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Natural Monopoly and Tariff Regulation of Drinking Water Companies: A Theoretical Analysis from a Public Economics Perspective

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Abstract

This study aims to evaluate the drinking water tariff policy of PT Air Minum Giri Menang (Perseroda) by examining the relationship between natural monopoly characteristics, cost recovery, and consumer welfare during the 2021–2024 period. This study employs a quantitative approach using secondary data obtained from company annual reports, financial statements, operational performance reports, and relevant tariff documents. Data were collected through documentary research and analyzed using Average Cost (AC), Marginal Cost (MC), Cost Recovery Ratio (CRR), and consumer surplus and deadweight loss calculations based on a linear demand function estimated using Ordinary Least Squares (OLS). The results indicate that the company exhibits structural characteristics of a natural monopoly; however, its Average Cost increased from IDR 2,181.50/m³ in 2021 to IDR 2,796.11/m³ in 2024, while Non-Revenue Water (NRW) remained relatively high at 36–38%, indicating that operational efficiency has not been fully achieved. The CRR ranged from 141.47% to 143.39%, demonstrating that water revenue was sufficient to cover the costs included in the calculation. Furthermore, the theoretical monopoly scenario generated an estimated deadweight loss of IDR 100.91 billion, representing a potential upper-bound welfare loss rather than an actual loss experienced by consumers. These findings imply that tariff regulation should not focus primarily on increasing tariffs to achieve cost recovery, as this objective has already been met. Instead, policy should prioritize reducing water losses, improving operational efficiency, maintaining appropriate tariff oversight, and protecting low-income consumers through an affordable and equitable tariff structure. Future research should incorporate more detailed historical tariff data by customer category to improve the estimation of demand and consumer welfare.

INTRODUCTION

Drinking water is one of the essential public services that plays a crucial role in supporting public health, economic activities, and quality of life. The provision of drinking water through piped networks is not only concerned with water availability but also with the ability of communities to access safe, sustainable, and affordable services. In the provision of these services, tariffs play an important role because they constitute a source of revenue for financing a company's operations, maintenance, and network development, while simultaneously representing a cost borne by consumers. Therefore, drinking water tariff determination needs to consider both the interests of service providers and consumers' ability to pay.

The provision of piped drinking water has economic characteristics that distinguish it from many other goods and services. The construction of water treatment plants, distribution networks, reservoirs, and supporting infrastructure requires substantial initial investment. The magnitude of these fixed costs makes the concept of a *natural monopoly* relevant to explaining the provision of drinking water services. In economic theory, a natural monopoly refers to a condition in which a

single firm can serve the entire market demand at a lower cost than would be possible if the market were served by several firms. (Nauges and van den Berg, 2007) identified economies of scale and economies of density among most of the water utilities examined in their study. However, the existence of a single service provider is not, by itself, sufficient to establish that a firm constitutes a natural monopoly. Establishing the presence of a natural monopoly requires an analysis of the cost structure and production characteristics of the firm. Accordingly, this study employs the concept of natural monopoly as a theoretical foundation for understanding tariff-setting and water supply efficiency issues, rather than treating it as a status determined solely by the existence of a single provider.

Tariff-setting is important because two interests must be considered simultaneously. On the one hand, tariffs determine consumer expenditure and may influence the quantity of water consumed. On the other hand, tariff revenue is necessary to finance a company's operations, network maintenance, and service development. Under monopoly theory, a firm determines its output where marginal revenue (MR) equals marginal cost (MC), while the price is theoretically above marginal cost ($P > MC$). This differs from the socially efficient condition, which is theoretically achieved when price equals marginal cost ($P = MC$) (Harberger, 1954; Hotelling, 1938). However, marginal-cost pricing by a drinking water utility may not necessarily generate sufficient revenue to cover its substantial fixed costs. Consequently, tariff evaluation should not be based solely on whether tariffs are high or low; it should also examine the relationship among prices, consumption levels, service provision costs, and company revenue.

From the consumer's perspective, the implications of tariffs can be analyzed using consumer surplus. Consumer surplus represents the difference between the amount consumers are willing to pay for a good and the amount they actually pay. When tariffs change, price adjustments may affect the quantity of water consumed and the economic benefits received by consumers. In addition, deadweight loss (DWL) can be used to describe the loss of surplus resulting from a consumption allocation that differs from a benchmark condition considered efficient. (Harberger, 1995) explains that when prices exceed marginal costs, some surplus that could otherwise be generated through market transactions may be lost. In the context of drinking water services, analyses of consumer surplus and DWL need to be based on a demand function and clearly defined benchmark scenarios. This ensures that the results provide not only mathematical estimates but also meaningful economic interpretations.

Consumer welfare must also be considered alongside the company's ability to recover the costs of providing services. One indicator that can be used is the Cost Recovery Ratio (CRR), which measures the relationship between a company's revenue and the costs incurred in providing services. A CRR of 100% or higher indicates that the revenue included in the calculation is sufficient to cover the costs accounted for. However, the interpretation of the CRR depends heavily on the scope of revenue and costs included in the calculation. In this study, the CRR is calculated by comparing water revenue with total cost based on company data. Accordingly, the resulting CRR indicates the ability of water revenue to cover the costs included in the calculation; it does not automatically demonstrate that the company has achieved efficiency in all aspects of its operations. This distinction is important because a company may continue to face operational problems even when it is financially capable of covering its costs.

These issues are relevant to PT Air Minum Giri Menang (Perseroda), which provides piped drinking water services in Mataram City and West Lombok Regency. Based on the company's annual reports for 2021–2024, the number of customer connections increased from 149,307 in

2021 to 156,633 in 2024. However, during the same period, the volume of water sold declined from 29,117,398 m³ in 2021 to 27,995,228 m³ in 2024, after reaching its lowest point in 2023. Meanwhile, total cost increased from approximately IDR 113.27 billion in 2021 to IDR 129.41 billion in 2024. These developments indicate changes in the relationship among customer growth, water sales volume, and service provision costs that warrant consideration in tariff evaluation.

At the same time, PT Air Minum Giri Menang's water revenue increased from IDR 160.24 billion in 2021 to IDR 183.57 billion in 2024. The calculations in this study also indicate that the CRR remained above 100% throughout the research period, reaching 141.47% in 2021, 143.39% in 2022, 141.56% in 2023, and 141.85% in 2024. This means that, based on the definitions of revenue and costs adopted in this study, water revenue was financially sufficient to cover total cost. Nevertheless, the level of *Non*-Revenue Water (NRW) remained within the range of 36–38%. This condition indicates that a company's ability to recover costs does not necessarily mean that all aspects of water supply and distribution are operating efficiently.

These developments are important for tariff analysis because the realized average price of water also increased. Based on water revenue and the volume of water sold, the average price rose from IDR 5,503.18/m³ in 2021 to IDR 6,557.25/m³ in 2024. These figures represent average realized prices calculated from revenue and water sales volume, rather than official tariffs for any specific customer category. Meanwhile, complete historical tariff data covering all customer categories for 2021–2024 were not available in this study. Therefore, the relationship between price and the quantity of water sold is analyzed using the realized average price. This approach allows the study to assess the implications of tariffs for demand and consumer welfare without treating the average price as the official tariff applicable to all customers.

Previous studies on drinking water tariffs have examined these issues from various perspectives. (Istichori et al., 2018) highlighted the importance of implementing the *full cost recovery* principle in supporting the financial condition and investment sustainability of water utilities. In contrast, (Samosir et al., 2023) found that tariffs at the South Halmahera Regency Regional Drinking Water Company (PDAM) remained below the unit cost of water, preventing the company from achieving full cost recovery. (Andini & Nurhayati, 2022) and (Arifin et al., (2022) also identified differences between prevailing tariffs and water provision costs at regional drinking water companies. Meanwhile, (Müller, 2015) and (Klassert et al., 2018) demonstrated that changes in tariff structures can affect consumer welfare and the demand responses of different consumer groups. These studies indicate that drinking water tariff issues concern not only a company's ability to recover costs but also the consequences of tariff policies for consumers.

Although numerous studies have examined tariffs, costs, cost recovery, and consumer welfare, research integrating these aspects into a single analytical framework for regional drinking water utilities remains limited. The research gap lies not merely in the simultaneous use of several indicators but also in the effort to examine the relationship among tariff structures, the ability of revenue to cover costs, and the implications of tariffs for consumer welfare. Accordingly, this study investigates not only whether the company is able to achieve full cost recovery but also how this condition should be interpreted alongside changes in consumption and estimates of consumer welfare. This approach is expected to provide a more comprehensive understanding of the trade-offs between service affordability for consumers and the company's financial sustainability.

Based on this background, this study aims to evaluate the drinking water tariffs of PT Air Minum Giri Menang (Perseroda) by examining the relationship among cost structure, cost

recovery, and consumer welfare. Specifically, this study seeks to answer the following research questions:

1. Does PT Air Minum Giri Menang (Perseroda) exhibit the characteristics of a natural monopoly based on its cost structure and service scale during the 2021–2024 period?
2. Was PT Air Minum Giri Menang (Perseroda) able to achieve full cost recovery during the 2021–2024 period?
3. How does the prevailing tariff policy affect consumer surplus and consumers' deadweight loss?

In response to these questions, this study aims to analyze the natural monopoly characteristics of PT Air Minum Giri Menang (Perseroda), evaluate the company's ability to achieve full cost recovery through the CRR, and measure consumer surplus and deadweight loss associated with the prevailing tariff policy. Furthermore, this study is expected to provide insights into how drinking water tariff policies can be designed while taking economic efficiency, consumer welfare, and the company's financial sustainability into account.

METHODS

This study uses a quantitative approach. The quantitative approach is used to analyze water tariff efficiency and to calculate deadweight loss, consumer surplus, and the cost recovery ratio (CRR) at PT Air Minum Giri Menang (Perseroda). The analysis uses secondary data for 2021–2024, which makes it possible to describe the development of tariff policy, cost structure, water sales volume, and the company's financial performance over time. The company was selected to test whether it meets the characteristics of a natural monopoly based on monopoly theory, welfare economics, and the principle of cost recovery. The study uses secondary data obtained from the company's financial statements, performance reports, customer data, tariff data, volume of water sold, revenue, and operating costs for 2021–2024.

The object of the study is PT Air Minum Giri Menang (Perseroda), a regionally owned enterprise (Badan Usaha Milik Daerah) that provides piped drinking water services in Mataram City and West Lombok Regency. In addition, the study uses supporting documents, namely the Minister of Home Affairs regulation on guidelines for setting drinking water tariffs and relevant statistical publications. Data were collected through documentary research, namely by gathering, identifying, selecting, and compiling all data related to the research variables before the analysis was carried out. The data analysis was carried out in stages in line with the research objectives.

The first stage is a descriptive analysis to identify natural monopoly characteristics through economies of scale. This analysis examines trends in water production volume, the volume of water sold, the Non-Revenue Water (NRW) rate, and the company's cost structure over 2021–2024. Average Cost (AC) and Marginal Cost (MC) are then calculated. Average Cost is calculated using the following equation:

$$AC = \frac{TC}{Q}$$

where AC is the average cost (IDR/m³), *TC* is the total operating cost (IDR), and *Q* is the volume of water produced (m³). The Average Cost value indicates the average cost the company must incur to produce one cubic meter of water. Marginal Cost is then calculated using the following equation:

$$MC = \frac{\Delta TC}{\Delta Q}$$

where MC is the marginal cost (IDR/m³), ΔTC is the change in total operating cost, and ΔQ is the change in the volume of water sold. The Marginal Cost value indicates the additional cost arising from a change in the volume of water produced or sold. The AC and MC results are then used to identify natural monopoly characteristics based on the tendency of the company's average cost.

The second stage evaluates the level of full cost recovery by calculating the Cost Recovery Ratio (CRR) using the following equation:

$$CRR = \frac{\text{Revenue}}{\text{Total Operating Costs}} \times 100\%$$

The CRR value is used to measure the company's ability to cover all operating costs from the revenue it earns. If CRR ≥ 1, the company is considered to have achieved full cost recovery, whereas CRR < 1 indicates that the company's revenue has not been able to cover all operating costs.

The third stage measures the magnitude of consumer surplus and deadweight loss resulting from the prevailing tariff policy. The analysis begins by constructing a water demand function using a linear model:

$$Q = a - bP$$

where Q is the volume of water sold (m³), P is the water tariff (IDR/m³), and a and b are constants obtained through manual calculation based on tariff and volume of water sold data over 2021–2024. This demand function is used to describe the relationship between changes in the water tariff and customer consumption.

The next step is to construct the Marginal Revenue (MR) function. In monopoly theory, a firm maximizes profit where Marginal Revenue equals Marginal Cost, that is:

$$MR = MC$$

Once the monopoly output level is determined, the monopoly price is obtained from the demand function, so that the monopoly price lies above marginal cost ($P_m > MC$). Conversely, the socially efficient condition is reached when price equals marginal cost, that is:

$$P = MC$$

The comparison between the monopoly condition and the efficient condition is used to determine how far the tariff deviates from the optimal condition, the change in output, and its impact on consumer welfare.

Next, the level of consumer welfare is measured using Consumer Surplus (CS) with the following equation:

$$CS = \frac{1}{2}(P_{max} - P_{actual})Q_{actual}$$

where P_{max} is the maximum price consumers are willing to pay, P_{actual} is the actual tariff, and Q_{actual} is the actual quantity consumed. Consumer Surplus indicates the economic benefit consumers obtain by paying a price lower than their maximum willingness to pay.
The welfare loss resulting from monopoly tariff setting is calculated using Deadweight Loss (DWL) with the following equation:

$$DWL = \frac{1}{2}(P_m - MC)(Q_e - Q_m)$$

where P_m is the monopoly price, MC is marginal cost, Q_e is the output under the efficient condition, and Q_m is the output under the monopoly condition. Deadweight Loss indicates the amount of social welfare lost because the tariff is set above marginal cost, so that the output produced is lower than under the efficient condition.

The results of all analyses are then interpreted descriptively and comparatively by comparing the actual condition of PT Air Minum Giri Menang (Perseroda) with the efficient condition according to natural monopoly theory and welfare economics. The findings are then compared with previous studies to evaluate the efficiency of the company's tariff policy and to formulate policy recommendations that can improve economic efficiency, consumer welfare, and the company's financial sustainability.

RESULTS AND DISCUSSION

Company Profile and Operational Performance

PT Air Minum Giri Menang originated from the Regional Drinking Water Company (PDAM) of West Lombok Regency, established under West Lombok Regency Regional Regulation No. 6 of 1980. Even before it became a PDAM, a water supply system had been built in Mataram City in 1973 through a central government project to meet the community's need for clean water. As the population and the demand for water services grew, the company went through several institutional changes, from PDAM Menang Mataram and PDAM Giri Menang to its formal conversion in 2019 into PT Air Minum Giri Menang (Perseroda). The change in status was intended to improve corporate governance, strengthen financial performance, and raise service quality (PT Air Minum Giri Menang, 2024).

The number of customers rose steadily over the study period. The company served 149,307 connections in 2021, 151,983 in 2022, 154,892 in 2023, and 156,633 in 2024 (Table 1), an increase of 7,326 connections, or about 4.91%, over 2021–2024. This growth indicates rising demand for piped water services and success in expanding access, but it also challenges the company to maintain distribution continuity, water quality, and operational efficiency (Romano et al., 2021).

Table 1. Number of customers of PT Air Minum Giri Menang, 2021–2024

Year	Customers (connections)	Growth (%)
2021	149,307	1.06
2022	151,983	1.79
2023	154,892	1.91
2024	156,633	1.12

Source: Processed from the Annual Reports of PT Air Minum Giri Menang, 2021–2024.

Operational performance can be read from the volume of water produced and the volume of water sold, two indicators that reflect the company's ability to meet the community's water needs through production and distribution (Hasan, 2022). As Table 2 shows, production fell from 51,922,767 m³ in 2021 to 46,069,376 m³ in 2023 before rising slightly to 46,282,729 m³ in 2024. Water sold followed the same pattern, declining from 29,117,398 m³ in 2021 to 27,925,008 m³ in 2023 and recovering to 27,995,228 m³ in 2024. Although the 2024 recovery is small, it suggests that the company has tried to stabilize operations after the declines of earlier years.

Table 2. Operational performance of PT Air Minum Giri Menang, 2021–2024

Year	Water Production (m^3)	Water Sold (m^3)
2021	51,922,767	29,117,398
2022	47,251,629	28,455,363
2023	46,069,376	27,925,008
2024	46,282,729	27,995,228

Source: Processed from the Annual Reports of PT Air Minum Giri Menang, 2021–2024.

DISCUSSION

Natural Monopoly Characteristics

Non-Revenue Water (NRW)

Non-Revenue Water (NRW) is a key indicator of the operational efficiency of a water utility. It is the percentage of produced water that cannot be billed to customers because of physical or non-physical losses, so a high NRW signals an inefficient distribution system and can weaken both operational performance and financial sustainability. Table 3 shows that NRW at PT Air Minum Giri Menang fell from 38.15% in 2021 to 36.21% in 2023 but rose again to 36.50% in 2024. The increase is small, yet NRW stayed above 30% throughout the study period, so water loss remains a persistent challenge.

Table 3. Non-Revenue Water (NRW) of PT Air Minum Giri Menang (Perseroda), 2021–2024

Year	NRW (%)	Remarks
2021	38.15	Physical water loss remained the main cause.
2022	37.07	Still dominated by physical water loss, although declining.
2023	36.21	Still fairly high.
2024	36.50	Rising again due to network damage, meter reading errors, and illegal connections.

Source: Annual Reports of PT Air Minum Giri Menang (Perseroda).

According to the company's annual reports, the high NRW stems from physical losses caused by leaks in the distribution network and pipe damage, due both to the technical age of the

pipes and to external construction projects. Non-physical losses arise from customer meter-reading errors and illegal connections. To reduce losses, the company has established District Metered Areas (DMAs), practised active leakage control, replaced old pipes, improved meter accuracy, and monitored illegal connections. (Samosir et al., 2023) note that high water loss reduces the volume that can actually be billed and thereby affects the operating efficiency of water utilities. NRW control therefore underpins the cost-structure analysis that follows.

Total Cost (TC)

Total Cost (TC) is the full amount the company spends on providing water services in a period. This study uses the "total expenses" item reported in the 2021–2024 annual reports. As Table 4 and Figure 1 show, TC rose in every year, from IDR 113.27 billion in 2021 to IDR 129.41 billion in 2024.

Table 4. Total Cost (TC) of PT Air Minum Giri Menang, 2021–2024

Year	Total Cost (TC) (IDR)
2021	113,268,390,000
2022	116,979,501,787
2023	128,278,849,982
2024	129,408,586,827

Source: Processed from the Annual Reports of PT Air Minum Giri Menang, 2021–2024.

Figure 1.

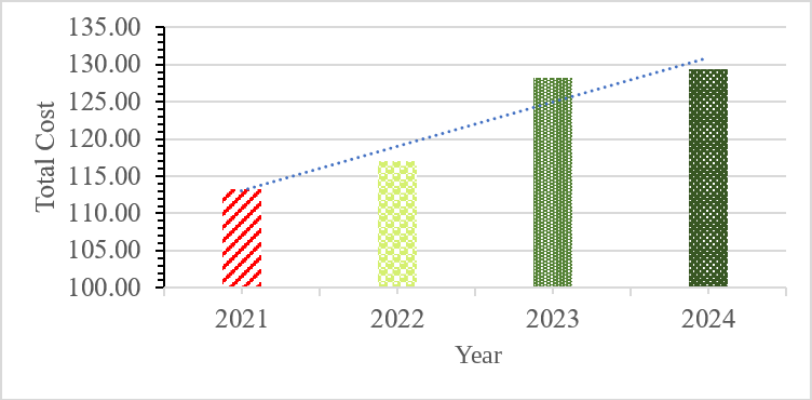


Figure 1. Total Cost of PT Air Minum Giri Menang, 2021–2024 (IDR billion). Source: Processed from the Annual Reports of PT Air Minum Giri Menang, 2021–2024. Note: the vertical axis starts at IDR 100 billion.

Costs climbed while production and water sold tended to fall, which suggests growing cost pressure. Plausible contributors include the maintenance and repair of the distribution network, the replacement of pipes past their technical life, higher energy costs, and the company's efforts to reduce NRW. In other words, the rise in operating costs has not yet been matched by a rise in the volume of water sold. (Samosir et al., 2023) stress that managing operating costs is essential to the efficiency of water utilities, because costs shape the ability to achieve financial sustainability and to apply tariffs consistent with full cost recovery.

Average Cost (AC)

Average Cost (AC) is the average cost of producing one cubic meter of water. It is

calculated by dividing TC by the volume of water produced (Q):

$$AC = \frac{TC}{Q}$$

where AC is average cost (IDR/m³), TC is total cost (IDR), and Q is the volume of water produced (m³). Table 5 shows that AC increased over the period, from IDR 2,181.50/m³ in 2021 to IDR 2,796.11/m³ in 2024. The largest increase occurred between 2022 and 2023, while the 2024 increase was comparatively small.

Table 5. Average Cost (AC) of PT Air Minum Giri Menang (Perseroda)

Year	Total Cost (IDR)	Water Production (m³)	Average Cost (IDR/m³)
2021	113,268,390,000	51,922,767	2,181.50
2022	116,979,501,787	47,251,629	2,475.65
2023	128,278,849,982	46,069,376	2,784.58
2024	129,408,586,827	46,282,729	2,796.11

Source: Processed from the Annual Reports of PT Air Minum Giri Menang, 2021–2024.

The rise in AC occurs because TC increased every year while production declined until 2023 and recovered only slightly in 2024, so the cost of each unit of output grew. Under the concept of economies of scale, a firm is efficient when a larger scale of production lowers its average cost. Here AC rose instead, which indicates that economies of scale have not been fully realized, because higher operating costs have not been followed by higher production. AC alone cannot settle whether the company is a natural monopoly, however, so the analysis turns to marginal cost.

Marginal Cost **(MC)**

Marginal Cost (MC) is the additional cost incurred when output changes by one unit. It is calculated from the change in TC and the change in water produced between periods:

$$MC = \frac{\Delta TC}{\Delta Q}$$

where MC is marginal cost (IDR/m³), ΔTC is the change in total cost (IDR), and ΔQ is the change in the volume of water produced (m³).

Table 6. Marginal Cost (MC) of PT Air Minum Giri Menang (Perseroda)

Year	ΔTC (IDR)	ΔQ (m³)	MC (IDR/m³)
2021	7,291,400,000	616,711	11,821.58
2022	3,711,111,787	-4,671,138	-794.48
2023	11,299,348,195	-1,182,253	-9,557.51
2024	1,129,736,845	213,353	5,295.13

Source: Processed from the Annual Reports of PT Air Minum Giri Menang, 2021–2024.

The results in Table 6 show that additional spending was not always accompanied by more production. In 2021, MC was positive because higher operating costs came with higher production

than in the previous year. In 2022 and 2023, MC turned negative because TC kept rising while production fell. In other words, the company spent more but could not raise output, and a persistently high NRW is one factor behind this: part of the water produced is lost to network leaks, pipe damage, meter-reading errors, and illegal connections, so higher spending does not translate into effective output. This is consistent with (Fransiska, 2022), who argues that the performance of a regional water utility depends not only on the resources it holds but also on the effectiveness of governance, regulatory implementation, and operational management. In 2024, MC became positive again as production increased, even though NRW remained relatively high. This value is carried forward as the marginal cost benchmark in the welfare analysis below.

Is the Company a Natural Monopoly?

A natural monopoly exists when a single firm can supply a good or service at lower cost than several firms could. The condition is typical of public utilities such as drinking water, where piped networks, treatment plants, reservoirs, and distribution systems require very large initial investment, so fixed costs are high and a larger scale of service is more efficient. (Baumol, Panzar, & Willig, 1988) define a natural monopoly as a situation in which one firm can meet total market demand at lower cost than any combination of firms, a condition usually shown by economies of scale, that is, average costs that fall or remain low at large scale.

The evidence on NRW, TC, AC, and MC shows that PT Air Minum Giri Menang matches the characteristics of a natural monopoly. The company bears a large operating cost to keep the water system running and is the only piped water provider in Mataram City and West Lombok Regency. From 2021 to 2024, TC rose continuously while production declined until 2023, so AC rose because total costs were spread over a smaller volume of output. MC was negative in 2022 and 2023 because costs rose without any increase in output, and NRW above 36% throughout the period meant that part of the water produced could not be used productively.

These results show that the natural monopoly character of the company is shaped not only by the size of its infrastructure investment but also by how well it manages operating costs and water losses. This agrees with (Fransiska, 2022) on the role of governance and operational management, and with (Samosir et al., 2023), who argue that the sustainability of PDAM services depends on operational efficiency that allows the cost of service to be covered by revenue. The company can therefore be classified as a natural monopoly: water supply requires heavy infrastructure investment, is inefficient if provided by more than one operator, and shows a close link between production cost, scale of service, and operational efficiency. The next step is to assess whether revenue covers these costs.

Full Cost Recovery

Water Revenue

Water revenue is the income the company earns from supplying water to customers and is an important indicator of its ability to finance operations. Table 7 shows that revenue increased from IDR 160.24 billion in 2021 to IDR 183.57 billion in 2024, even though the volume of water sold tended to fall over the same period. Revenue is therefore driven not only by the volume sold but also by the tariff structure and the composition of customers. To judge whether this revenue is sufficient, it must be compared directly with TC through the Cost Recovery Ratio (CRR).

Table 7. **.** Water revenue of PT Air Minum Giri Menang, 2021–2024

Year	Water Revenue (IDR)
2021	160,238,143,887
2022	167,732,546,368
2023	181,593,265,609
2024	183,571,588,435

Source: Annual Reports of PT Air Minum Giri Menang, 2021–2024.

Cost Recovery Ratio **(CRR)**

The CRR measures the ability of revenue to cover the cost of providing water services. It is calculated as water revenue divided by TC:

$$CRR = \frac{\text{Revenue}}{\text{Total Cost}} \times 100\%$$

Table 8. Cost Recovery Ratio of PT Air Minum Giri Menang, 2021–2024

Year	Water Revenue (IDR)	Total Cost (IDR)	CRR (%)
2021	160,238,143,887	113,268,390,000	141.47
2022	167,732,546,368	116,979,501,787	143.39
2023	181,593,265,609	128,278,849,982	141.56
2024	183,571,588,435	129,408,586,827	141.85

Source: Processed from the Annual Reports of PT Air Minum Giri Menang, 2021–2024.

The CRR was above 100% in every year: 141.47% in 2021, 143.39% in 2022, 141.56% in 2023, and 141.85% in 2024. Theoretically, a CRR above 100% means revenue is sufficient to cover all the costs of providing the service (full cost recovery), so the company can finance its operations without a revenue shortfall. The ratio also stayed relatively stable above 140%, which is important for the sustainability of a public service provider because adequate revenue supports operations, maintenance, and continuity of service. This finding is in line with (Samosir et al., 2023), who treat the ability of tariffs and revenue to cover service costs as a central criterion for assessing PDAM tariffs under the full cost recovery principle.

Achieving full cost recovery, however, should not be equated with full efficiency. With NRW at 36–38%, a share of the water produced still does not become revenue. The company's ability to cover its costs therefore rests more on the prevailing tariff structure than on efficient management of production and distribution. Reducing NRW remains necessary so that financial sustainability does not depend solely on tariff adjustments but is also supported by better overall operational performance. Overall, the CRR results show that the company has balanced revenue and operating costs within a full cost recovery framework, although room for improvement

remains on the efficiency side. The next section turns to the other side of tariff policy, its effect on consumer welfare.

Consumer Surplus and Deadweight Loss

Water Triff Structure

The tariff structure of PT Air Minum Giri Menang differentiates prices by customer group and consumption level (Table 9). In this study, the 2026 structure serves only as a general illustration of how the company sets tariffs; it is not the historical tariff for the 2021–2024 study period. Tariffs are divided into four consumption blocks (0–10 m³, 11–20 m³, 21–30 m³, and above 30 m³), and for most customer groups the tariff rises with the volume consumed. Tariffs also differ across groups within the same block. In the 0–10 m³ block, for example, they range from IDR 3,950/m³ for Household A to IDR 14,250/m³ for Large Business, and in the block above 30 m³ they range from IDR 8,350 to IDR 29,650/m³.

Table 9. Water tariff structure of PT Air Minum Giri Menang, 2026 (IDR/m³)

Code	Customer Group	0-10 m^3	11-20 m^3	21-30 m^3	>30 m^3
2A	Household A	IDR 3,950	IDR 4,850	IDR 6,250	IDR 8,350
2B	Household B	IDR 4,300	IDR 5,200	IDR 6,650	IDR 8,750
2C	Household C	IDR 4,950	IDR 6,100	IDR 7,750	IDR 10,150
2D	Household D	IDR 7,750	IDR 10,200	IDR 15,950	IDR 26,150
2E	Household E	IDR 7,900	IDR 11,750	IDR 18,250	IDR 29,650
3A	District/City Government Agencies	IDR 8,650	IDR 10,000	IDR 12,150	IDR 15,450
3B	Provincial Government Agencies	IDR 8,950	IDR 12,450	IDR 17,500	IDR 25,350
3C	Micro Business	IDR 7,600	IDR 9,700	IDR 12,650	IDR 16,900
3D	Small Business	IDR 7,700	IDR 10,150	IDR 13,900	IDR 19,300
3E	Medium Business	IDR 7,800	IDR 10,850	IDR 15,850	IDR 25,550
3F	Budget (Melati) Hotel	IDR 8,950	IDR 12,650	IDR 18,250	IDR 29,150
3G	Large Business	IDR 14,250	IDR 16,950	IDR 21,850	IDR 29,250

Source: PT Air Minum Giri Menang (Perseroda), 2026.

Economically, this differentiation matters for welfare analysis because prices shape the relationship between price (P) and quantity consumed (Q). The structure is therefore used as the basis for choosing a price approach in the demand function, which in turn feeds the analysis of marginal revenue, consumer surplus, and deadweight loss.

Water Demand Function

A demand function describes the relationship between the price of water and the quantity consumers demand. By the law of demand, price and quantity demanded are negatively related, *ceteris paribus*. For a water utility, tariff changes depend not only on customers' ability to pay but also on the cost of providing the service and the principle of full cost recovery (Mahmudah, 2016).

Because complete historical tariff data by customer group for 2021–2024 are not available, this study uses the realized average price of water, calculated as water revenue divided by the volume of water sold:

$$P_t = \frac{R_t}{Q_t}$$

where P_t is the average price of water (IDR/m³), R_t is water sales revenue (IDR), and Q_t is the volume of water sold (m³). For 2021, for example,

$$P_{2021} = \frac{160{,}238{,}143{,}887}{29{,}117{,}398} = 5{,}503.18 \text{ IDR/m3}$$

This is the average price actually realized across all sales in that year, not the official tariff of any customer group (Table 10).

Table 10. Average realized price of water

Year	Revenue (IDR)	Water Sold (m³)	Average Price (IDR/m³)
2021	160,238,143,887	29,117,398	5,503.18
2022	167,732,546,368	28,455,363	5,894.58
2023	181,593,265,609	27,925,008	6,502.89
2024	183,571,588,435	27,995,228	6,557.25
Σ	693,135,544,299	113,492,997	24,457.896

Source: Processed from the Annual Reports of PT Air Minum Giri Menang, 2021–2024.

The relationship between average price and water sold is estimated with a simple linear regression, $Q = a - bP$, using Ordinary Least Squares (OLS), where a is a constant and b is the change in water sold associated with a change in price. The negative sign reflects the inverse relationship between price and quantity demanded. Table 11 gives the inputs for the estimation, with $n = 4$ observations.

Table 11. Inputs for demand estimation

Year	P	Q	P^2	$P \times Q$
2021	5,503.175	29,117,398	30,284,937.783	160,238,143,887
2022	5,894.585	28,455,363	34,746,128.369	167,732,546,368
2023	6,502.890	27,925,008	42,287,583.166	181,593,265,609
2024	6,557.246	27,995,228	42,997,471.176	183,571,588,435
Σ	24,457.896	113,492,997	150,316,120.493	693,135,544,299

Source: Processed from the Annual Reports of PT Air Minum Giri Menang, 2021–2024.

The coefficient b is calculated by:

$$b = \frac{(\sum P)(\sum Q) - n \sum P\,Q}{(\sum P)^2 - n(\sum \sum P^2)}$$

$$b = \frac{(24{,}457.896)(113{,}492{,}997) - 4(693{,}135{,}544{,}299)}{4(150{,}316{,}120.493) - (24{,}457.896)^2}$$

$$b = 1{,}059.1493$$

And:

$$\bar{P} \frac{\Sigma P}{n}$$

$$\bar{P} = \frac{24{,}457.896}{4} = 6{,}114.474$$

$$\bar{Q} = \frac{\Sigma Q}{n}$$

$$\bar{Q} = \frac{113{,}492{,}997}{4} = 28{,}373{,}249.25$$

The calculation results show an average price of IDR 6,114.474/m³ and an average volume of water sold of 28,373,249.25 m³ over 2021–2024.
Because the demand equation takes the form $Q = a - bP$, at the mean point $\bar{Q} = a - b\bar{P}$ holds, so the value of a can be obtained by rearranging the equation to:

$$a = \bar{Q} + b\bar{P}$$
$$a = 28{,}373{,}249.25 + (1{,}059.1493)(6{,}114.474)$$
$$a = 28{,}373{,}249.25 + 6{,}476{,}140.89$$
$$a = 34{,}849{,}390.14$$

Thus, the water demand function is:

$$Q = 34{,}849{,}390.14 - 1{,}059.1493P$$

The price coefficient indicates a negative relationship between average price and volume sold: a price increase of IDR 1/m³ is associated with a decrease of about 1,059 m³ in water sold, other factors constant. This agrees with the law of demand. Because water is a basic necessity, however, demand is also shaped by other factors such as the number of customers, consumption needs, economic activity, and service and network conditions. To judge how well the model fits the data, the predicted values ($\hat{Q}$) were calculated for each year, as shown in Table 12.

Table. 12 Predicted demand and residuals

Year	P (IDR/m³)	$\hat{Q}$ (predicted, m³)	Q actual (m³)	Residual (Q − $\hat{Q}$)
2021	5,503.175	29,020,706.13	29,117,398	+96,691.87
2022	5,894.585	28,606,144.52	28,455,363	−150,781.52
2023	6,502.890	27,961,858.73	27,925,008	−36,850.73
2024	6,557.246	27,904,287.61	27,995,228	+90,940.39

Source: Processed from the Annual Reports of PT Air Minum Giri Menang, 2021–2024.

The sum of squared errors is:

$$SSE = \Sigma(Q - \hat{Q})^2$$
$$SSE = 96{,}691.87^2 + (-150{,}781.52)^2 + (-36{,}850.73)^2 + 90{,}940.39^2$$
$$SSE = 41{,}712{,}585{,}302.45$$

Next, the Sum of Squares Total (SST) is calculated by summing the squared differences between each actual Q value and its mean ($\bar{Q}$ = 28,373,249.25):

$$SST = \Sigma(Q - \bar{Q})^2$$
$$SST = 744{,}148.75^2 + 82{,}113.75^2 + (-448{,}241.25)^2 + (-378{,}021.25)^2$$
$$SST = 904{,}320{,}313{,}718.75$$

The SSE and SST values are then used to calculate the coefficient of determination (R^2) as follows.

$$R^2 = 1 - \frac{SSE}{SST} = 1 - \frac{41{,}712{,}585{,}302.45}{904{,}320{,}313{,}718.75} = 0.9539$$

An R^2 of 95.38% indicates that the model describes the pattern between average price and water sold during 2021–2024 very closely. It should not be read as a causal relationship, because the model uses only four annual observations and omits other factors that influence demand. In microeconomic terms, the result shows that water demand still follows the basic law of demand, although water's status as a necessity limits consumers' ability to cut consumption when prices rise. This matters for a natural monopoly: the supplier holds a strong market position while consumers continue to need the service. (Mahmudah, 2016) likewise emphasizes that PDAM tariffs should be adjusted with the cost of service in mind so that service remains sustainable, which means the demand function is useful not only for showing how quantity responds to price but also for assessing how pricing affects efficiency and consumer welfare.

For the marginal revenue analysis, the demand function is rearranged so that price is a function of quantity (the inverse demand function):

$$P = \frac{34{,}849{,}390.14 - Q}{1{,}059.1493} = 32{,}903.19 - 0.000944154\,Q$$

***Marginal Revenue* (MR)**

In monopoly theory, Marginal Revenue (MR) is the additional revenue from selling one more unit of output. A firm in perfect competition is a price taker, so $P = MR$. A monopolist faces a downward-sloping demand curve, so $MR < P$: selling more requires lowering the price on the units sold. This is one source of allocative inefficiency in monopoly, because the firm's output decision no longer follows the efficient market condition (Harberger, 1995). From the inverse demand function, Total Revenue is:

$$TR = P \times Q$$
$$TR = (32{,}903.19 - 0.000944154\,Q)Q$$
$$TR = 32{,}903.19\,Q - 0.000944154\,Q^2$$

and differentiating with respect to Q gives:

$$MR = \frac{dTR}{dQ}$$

$$MR = 32{,}903.19 - 2(0.000944154)Q$$

Thus:

$$MR = 32{,}903.19 - 0.001888308Q$$

The intercept of MR equals that of the inverse demand function (IDR 32,903.19/m³), while its slope is twice as steep (−0.001888308 versus −0.000944154). The more water the company sells, the lower the additional revenue from each extra unit, which matches the behavior of a monopolist facing falling demand.

The MR function should be understood as a theoretical device, not as evidence that the company actually sets prices to maximize profit. Water is a basic service, and PDAM tariffs also take into account the cost of provision and the sustainability of service. (Mahmudah, 2016) shows, for example, that PDAM tariff setting should consider all production costs through full costing and the full cost recovery principle. The MR function is therefore used to build a theoretical monopoly equilibrium (*MR = MC*), which is then compared with the efficient condition to analyze consumer welfare.

***Monopoly Equilibrium* (MR = MC)**

A profit-maximizing monopolist produces where MR equals MC. At that point price is theoretically above marginal cost, and the resulting markup, a consequence of market power, can produce deadweight loss (Harberger, 1995). The MC values for 2021–2024 are IDR 11,821.58, −794.48, −9,557.51, and 5,295.13 per m³. The negative values in 2022 and 2023 are a by-product of discrete marginal cost calculation when the change in quantity is negative. The 2024 MC of IDR 5,295.13/m³, the last observation and the only recent positive value, is therefore used as the reference MC. Setting MR = MC gives:

$$MR = MC$$
$$32{,}903.19 - 0.001888308Q = 5{,}295.13$$
$$0.001888308Q = 27{,}608.06$$
$$Q_m = 14{,}620{,}528 \text{ m}^3$$

and the theoretical monopoly price from the demand function is:

$$P_m = 32{,}903.19 - 0.000944154\ (14{,}620{,}528)$$
$$P_m = 0.000944154 \times 14{,}620{,}528 = 13{,}804.03$$
$$P_m = 32{,}903.19 - 13{,}804.03$$
$$P_m = IDR19{,}099.16/\text{m}^3$$

In the theoretical monopoly scenario, then, the company would choose an output of 14.62 million m³ at a price of IDR 19,099.16/m³, which exceeds the reference MC of IDR 5,295.13/m³ by a markup of about IDR 13,804.03/m³.

This result should not be read as evidence that the company applies pure monopoly pricing. The theoretical monopoly price is far higher than the actual average prices of IDR 5,503.18–6,557.25/m³ realized in 2021–2024, which shows that the company's actual tariff mechanism is not oriented solely toward profit maximization. This is consistent with an industry that is both a natural monopoly and a public service, where tariffs must account for cost of

provision, affordability, service sustainability, and full cost recovery (Mahmudah, 2016; Nauges & van den Berg, 2007). The MR = MC condition is thus a theoretical benchmark rather than an estimate of the company's optimal actual tariff. A further limitation is that only four observations are available and annual changes in quantity can make MC unstable. The scenario still serves to show analytically how profit-maximizing monopoly behavior differs from a water tariff mechanism that pursues both economic and social objectives.

Efficient Condition **(P = MC)**

In welfare economics, the efficient condition is reached when the price consumers are willing to pay equals the marginal cost of supplying one more unit ($P = MC$). Output is set where $MR = MC$ under monopoly and where $P = MC$ under efficiency, and the difference between the two points indicates the potential change in consumer welfare and deadweight loss (Harberger, 1995). Equating the inverse demand function to the reference MC gives:

$$P = 32{,}903.19 - 0.000944154\,Q$$

Meanwhile, the 2024 *MC* is used as the reference *MC* of:

$$MC = \text{IDR } 5{,}295.13/\text{m}^3$$

To obtain the output at the efficient condition (Q_e), the price in the demand function is set equal to *MC*:

$$P = MC$$

Thus:

$$32{,}903.19 - 0.000944154\,Q = 5{,}295.13$$

Next, the constant and *MC* are moved to different sides:

$$32{,}903.19 - 5{,}295.13 = 0.000944154Q$$
$$27{,}608.06 = 0.000944154Q$$

Then both sides are divided by the coefficient of Q:

$$Q_e = \frac{27{,}608.06}{0.000944154}$$
$$Q_e = 29{,}241{,}056 \text{ m}^3$$

After Q_e is obtained, the efficient price (P_e) can be found by substituting Q_e back into the demand function:

$$P_e = 32{,}903.19 - 0.000944154\,(29{,}241{,}056)$$
$$P_e = IDR5{,}295.13/\text{m}^3$$

At this output the efficient price is P_e = IDR 5,295.13/m³, which equals MC, so the last unit of water consumed yields a benefit equal to its cost of provision. Compared with the

monopoly scenario (Q_m = 14,620,528 m³ and P_m = IDR 19,099.16/m³), the efficient condition yields twice the output at a much lower price.

Consumer Surplus **(CS)**

Consumer Surplus (CS) measures the economic benefit consumers receive from water at a given price and output. It matters here because the study examines not only the company's natural monopoly character but also what that structure implies for consumer welfare; theoretically, when price rises and output is restricted, consumers keep a smaller share of the benefit (Harberger, 1995). The maximum price on the demand curve (the price intercept) is IDR 32,903.19/m³, and CS is calculated as:

$$CS = \frac{1}{2}(P_{\max} - P_{\text{actual}})Q_{\text{actual}}$$

Under monopoly (P_m = IDR 19,099.16/m³; Q_m = 14,620,528 m³):

$$CS_m = \frac{1}{2}(32{,}903.19 - 19{,}099.16)(14{,}620{,}528) = \text{IDR } 100{,}911{,}103{,}563.92$$

Under the efficient condition (P_e = IDR 5,295.13/m³; Q_e = 29,241,056 m³):

$$CS_e = \frac{1}{2}(32{,}903.19 - 5{,}295.13)(29{,}241{,}056) = \text{IDR } 403{,}644{,}414{,}255.68$$

CS_e exceeds CS_m by IDR 302,733,310,691.76, or about IDR 302.73 billion. If the company set output and price like a pure monopolist, consumers would theoretically face a higher price and receive a lower volume of service, so the economic benefit they obtain would be smaller. This reinforces the study's aim of analyzing the welfare consequences of natural monopoly: even though a natural monopoly can be justified by the network and infrastructure that water supply requires, the supplier's market power can still erode consumer surplus unless it is accompanied by appropriate tariff regulation. CS_m and CS_e are theoretical benchmarks for the difference in consumer benefit between the two conditions, not measures of the actual surplus of each customer group.

Deadweight Loss **(DWL)**

Deadweight Loss (DWL) is the potential economic welfare loss that occurs when output is below the efficient output level. In this study, DWL is used to see the potential welfare loss from the difference between the monopoly condition and the efficient condition in the clean water supply of PT Air Minum Giri Menang. According to (Harberger, 1995), monopoly power can cause resource allocation to move away from the efficient condition because the firm has an incentive to restrict output and set prices above marginal cost.

Based on the previous results, the monopoly condition yields:

$$Q_m = 14{,}620{,}528 \text{ m}^3$$
$$P_m = IDR19{,}099.16/\text{m}^3$$

Whereas the efficient condition yields:

$$Q_e = 29{,}241{,}056 \text{ m}^3$$
$$MC = \text{IDR } 5{,}295.13/\text{m}^3$$

DWL is calculated as the area between the demand curve and marginal cost over the output range
from Q_m to Q_e:

$$DWL = \frac{1}{2}(P_m - MC)(Q_e - Q_m)$$

$$DWL = \frac{1}{2}(19{,}099.16 - 5{,}295.13)(29{,}241{,}056 - 14{,}620{,}528)$$

$$DWL = \frac{1}{2}(13{,}804.03)(14{,}620{,}528)$$

$$DWL = IDR 100{,}911{,}103{,}563.92$$

The results suggest a potential welfare loss of IDR 100.91 billion under the theoretical monopoly scenario, associated with an output gap of 14,620,528 m³ between monopoly and efficient conditions. This indicates that some output, which could generate greater benefits for consumers than its marginal cost, is not provided because the firm determines output based on MR = MC.

This finding is consistent with (Larassati et al., 2024), who explain that monopoly can generate economies of scale and support investment, but may also lead to inefficiency, higher prices, and social welfare problems. For PT Air Minum Giri Menang, a natural monopoly is economically justified because water pipeline networks require substantial investment, and a single provider can avoid infrastructure duplication. However, economies of scale do not automatically guarantee optimal outcomes for consumers. Therefore, tariff regulation and effective oversight are necessary to maintain efficiency while ensuring affordability and public welfare. The IDR 100.91 billion figure represents an estimated potential welfare loss in a theoretical scenario, not an actual financial loss incurred by the company.

Implications for Tariff Policy

The findings indicate that PT Air Minum Giri Menang has the characteristics of a natural monopoly because piped water services require substantial infrastructure investment. However, comparing the theoretical monopoly scenario (*Pm* = IDR 19,099.16/m³; *Qm* = 14,620,528 m³) with the efficient scenario (*Pe* = IDR 5,295.13/m³; *Qe* = 29,241,056 m³) suggests a potential welfare loss of IDR 100.91 billion if the company maximizes monopoly profits. This highlights the importance of tariff regulation to protect consumer welfare (Larassati et al., 2024).

In practice, the average realized tariff increased from approximately IDR 5,503/m³ in 2021 to IDR 6,557/m³ in 2024, remaining far below the theoretical monopoly price and relatively close to the efficient price. Therefore, the estimated deadweight loss (DWL) represents a potential risk under a theoretical scenario rather than an actual loss currently experienced by consumers. Regional authorities should continue monitoring tariffs to prevent excessive price increases.

Regarding financial sustainability, the Cost Recovery Ratio (CRR) remained above 140% throughout 2021–2024, indicating that revenue exceeded operating costs (Istichori et al., 2018). Thus, substantial tariff increases solely to achieve cost recovery are not necessary. Instead, the available financial surplus should support operational improvements, particularly reducing non-revenue water (NRW), which remained at 36–38%. NRW contributes to higher average costs, increasing from IDR 2,181.50/m³ in 2021 to IDR 2,796.11/m³ in 2024. Accordingly, tariff

adjustments, if necessary, should be accompanied by measurable NRW reduction targets to improve efficiency rather than shifting operational costs to consumers (Nauges & van den Berg, 2007).

Consumer protection should also remain central to tariff policy. The existing block tariff structure should be reviewed periodically to ensure that basic water consumption remains affordable, particularly for low-income households (Klassert et al., 2018; Müller, 2015). Progressive tariffs and cross-subsidies from commercial and industrial customers can help prevent future tariff increases from disproportionately burdening vulnerable households.

Overall, tariff policy at PT Air Minum Giri Menang should prioritize three measures: maintaining reasonable tariff levels through effective regulatory oversight, directing financial surpluses toward operational efficiency and NRW reduction, and preserving a progressive tariff structure to protect low-income consumers. This approach can balance cost efficiency, financial sustainability, and consumer welfare in Mataram City and West Lombok Regency.

CONCLUSION

This study evaluated the drinking water tariff policy of PT Air Minum Giri Menang (Perseroda) over 2021–2024 by linking cost structure, cost recovery, and consumer welfare. First, the company shows natural monopoly characteristics. Piped water supply requires large infrastructure investment, so service by a single provider is more efficient than by several providers. However, Average Cost actually rose from IDR 2,181.50/m³ in 2021 to IDR 2,796.11/m³ in 2024, because Total Cost increased from IDR 113.27 billion to IDR 129.41 billion while production volume tended to decline. This means that economies of scale have not been optimally exploited. One cause is the Non-Revenue Water (NRW) rate, which remains in the range of 36–38%.

Second, the company's water revenue achieved full cost recovery in all periods studied. The Cost Recovery Ratio (CRR) was in the range of 141.47%–143.39%, so water revenue was able to cover Total Cost. This achievement does not yet show comprehensive operational efficiency, because part of the water produced has not generated revenue owing to the high NRW. The ability to cover costs is supported more by the tariff structure than by production and distribution efficiency.

Third, the estimated demand function (Q = 34,849,390.14 − 1,059.1493P, with an R^2 of 95.38%) is used to compare the theoretical monopoly condition ($MR = MC$) with the efficient condition ($P = MC$). In the monopoly scenario, an output of 14.62 million m³ is sold at a price of IDR 19,099.16/m³. In the efficient condition, output reaches 29.24 million m³ at a price of IDR 5,295.13/m³. The difference in consumer surplus between the two conditions is about IDR 302.73 billion, with a deadweight loss of IDR 100.91 billion. This value is the potential welfare loss in a theoretical scenario (upper bound), not an actual loss to consumers. The realized average prices (IDR 5,503.18/m³ in 2021 and IDR 6,557.25/m³ in 2024) are far below the theoretical monopoly price and relatively close to the efficient price. The company does not appear to exploit its monopoly power fully.

Based on these findings, tariff policy should not focus on raising tariffs for cost recovery, because CRR is already sufficient. Three policy directions are suggested: (1) maintain tariff discipline so that tariffs do not approach the monopoly price, (2) allocate the excess revenue to reduce NRW and expand services, and (3) maintain the progressive block tariff structure and cross-

subsidies to protect low-income customers. Future tariff adjustments should be linked to operational performance targets, so that the burden of inefficiency is not shifted to consumers.

This study has several limitations. The data used consist of only four annual observations. The demand function was estimated from the realized average price, not the official tariff per customer group, and includes only price as an explanatory variable. The reference Marginal Cost was taken from 2024 because the 2022 and 2023 values were negative. Future research could use historical tariff data by customer group, a longer time span, and additional demand variables such as the number of customers and household income. The analysis could also be complemented by estimating a cost function to test economies of scale more formally.

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