



Decomposition of Coal Consumption, Economic Scale, and Coal Intensity in Indonesia: A Laspeyres Index Approach

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Abstract

Background: Indonesia's dependence on coal creates energy and economic challenges that cannot be explained solely by changes in consumption volume.

Objective: This study analyzes changes in Indonesia's coal energy consumption at the national aggregate level during 2000–2024 by decomposing the economic scale effect (ESE) and coal intensity effect (CIE).

Methods: The study applies a two-factor Laspeyres index decomposition analysis adapted from Tang 2024. Coal consumption is expressed as the product of real economic scale and coal intensity per unit of real GDP. Data are obtained from the Indonesian Energy Balance, BPS real GDP statistics, and official energy and economic publications.

Results: Indonesia's coal consumption increased by 6,272,042 terajoules during 2000–2024. The CIE contributed 3,620,525 terajoules, exceeding the ESE contribution of 2,651,517 terajoules. The five-year decomposition reveals a nonlinear pattern: the CIE constrained consumption growth during 2000–2004, became the dominant driver during 2005–2009, weakened during 2010–2014, regained dominance during 2015–2019, and reached its largest contribution during 2020–2024. These findings indicate that rising coal consumption reflects not only economic expansion but also increasing coal use per unit of economic output.

Conclusion: Indonesia's coal-use control strategy should prioritize reducing coal intensity through energy-mix transformation, improvements in power-system efficiency, and restraint on coal-based capacity expansion.

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INTRODUCTION

Coal remains a major component of Indonesia's energy system, particularly in electricity generation and energy-intensive economic activities. Its continued use is supported by domestic resource availability and its role in meeting growing energy demand associated with economic expansion, electrification, industrialization, urbanization, and infrastructure development. Consequently, coal consumption has increased substantially over the past two decades. Indonesia's Energy Balance records an increase in national coal consumption from approximately 531,708 terajoules in 2000 to 6,823,092 terajoules in 2024. In 2024, coal accounted for 40.37% of the national primary energy mix, indicating that coal remains structurally important despite the ongoing energy transition agenda.

The increase in coal consumption, however, cannot be interpreted solely as a consequence of economic growth. Economic expansion increases energy demand through higher production,

investment, electricity consumption, mobility, and household activities. At the same time, the amount of coal required to generate each unit of economic output may change because of shifts in the energy mix, technological efficiency, power generation structure, and economic activity. Thus, an increase in coal consumption may occur because the economy becomes larger, because coal is used more intensively per unit of output, or because both mechanisms operate simultaneously. Distinguishing these mechanisms is important because they imply different policy responses. If consumption growth is primarily associated with economic scale, the policy challenge concerns improving the energy efficiency of economic expansion. If it is driven by coal intensity, the problem is more closely related to the structure of energy supply, generation technology, and the persistence of coal-dependent economic activities.

This distinction is particularly relevant for Indonesia because the country faces a trade-off between energy security, economic development, environmental quality, and the transition toward a lower-carbon energy system. Global climate objectives further increase the urgency of reducing coal dependence. The International Energy Agency has emphasized the need for a substantial reduction in global coal consumption under pathways toward net-zero emissions, while the IPCC has highlighted the need for a phased reduction of unabated coal-fired power generation to limit global warming. Indonesia therefore faces significant pressure to transform its energy system while maintaining economic growth and meeting domestic energy needs.

Previous empirical studies indicate that the relationship between coal consumption and economic growth is not uniform across countries and development contexts. Bloch et al. (2015) show that energy consumption and economic growth are closely interconnected, while fuel substitution can influence this relationship. Jin and Kim (2018) find that the association between coal consumption and economic growth is stronger in non-OECD countries. In Indonesia, Irwandi (2018) demonstrates that the relationship between coal consumption and economic growth is not necessarily straightforward. These findings suggest that aggregate coal consumption should not be interpreted solely through the growth of economic output but should also account for changes in the intensity and structure of energy use.

Decomposition studies provide a suitable framework for identifying the sources of changes in aggregate energy consumption. Kurniawan et al. (2020), for example, show that Indonesia's increase in coal consumption is associated not only with economic growth but also with changes in the energy mix, urbanization, urban income, and population. Setyawan (2020) focuses on energy efficiency in Indonesia's manufacturing sector and demonstrates the relevance of energy intensity in explaining changes in energy use. These studies provide important evidence on the drivers of energy and coal consumption, but their analytical focus differs from that of the present study. Kurniawan et al. (2020) employ a broader multifactor decomposition over a longer historical period, whereas Setyawan (2020) focuses on the manufacturing sector. Consequently, the specific contributions of economic scale and coal intensity to national aggregate coal consumption remain insufficiently examined.

Tang et al. (2024) provide a closely related methodological reference by applying a two-factor Laspeyres decomposition to coal consumption in Pakistan. Their approach separates changes in coal consumption into economic scale and intensity effects, providing a direct framework for identifying whether consumption changes are associated with economic expansion or changes in coal-use intensity. However, the energy structure and development characteristics of Pakistan differ from those of Indonesia. Moreover, the existing Indonesian literature has not applied this two-factor framework to examine national coal consumption over the 2000–2024 period while simultaneously comparing annual changes and five-year development-policy periods.

In consumption theory, the demand for a good is influenced by income, relative prices, and preferences. Energy has a distinct characteristic because its benefits are generally obtained through energy services rather than from energy itself. Households require lighting, thermal comfort, mobility, and cooking services, while production activities require heat, mechanical power, electricity, and material transformation processes. Therefore, energy demand is a derived demand. An increase in economic activity will increase the demand for energy services, while technological changes and relative prices affect the type and amount of energy used to provide those services (Zweifel et al., 2017).

At the macroeconomic level, energy can be understood as an input that enables the

production process to operate effectively alongside capital, labor, and technology. Conventional production functions represent output as a function of the factors of production, whereas energy economics emphasizes that the availability and cost of energy affect the ability of those factors to generate output. From this perspective, economic growth has direct implications for energy requirements, but the magnitude of these implications depends on efficiency and technological structure. Therefore, the relationship between GDP and coal consumption cannot be assumed to be one-to-one.

Energy intensity is a measure of energy use per unit of economic activity. In this article, coal intensity is defined as coal energy consumption per unit of real GDP. This indicator is not a measure of purely technical efficiency because it can be influenced by changes in economic structure, the energy mix, technology, and economic cyclical factors. However, intensity remains relevant as a macroeconomic indicator for determining whether the economy is moving toward greater coal efficiency or becoming more coal-intensive. An increase in coal intensity indicates that additional economic output is being generated with a relatively greater use of coal.

Index Decomposition Analysis (IDA) has been widely used in energy and environmental studies because it can separate changes in aggregate indicators into the contributions of their underlying driving factors. Ang (2004) explained that decomposition is an important analytical tool for energy policy because it can quantitatively identify the sources of changes in energy consumption or emissions. In practice, the two most used families of methods are Divisia and Laspeyres. The choice of method is not universal across all contexts but is influenced by the purpose of the analysis, data availability, ease of interpretation, and the need for effective policy communication.

The Laspeyres approach has advantages in terms of the simplicity and readability of its results. In a study that aims to explain the contributions of economic scale and coal intensity to policymakers and other policy-oriented readers, the two-factor Laspeyres formulation is relatively easy to understand. This article does not position Laspeyres as a method that is always superior to LMDI, but rather as a method that suits the needs of the research by measuring the contributions of ESE and CIE in an additive and direct manner and by allowing application to annual changes and five-year subperiods. This framework is consistent with Tang et al. (2024), who used Laspeyres decomposition to analyze coal consumption, economic growth, and intensity effects in Pakistan.

The choice of the Laspeyres method over LMDI in the context of this article is based on three methodological considerations. First, the two-factor Laspeyres decomposition yields zero residuals under the two-factor identity condition—a relevant advantage when changes in coal consumption are decomposed solely into ESE and CIE without a third component (Sun, 1998). Second, LMDI is particularly advantageous in avoiding residuals and handling zero values in the data; however, in the case of Indonesia—where national coal consumption data remained consistently positive from 2000 to 2024—this issue is not a binding constraint. Third, the Laspeyres formulation used by Tang et al. (2024) allows for direct comparability between Indonesia's decomposition results and those of Pakistan, providing an important analytical advantage for situating the findings of this article within the cross-country literature. This methodological choice is not without limitations: Laspeyres decomposition is inherently deterministic and accounting-based and therefore cannot be used to establish causal relationships. This limitation is explicitly acknowledged in the conclusion section.

In the Indonesian context, a number of studies have used decomposition approaches to analyze changes in energy consumption or emissions, but their focus is not always on national coal consumption. Setyawan (2020) analyzed the energy efficiency of Indonesia's manufacturing industry using LMDI, while Hastuti et al. (2021) used structural decomposition analysis to examine changes in energy-related emissions. Kurniawan et al. (2020) examined the drivers of Indonesia's increase in coal consumption using broader factors, such as the energy mix, population, urbanization, and urban income. This article differs in that it focuses on the separation of two core factors in the national coal consumption identity, namely economic scale and coal intensity. With this focus, this article addresses whether the Indonesian economy is growing only in terms of output or is also becoming structurally more coal-intensive.

The literature on coal and economic growth yields mixed results. Bloch et al. (2015) show that, in China, energy consumption, including coal consumption, is closely related to economic

growth and that there is scope for fuel substitution through changes in relative prices. Jin & Kim (2018) found that the relationship between coal consumption and economic growth differs between OECD and non-OECD countries; in non-OECD countries, coal consumption has a stronger correlation with economic growth, especially in the short term. Other studies have also shown that the relationship between coal consumption, economic growth, and energy prices is highly dependent on economic structure and stages of development (Lei et al., 2014). In the Indonesian context, Irwandi (2018) examined the relationship between coal consumption and economic growth using a VECM and found that causal relationships are not always straightforward. The diversity of these findings shows that the relationship between coal consumption and economic growth must be interpreted according to the characteristics of each country's energy economy.

Kurniawan et al. (2020) is one of the most relevant studies for the Indonesian context because it shows that the increase in Indonesia's coal consumption is driven not only by economic growth but also by changes in the energy mix, urbanization, urban income, and population. These findings are important for this article because CIE in the national decomposition can be interpreted as a macro-level summary of changes in energy and technological structures that cause economic output to require more or less coal. As such, this article does not replace multi-factor studies but provides a more direct aggregate assessment of two key components: real output and coal intensity.

The position of this article lies at the intersection of the energy decomposition literature and the coal-growth nexus literature. In terms of methodology, this article follows Tang et al. (2024) in using a two-factor Laspeyres decomposition. In terms of its object of analysis, this article fills an empirical gap for Indonesia by examining the 2000–2024 period at the national aggregate level. In terms of its policy contribution, this article emphasizes that the increase in coal consumption needs to be interpreted according to its source: whether it results from the need associated with economic scale or from increasing coal intensity.

Table 1

Summary of Relevant Literature and Article Position

No	Researcher	Focus and Method	Key Findings	Relevance to This Article
1	Sun (1998)	The decomposition model changes energy consumption and energy intensity.	Developed a decomposition formulation that separates the changes of aggregate indicators into the driving factors.	It is the technical basis for separating changes in coal consumption into scale and intensity effects.
2	Ang (1998)	Evaluation of the IDA method and LMDI/Laspeyres implementation guidelines.	The selection of decomposition methods should consider the purpose, data, convenience, and interpretation of the policy.	It is a methodological justification for the use of IDA in energy studies.
3	Tang et al. (2024)	Laspeyres decomposition for Pakistani coal consumption.	Economic growth increases coal consumption; intensity indicates a mixed pattern.	Be the main template for article structure and method.
4	Bloch et al. (2015)	ARDL/VECM China's coal, oil, renewable energy, growth, and emissions linkage.	Growth and energy are intertwined; Fuel substitution is relevant for sustainability.	Affirming the importance of looking at coal in the framework of energy growth and substitution.
5	Jin and Kim (2018)	Panel on cointegration and causality of coal consumption in OECD and non-OECD.	The correlation between coal and growth is stronger in non-OECD; Long-term dependence on coal can stifle growth.	Strengthening the relevance of the context of developing countries such as Indonesia.

No	Researcher	Focus and Method	Key Findings	Relevance to This Article
6	Irwandi (2018)	VECM the relationship between coal consumption and Indonesia's economic growth.	It did not find a simple causal relationship between coal consumption and Indonesia's economic growth.	Demonstrates the need for a non-causal approach that separates the contribution of driving factors.
7	Kurniawan et al. (2020)	LMDI energy intensity of Indonesia's manufacturing industry.	The decrease in manufacturing energy intensity is mainly influenced by efficiency improvements in the industry.	Providing a comparison that Indonesia's decomposition study focuses a lot on manufacturing/efficiency, not national coal.
9	Andreoni (2022)	Decomposition changes China's regional coal consumption.	Changes in coal consumption are influenced by structural factors and intensity at the regional level.	Affirms the relevance of decomposition to identify coal drivers.

Source: Research data processing results

Based on the literature review above, several research gaps have not yet been addressed. First, decomposition studies in Indonesia have so far focused primarily on the manufacturing sector Setyawan (2020) or employed a multifactor approach with a longer historical span but a broader range of variables Kurniawan et al. (2020); consequently, no national aggregate analysis has yet been conducted that focuses specifically on the two core components: economies of scale and coal intensity. Second, the existing literature has not explicitly linked annual and five-year decomposition patterns to the periods of the *Rencana Pembangunan Jangka Menengah Nasional* (RPJMN; National Medium-Term Development Plan), so the decomposition results cannot yet be directly used as an instrument for evaluating energy policies across planning periods. Third, the study by Tang et al. (2024), which serves as the primary methodological reference, was applied to the context of Pakistan, which has different energy characteristics; consequently, its application to Indonesia, with its high reliance on coal-fired power generation and distinctive energy transition agenda, may yield findings that cannot be assumed to be directly transferable. This article aims to address these three gaps.

This study addresses these gaps by applying a two-factor Laspeyres Index Decomposition Analysis to Indonesia's national coal energy consumption during 2000–2024. The analysis separates changes in coal consumption into the economic scale effect (ESE), representing the contribution of changes in real GDP, and the coal intensity effect (CIE), representing the contribution of changes in coal consumption per unit of real GDP. The decomposition is examined both annually and across five-year periods to identify changes in the dominant source of coal consumption growth. The study therefore aims to determine whether Indonesia's rising coal consumption is primarily associated with economic expansion or with increasing coal intensity.

The contribution of this study is twofold. Academically, it extends the application of two-factor Laspeyres decomposition to Indonesia's national coal consumption and provides a long-term assessment covering 2000–2024. Empirically, it identifies the relative contributions of economic scale and coal intensity and examines how their dominance changes across five-year periods. From a policy perspective, the decomposition provides a basis for distinguishing consumption increases generated by economic expansion from those associated with increasing coal intensity, thereby supporting more targeted energy-transition policies.

METHOD

This study is a quantitative-descriptive-explanatory study based on secondary data that aimed to measure and interpret the contributions of two factors to changes in national coal consumption. The research design employed Index Decomposition Analysis (IDA) using the two-factor Laspeyres approach. The unit of analysis was the national aggregate for Indonesia rather than a specific sector or region. Data were collected from official secondary sources through

documentation and the compilation of time-series data. The operational definitions of the variables, the analytical model, and the data analysis techniques are described in the following subsections.

This article used Indonesia's annual data for the period 2000–2024. The main variables were national coal energy consumption (CC), national real GDP as a proxy for national economic scale (ESE), and coal intensity (CIE). Coal consumption was expressed in terajoules, while real GDP was expressed in billions of rupiah at constant 2010 prices. The selection of real GDP was important because the decomposition was intended to capture changes in coal consumption attributable to changes in the volume of economic activity, rather than changes in nominal economic value that still contained the influence of prices.

It should be emphasized that, in this article, ESE was used consistently to refer to the economic scale effect (that is, the contribution of changes in real GDP to changes in coal consumption) rather than as an abbreviation for a level variable. The economic scale variable was represented by national real GDP (ESEt), while the decomposition effect was denoted by ΔCCtESE . This distinction was important for avoiding conceptual ambiguity between the level of the variable and its contribution to the decomposition.

Coal consumption data mainly referred to the Indonesian Energy Balance published by the Central Statistics Agency and energy publications of the Ministry of Energy and Mineral Resources. Real GDP data referred to BPS publications on GDP. The use of official data was necessary because this study employed a macro-accounting framework and depended on consistency across the time series. Differences in the units and base years of the data were adjusted so that the identity $\text{CIE} = \text{CC}/\text{real GDP}$ remained consistent throughout the analysis period.

The main analysis was conducted at the national aggregate level. This restriction was important because the article was designed as a specialized study to explain national dynamics rather than variations across sectors. Therefore, all empirical results, graphs, tables, and discussions were directed toward interpreting changes in national coal consumption. Information on the electricity system, energy mix, and coal consumption by power plants was used only as a macro-level context to explain changes in national coal intensity, rather than as a basis for sectoral decomposition analysis.

The data-processing steps in this study were carried out systematically as follows. First, coal consumption data from various editions of the Indonesian Energy Balance were compiled and harmonized by observation year (2000–2024), with consistency checks across editions to detect revisions to historical data. Second, real GDP data from BPS publications were adjusted to the 2010 base year using officially available deflators. Third, the consistency of the identity $\text{CIEt} = \text{CCt} / \text{ESEt}$ was verified for each year, and intensity values were calculated as the ratio of two variables with harmonized units (terajoules per billion rupiah at constant 2010 prices [ADHK]). Fourth, the two-factor Laspeyres decomposition was calculated using Equations (2.5) and (2.6), implemented in Microsoft Excel, where each annual ESE and CIE value was verified through arithmetic checks ($\Delta\text{CCtESE} + \Delta\text{CCtCIE} = \Delta\text{CCt}$). Fifth, five-year aggregates were obtained by summing the annual values in accordance with the RPJMN periodization. No additional normalization procedures were required because the data were based on absolute values expressed in consistent units.

Table 2

Variables, Operational Definitions, and Data Sources

Variable	Notation	Operational Definition	Units	Main Source
National coal energy consumption	CCt	The amount of Indonesia's coal energy consumption in 2010.	Terajoule	BPS, Indonesian Energy Balance; Ministry of Energy and Mineral Resources
Economic Scale	ESEt	National real GDP which represents the volume of economic activity.	Billion rupiah ADHK 2010	BPS, Gross Domestic Product
Coal intensity	CIEt	The ratio of coal energy	Terajoules	Results of the author's

Variable	Notation	Operational Definition	Units	Main Source
Changes in coal consumption	ΔCC_t	consumption to national real GDP. The difference in coal consumption between year t and the base year/previous period.	per billion rupiah Terajoule	calculations Results of the author's calculations
Economic scale effect	ΔCC_t^{ESE}	The contribution of changes in real GDP to changes in coal consumption.	Terajoule	Laspeyres decomposition results
Coal intensity effect	ΔCC_t^{CIE}	The contribution of changes in coal intensity to changes in coal consumption.	Terajoule	Laspeyres decomposition results

Source: Research data processing results

Laspeyres Two-Factor Decomposition Model

The analytical framework refers to the basic identity that coal consumption is the result of multiplication between coal intensity and economic scale. At the national level, the identity is expressed as follows:

$$CC_t = CIE_t \times ESE_t \quad (2.1)$$

$$CC_t = \frac{CC_t}{PDB_t} \times PDB_t \quad (2.2)$$

$$\Delta CC_t = CC_t - CC_0 \quad (2.3)$$

$$\Delta CC_t = \Delta CC_t^{ESE} + \Delta CC_t^{CIE} \quad (2.4)$$

$$\Delta CC_t^{ESE} = \frac{1}{2} (CIE_t + CIE_0) (ESE_t - ESE_0) \quad (2.5)$$

$$\Delta CC_t^{CIE} = \frac{1}{2} (ESE_t + ESE_0) (CIE_t - CIE_0) \quad (2.6)$$

Equation (2.1) states that national coal consumption in year t is determined by coal intensity and economic scale. Equation (2.2) defines CIE as the ratio of coal consumption to real GDP, while ESE is represented by real GDP. Equation (2.3) shows the change in coal consumption between the base year and the reporting year. Equation (2.4) decomposes this change into two contributions, namely ΔCC_t^{ESE} and ΔCC_t^{CIE} . Equations (2.5) and (2.6) apply the principle of average values, such that the change in economic scale is multiplied by the average coal intensity, while the change in coal intensity is multiplied by the average economic scale.

In the annual implementation, the base year in Equations (2.3)–(2.6) is treated as the previous year (t–1). Thus, each annual interval yields the contribution of ESE, the contribution of CIE, and the change in total coal consumption. For the five-year analysis, the annual contributions were aggregated according to the 2000–2004, 2005–2009, 2010–2014, 2015–2019, and 2020–2024 periods. This periodization facilitates interpretation of the decomposition results within the context of the medium-term development policy regimes established under Proenas and RPJMN.

RESULTS AND DISCUSSION

Results

Descriptive Statistics of National Variables

Descriptive statistics show that national coal consumption underwent substantial changes during the observation period. The minimum value was 531,708 terajoules, while the maximum reached 6,823,092 terajoules. The average national coal consumption during 2000–2024 was 2,474,299 terajoules, with a standard deviation of 1,748,653 terajoules. The magnitude of this standard deviation indicates a high degree of dispersion around the mean, reflecting significant variability in annual coal consumption throughout the observation period. The existence of acceleration and correction phases is more clearly illustrated through the year-on-year analysis presented in Table 4 and Figure 1.

National real GDP, used as a proxy for economic scale, also increased substantially, ranging from 4,121,726 billion rupiah to 12,920,532 billion rupiah. Meanwhile, coal intensity ranged from

0.1137 to 0.5281 terajoules per billion rupiah, with an average of 0.2783 terajoules per billion rupiah. The wide range of coal intensity values confirms that changes in coal consumption are not merely a mechanical consequence of GDP growth. Changes in coal intensity therefore constitute an important component that must be analyzed separately.

Table 3*Descriptive Statistics of National Level Research Variables 2000–2024*

Variable	Units	Observations	Minimum	Maximum	Red	Std. Deviation
National Coal Energy Consumption	Terajoule	25	531.708	6.823.092	2.474.299	1.748.653
National Economic Scale (real GDP)	Billion Rupiah	25	4.121.726	12.920.532	7.946.521	2.766.707
National Coal Intensity	terajoules per billion rupiah	25	0,1137	0,5281	0,2783	0,1127

Source: Research data processing results

Annual Decomposition of Economic Scale Effect and Coal Intensity Effect

The results of the annual decomposition show that changes in Indonesia's coal consumption do not follow a single pattern. There are years when the ESE and CIE are both positive, years when the ESE is positive but the CIE is negative, and years when both components are negative. Because the ESE is mostly positive, economic growth generally continues to contribute to increases in coal consumption. However, the magnitude and direction of the total change are largely determined by the direction and magnitude of the CIE.

Cumulatively, national coal energy consumption increased by 6,272,042 terajoules during 2000–2024. This increase consists of an ESE contribution of 2,651,517 terajoules and a CIE contribution of 3,620,525 terajoules. In other words, approximately 57.7 percent of the total increase came from increasing coal intensity, while approximately 42.3 percent came from increasing economic scale. This finding is the main result of the article: Indonesia's national coal consumption is rising not primarily because the economy is growing, but because coal use per unit of real GDP has also increased substantially.

The annual pattern reveals several important points. The declines in 2001–2002 and 2002–2003 occurred when the negative CIE was greater in magnitude than the positive ESE. Conversely, the large increases in 2005–2006 and 2006–2007 were driven by a much larger positive CIE than ESE. The sharp declines in 2007–2008 and 2013–2014 again demonstrate the role of the CIE as a correction factor. In the final phase, particularly in 2021–2022, the CIE increased by 1,885,132 terajoules and became the main component of the 2,125,610-terajoule increase in coal consumption. This surge shows that the post-pandemic economic rebound, together with the increase in coal intensity, had a major impact on national coal consumption.

Table 4*Changes in National Coal Consumption for the Period 2000–2024 (Terajoule)*

Period	$\Delta C C t E s E$	$\Delta C C t c I E$	$\Delta C C t$
2000–2001	22.848	154.885	177.733
2001–2002	29.978	-127.857	-97.879
2002–2003	27.209	-126.405	-99.196
2003–2004	27.274	21.374	48.648
2004–2005	38.810	208.606	247.416
2005–2006	56.992	427.984	484.976
2006–2007	93.927	345.800	439.727
2007–2008	92.483	-442.115	-349.632
2008–2009	64.868	-2.984	61.884

Period	ΔCCtEsE	ΔCCtIE	ΔCCt
2009–2010	95.718	150.936	246.654
2010–2011	121.686	537.907	659.593
2011–2012	144.923	66.687	211.610
2012–2013	140.690	-104.702	35.988
2013–2014	115.755	-628.439	-512.684
2014–2015	104.786	88.086	192.872
2015–2016	116.453	30.769	147.222
2016–2017	124.437	17.434	141.871
2017–2018	151.926	714.671	866.597
2018–2019	181.575	334.360	515.935
2019–2020	-80.116	-181.380	-261.496
2020–2021	133.171	-229.099	-95.928
2021–2022	240.478	1.885.132	2.125.610
2022–2023	290.103	15.099	305.202
2023–2024	315.541	463.778	779.319
2000–2024	2.651.517	3.620.525	6.272.042

Source: Research data processing results

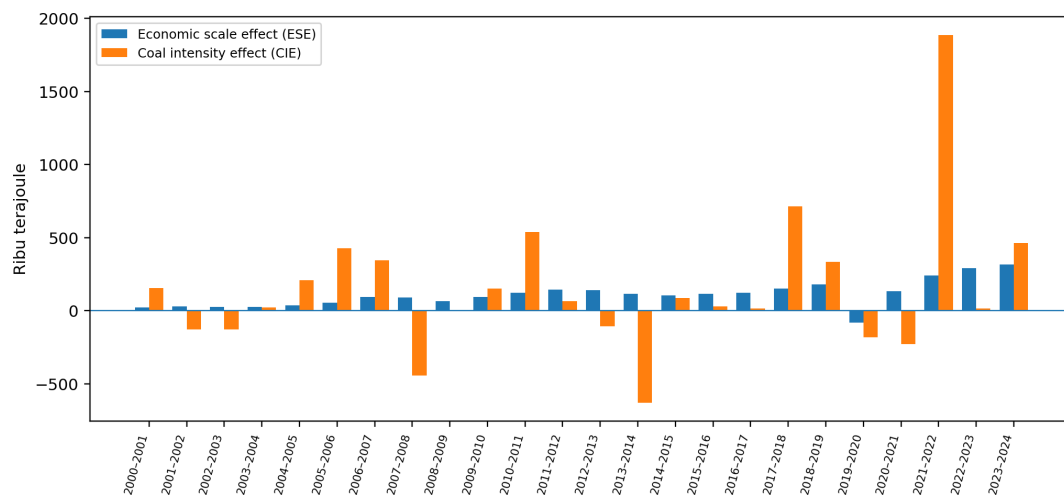


Figure 1. Trends in Coal Consumption at the National Level for the Period 2001–2024
Source: Results of research data processing.

Figure 1 makes it clear that the contribution of the CIE has a much greater amplitude than that of the ESE in many intervals. The ESE tends to move positively and more steadily because it follows real GDP growth, except in 2019–2020, when the pandemic suppressed economic activity. The CIE is more volatile: sometimes it is a strong driver of increases, while at other times it constrains consumption. CIE volatility shows that coal intensity is highly sensitive to changes in the energy mix, the structure of electricity supply, power plant utilization, and changes in production activities that use coal directly or indirectly.

This interpretation is important because energy policy often focuses on the requirements of economic growth and energy supply security. The decomposition results show that the main issue is not only how fast the economy grows, but also how the structure of economic growth affects coal use. If additional economic output becomes increasingly dependent on coal, economic growth will increase coal consumption more than proportionately. Conversely, if coal intensity decreases, the economy can continue to grow while requiring less additional coal consumption.

Five-Year Decomposition Based on Development Policy Period

Five-year aggregation is required to interpret the decomposition results within the development policy horizon. Indonesia uses medium-term planning documents, beginning with Proenas 2000–2004 and continuing through the 2020–2024 RPJMN. By dividing the annual results into five-year periods, changes in ESE and CIE contributions can be associated with changes in the orientation of development, infrastructure, industrialization, and energy policy.

The period 2000–2004 recorded an increase in coal consumption of 29,306 terajoules. The ESE was positive at 107,309 terajoules, while the CIE was negative at –78,003 terajoules. This means that economic growth contributed to an increase in coal consumption, but changes in coal intensity partially offset that increase. The period 2005–2009 shows a different pattern. Coal consumption increased by 884,371 terajoules, with an ESE of 347,081 terajoules and a CIE of 537,290 terajoules. The dominance of the CIE shows that the increase in coal consumption during this period was driven not only by economic growth but also by increased coal intensity.

The 2010–2014 period recorded an increase of 641,161 terajoules. The ESE contribution of 618,772 terajoules was the main component, while the CIE was only 22,389 terajoules. This pattern shows that coal consumption continued to increase, but the increase was mainly attributable to an expansion in economic scale rather than a sharp increase in coal intensity. The 2015–2019 period again showed the dominance of the CIE. Coal consumption increased by 1,864,497 terajoules, with an ESE of 679,178 terajoules and a CIE of 1,185,319 terajoules. In the 2020–2024 period, coal consumption increased by 2,852,707 terajoules, with an ESE of 899,177 terajoules and a CIE of 1,953,530 terajoules. This was the largest increase over the entire study period.

Table 5

Five-Year Decomposition of National Coal Consumption (Terajoule)

Period	ΔC_{tEsE}	ΔC_{tCIE}	ΔC_{tT}	Brief Interpretation
2000–2004	107.309	-78.003	29.306	ESE positive, CIE retains consumption increase
2005–2009	347.081	537.290	884.371	CIE is the main driver of the increase
2010–2014	618.772	22.389	641.161	ESE dominant, CIE relatively neutral
2015–2019	679.178	1.185.319	1.864.497	CIE is again the main channel of growth
2020–2024	899.177	1.953.530	2.852.707	Biggest increase, CIE is very dominant
2000–2024	2.651.517	3.620.525	6.272.042	CIE is greater than ESE cumulatively

Source: Research data processing results

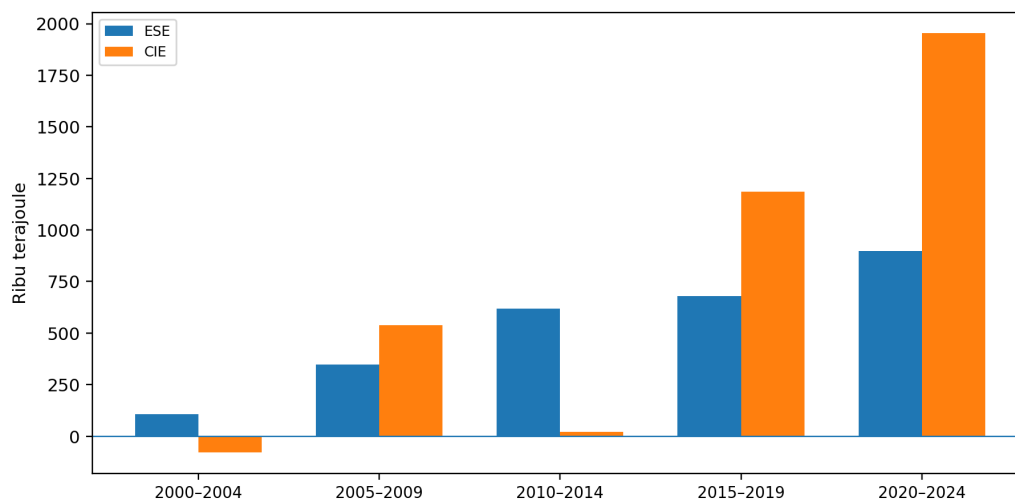


Figure 2. Trends in Coal Consumption Changes at the National Level for the Five-Year Period

Source: Research data processing results

Figure 2 shows the shift in the dominant components across periods. In 2000–2004, the CIE was negative, so the total increase was relatively small. In 2005–2009, the CIE became a major driver. In 2010–2014, the ESE became the largest component, while the CIE was almost neutral. The last two periods show a more concerning pattern, as both the ESE and CIE were positive, but the CIE was substantially larger. From a policy perspective, this pattern means that Indonesia's economic growth during 2015–2024 was still accompanied by a deepening of coal use, rather than merely an increase in energy demand resulting from greater economic output.

Discussion

From Decomposition Figures to Economic Meaning: Deepening Coal Intensity

The main finding of this article is that CIE contributed more than ESE to the increase in national coal consumption during 2000–2024. Mathematically, these results mean that changes in coal consumption do not simply follow the expansion of real GDP. Economically, this result is more important: Indonesia's economy has experienced a deepening of coal use per unit of output during several important phases. In other words, Indonesia's coal problem is not solely that the economy is growing and therefore requires more energy, but also that the energy structure supporting this growth continues to make additional output relatively coal-intensive.

If the increase in coal consumption mainly comes from ESE, then the main policy question is how to ensure that economic growth is accompanied by greater energy efficiency. However, as CIE becomes more dominant, the policy question becomes more structural: why does additional economic output require increasing amounts of coal? The answer cannot be found in GDP figures alone. CIE captures changes in the energy mix, the utilization of coal-fired power plants, technological efficiency, the quality of coal used, changes in electricity demand patterns, and the structure of production activities that are increasingly dependent on coal-based energy.

Kurniawan et al. (2020) provide an explanation that is consistent with these findings. In a multi-factor study of Indonesia, changes in the energy mix were the largest drivers of the increase in coal consumption, followed by changes in urban income, urbanization, and population. This article does not decompose CIE into all of these factors, but the results point in the same direction: the increase in coal consumption is not explained by output growth alone, but also by changes in the energy structure that make coal increasingly important in the national energy supply.

CIE's dominance also explains why energy policies based on additional supply alone are insufficient. As electricity and energy demand increase, the decision to meet those additional needs with coal may reduce short-term costs and strengthen supply resilience, but at the same time it increases coal intensity. Therefore, the decomposition results signal that energy policy needs to be evaluated not only by its success in meeting electricity demand and maintaining energy prices, but also by its ability to reduce coal consumption per unit of real GDP.

From the perspective of energy economics theory, the CIE dominance identified in this article has important implications for the concept of decoupling between economic growth and coal consumption. Decoupling—whether relative or absolute—requires energy intensity or emissions intensity to decline as output grows (Wang et al., 2018). The findings of this article indicate that Indonesia has not yet achieved decoupling; in fact, it experienced a “recoupling” of coal intensity during the 2015–2024 period, as output growth was accompanied by an increase in coal intensity, while the economic scale effect (ESE) remained smaller than the coal intensity effect (CIE). This is also relevant to the literature on energy efficiency: an increase in renewable generation capacity does not automatically transform the operational energy mix if the dispatch of coal-fired power plants remains dominant in the electricity system (Bhattacharyya, 2011). Furthermore, within the framework of sustainable economic growth, high coal intensity indicates that the quality of growth has not yet met the energy-efficiency requirements needed to support long-term growth without increasing environmental costs (Wei & Liao, 2016). Thus, the findings of this decomposition are relevant not only as an accounting analysis but also as empirical evidence for evaluating the extent to which Indonesia's energy policies are aligned with the principles of energy transition and sustainable economic growth.

Policy Period Reading: Why Does CIE Patterns Change Between Periods?

The period 2000–2004 can be interpreted as a post-crisis recovery phase in which economic expansion began to take place, but a coal-intensive growth pattern had not yet fully emerged. The positive ESE shows that the recovery in economic activity contributed to additional coal consumption. However, the negative CIE shows that the increase in output was not accompanied by a deepening of coal intensity. Substantively, this phase reflects the initial conditions of recovery, when the electricity system and industrial sector had not yet experienced the same acceleration in coal-based expansion as in the subsequent periods. Therefore, the increase in coal consumption remained relatively limited.

The period 2005–2009 marked an important change. CIE, at 537,290 terajoules, was greater than ESE, at 347,081 terajoules. This means that the additional coal consumption during

this period was driven more by an increase in coal intensity than by economic expansion. This phase coincided with increasing pressure on electricity demand and policy efforts to accelerate power-plant construction. In the Indonesian literature, Kurniawan et al. (2020) explain that the expansion of coal-fired power plants was a major factor in the increase in coal consumption, particularly following the implementation of the power-plant acceleration program. Thus, CIE's dominance during this period can be interpreted as an early sign of a shift in the energy supply structure toward greater reliance on coal.

The period 2010–2014 is more complex. On a five-year basis, ESE was the dominant component, while CIE was relatively small. However, the annual pattern suggests that this phase was not completely neutral. In 2010–2011, the positive CIE was very large, but it was subsequently offset by negative CIE in 2012–2013 and, especially, 2013–2014. BPS noted that in 2011, several new coal-fired power plants associated with the 10,000 MW Power Project began operating, and some of them used coal, thereby increasing coal demand (BPS, 2012). However, toward the end of the period, weakening commodity prices, macroeconomic adjustments, and shifts in economic activity patterns did not sustain the increase in intensity at the same magnitude as in the preceding phase. It should be noted that the causal relationships between commodity price movements, macroeconomic adjustments, and CIE have not been formally tested in this article; the interpretation is contextual and based on the temporal alignment of observed trends rather than on econometric inference. Therefore, the five-year CIE appears small not because Indonesia had moved away from coal dependence, but because the increase in intensity at the beginning of the period was partially offset by a correction toward the end of the period.

The 2015–2019 period was a phase in which coal intensity strengthened again. The increase in coal consumption of 1,864,497 terajoules was explained more by CIE, at 1,185,319 terajoules, than by ESE, at 679,178 terajoules. This phase coincided with massive infrastructure development, expansion of electricity capacity, and increased coal consumption for power generation. This dependence is also evident in PLN's power plants. Based on Fuel Consumption of PLN Power Plant data, PLN's coal consumption for power generation increased from 48.99 million tons in 2015 to 67.01 million tons in 2019, showing that the expansion of electricity supply during this period still relied heavily on coal as a fuel (Ministry of Energy and Mineral Resources, 2025). This fact reinforces the interpretation that economic growth and infrastructure development during this phase took place within an increasingly coal-centric energy structure.

The 2020–2024 period was the most decisive phase. Coal consumption increased by 2,852,707 terajoules, with CIE accounting for 1,953,530 terajoules and ESE for 899,177 terajoules. The COVID-19 pandemic suppressed real GDP in 2020 and reduced coal consumption. However, the post-pandemic economic recovery took place within an energy structure that had not changed substantially. In 2024, Indonesia's energy structure still showed a strong dependence on coal. The national primary energy supply mix was still dominated by coal, at 40.37 percent, while national electricity generation also remained heavily reliant on coal-fired power plants. This condition shows that the dynamics of national coal consumption cannot be understood solely as a consequence of economic growth, but also as a reflection of an energy supply structure that remains coal-based (Ministry of Energy and Mineral Resources, 2025; BPS, 2025). With such a structure, a rebound in output not only restores energy demand but can also magnify coal consumption per unit of output. CIE's dominance during 2020–2024 records this process particularly clearly.

Table 6

Economic-Energy Interpretation Matrix on Five-Year Decomposition Results

Period	Decomposition Pattern	Economic-Energy Context	Analytical Meaning
2000–2004	ESE positive, CIE negative	Post-crisis economic recovery; Energy expansion has not been entirely based on coal.	Growth began to increase consumption, but intensity held back the increase.
2005–2009	CIE is larger than ESE	The pressure on electricity demand and the change in the direction of energy supply towards coal are getting	Growth is starting to take place on an energy structure that is increasingly coal-intensive.

Period	Decomposition Pattern	Economic-Energy Context	Analytical Meaning
2010–2014	ESE dominant, CIE small	stronger. The beginning of the period is encouraged by the operation of new coal-fired power plants; The end of the period experienced an intensity correction.	A small CIE does not mean being separated from coal, but the results of eliminating each other between years.
2015–2019	CIE is dominant again	The expansion of infrastructure and electricity systems went hand in hand with the increase in coal consumption of power plants.	Economic development is supported by an increasingly coal-centric energy structure.
2020–2024	CIE is very dominant	The pandemic suppressed output, but a rebound occurred in energy structures that remained coal-based.	The economic recovery resulted in a surge in coal consumption due to increased intensity.

Source: Research data processing results

CIE Annual Volatility as an Indicator of Energy Structure Sensitivity

Annual readings provide information that is not visible in five-year aggregations. ESE is relatively stable because it follows changes in real GDP, whereas CIE moves much more sharply. This pattern suggests that national coal intensity is more sensitive to changes in the energy structure and economic shocks than to changes associated with economic scale. The years 2007–2008 and 2013–2014 showed large negative CIE values, whereas 2010–2011, 2017–2018, and 2021–2022 showed large positive CIE values. This means that changes in national coal consumption do not move mechanically with GDP but are also strongly influenced by changes in how energy is supplied and used.

The 2021–2022 surge is the most obvious example. CIE of 1,885,132 terajoules was the main component of the 2,125,610-terajoule increase in coal consumption. If the increase were mainly attributable to ESE, the explanation could be directed primarily toward the recovery of economic output. However, because CIE was much larger, the explanation must also consider the energy structure. The post-pandemic economic recovery restored electricity consumption and production activities, but the energy supply underpinning the recovery remained heavily reliant on coal. Therefore, the economic rebound also became a coal rebound.

With this approach to interpretation, CIE can be positioned as an early-warning indicator. An increase in CIE shows that the economy not only requires more energy but also uses coal more intensively to produce output. A decline in CIE indicates a relative improvement that may result from greater efficiency, substitution, changes in plant utilization, or changes in the structure of economic activity. Governments can use this indicator to assess whether energy policy is moving toward decoupling economic growth from coal consumption.

Position of Findings on Prior Literature

Compared with Tang et al. (2024), this article finds a stronger pattern on the intensity side. Tang et al. (2024) show that economic growth increases coal consumption in Pakistan, while the effects of changes in intensity are mixed. In the Indonesian context, a mixed pattern also occurs at the annual level, but cumulatively, CIE is greater than ESE. This difference suggests that Indonesia's coal dependence during 2000–2024 is related not only to economic expansion but also to a deepening of the coal-intensive structure of energy use.

Compared with Kurniawan et al. (2020), this article is narrower in terms of the number of factors considered but sharper in its interpretation of the two main macro-level components. Kurniawan et al. (2020) show that the increase in coal consumption is influenced by the energy mix, urbanization, urban income, and population. This article does not explicitly decompose these factors, but instead treats them as mechanisms that may be reflected in CIE and ESE. Urbanization and income growth can increase ESE through higher economic output and energy demand, while

a shift in the energy mix toward coal will be reflected in an increase in CIE.

Compared with Setyawan (2020), this article does not focus on energy efficiency in manufacturing but on national coal consumption. However, both studies share a common theme: the importance of intensity as an indicator of the quality of energy use. If Setyawan points out that manufacturing energy intensity can decrease because of efficiency improvements, this article shows that, at the national coal level, intensity is instead the main driver of the increase in consumption. This difference indicates that efficiency improvements in some economic activities have not been sufficient to reduce aggregate coal intensity when the national energy system continues to rely heavily on coal.

Thus, the contribution of this article is not limited to adding an Indonesian case study; it also sharpens the interpretation of policy implications. This article shows that the central question in Indonesia's coal policy is not simply "how much has coal consumption increased?" but rather "why is the increase occurring?" The decomposition results show that the main concern lies in coal intensity, particularly during 2015–2024. These findings provide several key insights that distinguish this article from analyses based solely on ordinary consumption trends.

On the other hand, it must be acknowledged that some findings in the literature are not entirely consistent with the results of this article. Apergis & Payne (2010) found that, in OECD countries, coal consumption and economic growth have a relatively neutral causal relationship in the long run, implying that changes in coal consumption are not necessarily attributable to intensity effects alone but may also reflect changes in the composition of energy demand. Meanwhile, Chen et al. (2022) found at the city level in China that coal intensity tends to decline in high-income cities, a pattern that differs from Indonesia, where intensity increased alongside national economic growth. This difference may be explained by variations in energy-mix structures, stages of industrialization, and policy commitments to the energy transition across countries. In the Indonesian context, the persistent dominance of CIE most likely reflects the electricity system's reliance on coal-fired power plants built on a massive scale since 2006, which has created a long-term technological lock-in that hampers the pace of decline in coal intensity. Identifying the explanatory factors behind these contextual differences is an important agenda for future research.

Policy Implications: Shifting Focus from Volume to Intensity

The decomposition results provide clear policy implications. Controlling coal consumption cannot be achieved by restraining economic growth. What needs to change is the way in which economic growth is supplied with energy. As long as additional output is produced within an energy system that is increasingly dependent on coal, economic growth will continue to generate substantial increases in coal consumption. Therefore, energy-transition policies must explicitly target reductions in CIE.

First, electricity planning needs to be assessed based on its impact on national coal intensity, not merely on supply adequacy. Additional low-carbon generation capacity must displace coal-fired generation in system operations, rather than simply increase nominal generation capacity. If low-carbon generation increases while the utilization of coal-fired power plants remains high, aggregate CIE will be difficult to reduce materially. Second, the efficiency and flexibility of the power system should be treated as instruments for reducing intensity, because reductions in system losses, improved dispatch, and greater integration of renewable energy will determine whether coal consumption per unit of output can be reduced.

Third, industrial policy needs to be linked to energy policy. Downstreaming, infrastructure development, and manufacturing expansion can increase value added, but if production processes and energy supplies remain coal-based, the resulting economic benefits will be accompanied by higher coal intensity. Therefore, industrial expansion needs to be accompanied by energy-efficiency standards, more energy-efficient process technologies, and improved access to investment in low-carbon technologies. Fourth, annual energy-policy evaluations should not report only the volume of coal consumption but should also separate the ESE and CIE components. This separation allows policymakers to distinguish between increases in consumption stemming from output expansion and increases stemming from changes in coal intensity.

The practical value of this article lies in the simplicity of its indicators. ESE and CIE can be used as medium-term policy-evaluation tools. If ESE increases while CIE decreases, the economy

is still growing while using coal relatively more efficiently. If both ESE and CIE increase, as occurred in 2015–2019 and 2020–2024, economic growth is taking place alongside a deepening of coal dependence. This second pattern should be a primary concern in the design of Indonesia's energy policy.

Table 7

Policy Implications Based on National Decomposition Results

Empirical Findings	Economic Meaning	Policy Risks	Priority Policy Directions
CIE is greater than ESE cumulatively	The increase in coal consumption mainly comes from deepening intensity, not just economic growth.	Economic growth is becoming increasingly coal-intensive.	Focus on reducing coal intensity through changes in energy mix, system efficiency, and low-carbon technologies.
ESE is relatively stable and generally positive	Rising real GDP continues to drive energy demand.	Energy needs increase when growth is not accompanied by efficiency and substitution.	Make sure the output expansion is supplied by the lower and lower carbon energy.
CIE is highly volatile between years	The structure of coal use is sensitive to shocks, supply policies, and changes in plant utilization.	Economic recovery could turn into a coal rebound.	Use CIE as an early warning in energy policy evaluation.
2020–2024 will be the largest phase of increase	The economic recovery takes place in a coal-based energy structure.	The energy transition has not been enough to contain the intensity of aggregate coal.	Accelerate coal-generation substitution, energy efficiency, and control coal-based expansion.

Source: The results of research data/compilation of authors based on thesis documents and related official publications.

CONCLUSION

This study concludes that the increase in Indonesia's national coal consumption during 2000–2024 was driven by both economic scale and coal intensity effects, with the coal intensity effect making the larger contribution. Total coal consumption increased by 6,272,042 terajoules, comprising 2,651,517 terajoules from the economic scale effect and 3,620,525 terajoules from the coal intensity effect. The five-year decomposition also reveals a nonlinear pattern, in which the coal intensity effect constrained consumption growth during 2000–2004, became the dominant driver during 2005–2009, weakened during 2010–2014, and regained dominance during 2015–2019 and 2020–2024. These findings indicate that Indonesia's increasing coal consumption cannot be attributed solely to economic expansion but also reflects the persistence and intensification of coal use per unit of economic output.

The findings imply that efforts to control coal consumption should not focus solely on moderating energy demand associated with economic growth but should also directly address coal intensity. Policy priorities should include transforming the national energy mix, improving electricity system efficiency, limiting additional coal-based capacity, and encouraging technological change and energy substitution in coal-intensive activities. The decomposition framework can also support policy evaluation by identifying whether changes in coal consumption originate primarily from economic expansion or changes in coal intensity. However, because the analysis is based on a two-factor deterministic decomposition, it does not explicitly identify the individual contributions of energy prices, the energy mix, technology, fiscal policies, or sectoral differences. Future research can therefore extend the analysis using multifactor decomposition or econometric approaches to examine the mechanisms underlying changes in coal intensity.

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AUTHOR CONTRIBUTION STATEMENT

Muhammad Aritama Juniarto: Conceptualization, methodology design, data collection, formal analysis, and writing—original draft preparation. Deni Kusumawardani: Literature review, validation of decomposition results, and intellectual contribution to the manuscript. All authors have read and agreed to the published version of the manuscript.

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