.60 Mt at 1,500 litres, and 0.80 Mt at 2,000 litres. The highest figure is equivalent to 0.6% of 2025 emissions, 5.5% of the biodiesel effect, and 6.4% of the fuel intensity effect in 2019–2025. In other words, even in the scenario most favourable to the policy, the contribution of PPnBM through electric vehicles is on the order of hundreds of thousands of tonnes, while other factors move emissions on the order of tens of millions of tonnes.

The answer to the article's central question is therefore clear. The restraint in transport emissions after PPnBM took effect is explained mainly by biodiesel blending and a decline in fuel intensity that predates the policy, not by PPnBM. This does not mean that PPnBM has had no effect at all; its effect on the composition of new vehicles, especially BEVs, is clearly visible in sales data. Over the 2022–2025 horizon, however, that effect is too small relative to other factors to explain aggregate emission patterns, consistent with the literature showing that vehicle taxes work slowly through fleet renewal (Ciccone, 2018; O'Riordan *et al.*, 2023).

Synthesis of Findings and Limits of Interpretation

Overall, the findings of this article can be summarised in a single answer: the post-policy restraint in Indonesia's transport emissions is not primarily the result of PPnBM. Fuel-based aggregate emissions in the first four full years after the policy returned to around their 2019 level. Emission intensity relative to GDP did fall faster than before the pandemic, but the decomposition shows that this acceleration came from biodiesel blending, while the decline in fuel use per unit of GDP actually slowed. BEV sales grew rapidly and are the most tangible footprint of PPnBM, but the upper bound on their emission contribution is less than 1 Mt. This pattern is consistent with the literature's account that vehicle taxes shift new vehicle composition gradually, so that their footprint on fleet emissions will only become visible over a longer horizon (Ciccone, 2018; Klier & Linn, 2015; O'Riordan *et al.*, 2023).

Interpreting the findings also requires accounting for overlapping events. Within the same window, the pandemic and recovery, the extension of the PPnBM DTP incentive until December 2021, the expansion of biodiesel blending to about 40% in 2025, changes in fuel types and prices, and the VAT incentive for electric vehicles from 2023 all occurred. Because all of these events moved together in a single national series, PPnBM is best regarded as one of several factors accompanying the change in emissions rather than as a sole explanation. The findings of this article can thus be read as a map of changes and their relative scale: the pandemic and biodiesel blending moved recorded emissions on the order of millions of tonnes, while the shift in new vehicle sales remains on the order of a few percent of the market.

Limitations and Implications

Several limitations should be noted. First, the data are annual, so the comparison before and after the policy rests on only 13 observations, and 2021, the year the policy took effect, is largely pre-policy. Second, fuel consumption is measured from supply-side sales data, and the transport sector as defined in the handbook also includes some off-road diesel use, so the series is a proxy rather than a pure road transport figure (MEMR, 2024). Third, the biodiesel share is taken from economy-wide data and applied to transport, with default emission factors and typical densities, while the 2025 figures were compiled with a new sectoral allocation method (MEMR, 2026). Fourth, PPnBM targets only new vehicles, which make up a small part of the fleet in any given year, whereas fuel data cover the entire fleet. Fifth, the electric vehicle sales data used for triangulation are wholesales data from secondary sources, not retail sales or registrations, and therefore do not precisely reflect vehicles entering operation. Sixth, the fuel intensity effect in the decomposition combines many factors and therefore cannot separate the effect of PPnBM on conventional vehicles from other influences, and the upper bound on the BEV contribution depends on assumptions about fuel use per vehicle that are not available in official statistics. The findings of this article are therefore best read as a description of conditions and policy context.

These limitations also point to three implications. First, the government should publish monthly or quarterly fuel sales by product and region, as well as vehicle registrations by emission class, so that transport emissions can be monitored at a frequency suitable for policy evaluation. Second, the average CO₂ intensity of new vehicles (g/km) should be reported regularly, because this intermediate outcome is much closer to the PPnBM mechanism than fleet fuel use (Ciccone, 2018; Klier & Linn, 2015). Third, PPnBM should be evaluated as part of a policy mix that includes electric vehicle incentives, biodiesel blending, and fuel prices, because international evidence shows that large emission reductions result from combinations of instruments (Koch *et al.*, 2022; Stechemesser *et al.*, 2024). Once such data are available, future research can complement this descriptive picture by measuring impacts with counterfactual methods accompanied by placebo tests (Abadie, 2021; Brodersen *et al.*, 2015).

CONCLUSION

This article asks whether the pattern of Indonesia's transport CO₂ emissions after the emissions-based PPnBM took effect can be explained by the policy, using official annual fuel statistics for 2013–2025. Estimated emissions averaged 140.9 Mt in 2022–2025, 2.0% above 2019, with growth slowing to 0.2% per year in 2019–2025.

Emissions per unit of GDP in 2025 were 18.4% lower than in 2019, but fell by only 1.5% per year when the biodiesel share is held at its 2019 level. The rise in the biodiesel share to 40.9% reduced recorded fossil emissions by 16.7 Mt in 2025. The LMDI decomposition shows that the emissions added by economic growth in 2019–2025 (+29.9 Mt) were offset mainly by biodiesel blending (–14.5 Mt) and a decline in fuel use per unit of GDP (–12.4 Mt) whose pace actually slowed relative to the pre-policy period, while the upper bound on the PPnBM contribution through BEVs is only 0.4–0.8 Mt. The answer is therefore clear: post-policy restraint in emissions is mainly the result of biodiesel blending and a pre-existing efficiency trend, not of PPnBM.

These findings do not deny a role for PPnBM. The policy has left a tangible footprint on the composition of new vehicle sales, with the BEV share reaching 12.9% in 2025, but that footprint is not yet large enough to change fleet emissions. The implication is that claims that PPnBM has reduced transport emissions are not yet supported by the data, and that assessments of the policy should focus on intermediate outcomes such as the CO₂ intensity of new vehicles. Future research can draw on monthly or quarterly emission series from fuel sales and vehicle registrations by emission class, examine the CO₂ intensity of new vehicles, and measure policy impacts directly once such data become available.

NOTATION

E_t = estimated CO₂ emissions from transport-sector gasoline and diesel in year t (Mt CO₂)

V_t^g , V_t^d , V_t^b = volumes of gasoline, conventional diesel, and BioGasoil in year t (kL)

s_t = biodiesel share of BioGasoil in year t (energy basis)

EF^g , EF^d = CO₂ emission factors of gasoline and diesel (kg CO₂ per liter)

g = average annual growth rate between two years (% per year)

CO₂ intensity = E_t divided by GDP at constant 2010 prices (t CO₂ per IDR billion)

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