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Identification of Energy Costs in The Gowongan Water Supply System of Perumda Air Minum Tirta Moedal, Semarang, Indonesia

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ABSTRACT

Energy efficiency is a growing concern in water supply systems, especially in pump-driven networks. This study evaluates the E4 pump at the Gowongan Water Supply System (SPAM) operated by Perumda Air Minum Tirta Moedal, Semarang. Field data were collected in April 2025 using ultrasonic flow and digital power meters. This study is among the first to analyze how elevation-related hydraulic constraints interact with PLN's time-of-use electricity tariffs, providing new insights into their combined impact on energy efficiency. The analysis includes pump efficiency, Specific Energy Consumption (SEC), and electricity usage during peak (WBP) and off-peak (LWBP) hours, based on Ministry of Energy Regulation No. 7/2024. Results show a pump efficiency of 60.3% and an SEC of 0.221 kWh/m³. Over 83% of energy use occurred during LWBP periods, indicating effective use of Variable Speed Drive (VSD) technology. The study highlights how time-based operation can reduce energy costs while maintaining performance. The analysis provides insights that support utility-level strategies as outlined in RKAP and RPAM frameworks. Recommended actions include refining pump scheduling and exploring alternative energy options. The results provide technical and strategic insights to improve energy management in urban water utilities.

Keywords: *Detailed Energy Audit; Electricity Cost; Pump Performance; SEC; SPAM Gowongan*

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ABSTRAK

Efisiensi energi menjadi perhatian yang semakin penting dalam sistem penyediaan air, terutama pada jaringan yang bergantung pada pompa. Penelitian ini mengevaluasi pompa E4 pada Sistem Penyediaan Air Minum (SPAM) Gowongan yang dioperasikan oleh Perumda Air Minum Tirta Moedal, Semarang. Pengumpulan data lapangan dilakukan pada April 2025 menggunakan flowmeter ultrasonik dan power meter digital. Studi ini merupakan salah satu yang pertama menganalisis bagaimana kendala hidraulik akibat elevasi berinteraksi dengan tarif listrik berbasis waktu dari PLN, sehingga memberikan wawasan baru tentang dampak gabungan keduanya terhadap efisiensi energi. Analisis mencakup efisiensi pompa, Specific Energy Consumption (SEC), serta penggunaan listrik pada jam beban puncak (WBP) dan luar beban puncak (LWBP), mengacu pada Peraturan Menteri Energi No. 7 Tahun 2024. Hasil menunjukkan efisiensi pompa sebesar 60,3% dan nilai SEC sebesar 0,221 kWh/m³. Lebih dari 83% penggunaan energi terjadi pada periode LWBP, menunjukkan efektivitas penggunaan teknologi Variable Speed Drive (VSD). Studi ini menyoroti bagaimana pengoperasian berbasis waktu dapat menurunkan biaya energi tanpa mengurangi kinerja. Analisis ini memberikan wawasan yang mendukung strategi di tingkat perusahaan sebagaimana tercantum dalam kerangka RKAP dan RPAM. Tindakan yang direkomendasikan mencakup penjadwalan ulang pompa dan eksplorasi opsi energi alternatif. Hasil penelitian ini memberikan panduan teknis dan strategis untuk meningkatkan manajemen energi pada utilitas air perkotaan.

Keywords: *Audit Energi Terperinci; Biaya Energi; Kinerja Pompa; SEC; SPAM Gowongan*

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INTRODUCTION

According to the International Water Association (IWA), the water sector contributes around 4% to global electricity consumption, with a large portion attributed to the energy-intensive processes of water treatment and distribution. These processes involve several electricity-dependent stages, such as pumping, aeration, filtration, disinfection, and filter backwashing [1]. The total energy demand of a water treatment system is influenced not only by the quality of the raw water, but also by the scale of the facility, the choice of treatment technologies, and the efficiency of operational practices [2]. Several studies emphasize that Drinking Water Treatment Plants (DWTPs) are major contributors to energy use and carbon emissions, thereby prompting the development of performance metrics and benchmarking tools to identify potential efficiency gains [3], [4]. These findings underscore the importance of enhancing operational efficiency. A particular focus should be placed on pump systems, given their significant role in reducing energy costs and environmental impacts.

In line with the global agenda for energy-efficient and sustainable water services, the Government of Indonesia aims to achieve universal 100% access to drinking water services by 2024. To support the goal of universal access to safe drinking water, the Government of Indonesia implements the Drinking Water Safety Plan (RPAM) as a strategic framework for ensuring equitable and sustainable service delivery. This approach is guided by four criteria, i.e., Quantity, Quality, Continuity, and Affordability. Specifically, the criteria require a minimum supply of 60 liters per person per day (quantity), compliance with national health standards as stated in Ministry of Health Regulation No. 492/2010 (quality), 24-hour water availability (continuity), and cost structures that are affordable to all segments of society (affordability) [5].

According to the 2025 Corporate Work and Budget Plan (RKAP) of Perumda Air Minum Tirta Moedal, the demand for clean water in Semarang City is largely met by surface water and deep groundwater sources. However, in 2024, groundwater production only accounted for approximately 12.94% of the total water volume, equivalent to 14,774,667 m^3 per year. This indicates a high level of reliance on surface water, which requires more energy for treatment and distribution. The same document also notes an increase in the electricity budget of 20.07%, from IDR 31.98 billion to IDR 38.39 billion [6], suggesting that improvements are needed in how energy is managed.

National trends mirror this concern. The 2024 Performance Report of Regional Drinking Water Companies (BUMD) states that electricity is one of the largest components in the overall operating costs, comprising 10% of the total IDR 21.1 trillion expenditure [7]. In addition, training materials from the Field Assistant Program under NUWSP indicate that 50–80% of the electricity used by water utilities is consumed by pumps, with the remainder used for administrative and lighting purposes [5]. These data point to pump efficiency as a crucial factor in improving energy performance across water utilities.

The Gowongan distribution system exemplifies these challenges. It serves customers in elevated terrain and includes a Pressure Break Tank (Bak Pelepas Tekan/BPT) in Pudak Payung to mitigate pressure surges caused by elevation differentials. With a distribution volume of 169,316 m^3 and 5,970 service connections, the system currently suffers from a high non-revenue water (NRW) rate of 40.29%, reflecting both operational inefficiencies and energy wastage. In this study, electricity consumption is analyzed based on the time-of-use tariff structure by PLN, which distinguishes between peak (WBP) and off-peak (LWBP) hours [6]. The share of energy used during peak hours is considered a key indicator of operational efficiency, especially in relation to pump scheduling.

Energy audits are widely recognized as systematic tools for identifying consumption patterns and efficiency improvement opportunities. These audits are typically classified into three levels: preliminary, walkthrough, and detailed audits, each differing in data depth and analysis methods [8]. This research adopts a detailed audit methodology that includes real-time measurements of hydraulic performance, electricity consumption, and evaluation of scheduling practices under different tariff conditions.

Several previous audits in Indonesia provide valuable insight. In Malang, energy inefficiencies were attributed to aging network infrastructure and mismatched pump loads [9]. In Palangka Raya, oversized pumps contributed to elevated Specific Energy Consumption (SEC) [10]. In Surabaya, continuous monitoring at Ngagel I WTP proved effective in reducing inefficiencies

[11]. Meanwhile, in Palembang pump operation significantly improved energy efficiency [12]. However, these studies often focused on isolated factors, such as equipment sizing or control settings, and rarely connected audit findings to institutional planning tools. Moreover, few addressed the unique interplay between elevation-induced pressure variation and time-based electricity tariffs.

While many studies have explored energy efficiency in water utilities, the combined impact of elevation-related hydraulic challenges and PLN's time-of-use tariffs remains underexplored.

Even fewer have contextualized audit results within planning frameworks like RKAP or RPAM. This study addresses those gaps by evaluating the energy performance of the high-elevation Gowongan system using a detailed audit approach. The audit incorporates real-time hydraulic measurements, electricity usage tracking, and scheduling evaluation based on PLN's tariff structure. Results from this study are intended to support technical improvements and inform broader planning instruments such as RKAP and RPAM. By explicitly linking pump energy performance, SEC, and time-based electricity use to institutional policies and operational frameworks, this research aims to serve as a practical reference for utility managers and policymakers. Additionally, the high NRW rate is analyzed in terms of its impact on energy inefficiency, offering a more holistic view of system performance.

METHOD

A comprehensive energy audit was conducted in April 2025 at the Gowongan Water Supply System (SPAM Gowongan) to assess the energy performance of its pumping operations. The audit involved the collection of both primary and secondary data to evaluate the technical performance and energy efficiency of the pumping system. Primary data were obtained through direct field measurements. The water flow rate was measured on the discharge side of the pipeline using a portable ultrasonic flowmeter [3], while water pressure was recorded using a pressure gauge installed on the same discharge pipe [8], [13], as shown in Figure 1 (a) and (b).

(a) (b)

Figure 1. a) Ultrasonic Flow Meter, b) Discharge Pressure

The pumping system at SPAM Gowongan is equipped with a Variable Speed Drive (VSD), which allows dynamic adjustments to the pump's rotational speed based on real-time pressure and flow demands. The use of VSDs in water distribution systems has been widely recognized for improving operational efficiency and reducing energy losses [4],[14]. Therefore, electrical parameters including current, voltage, active power, power factor, and frequency were measured using a digital power meter capable of capturing real-time load variations. The power meter was connected to a data logger, which recorded measurements at one-minute intervals over a one-hour measurement period [9]. The electrical measuring setup is illustrated in Figure 2.

Figure 2. Variable Speed Drive Panel

The collected data were then analyzed to calculate the Specific Energy Consumption (SEC) in units of kWh/m³ and the total pump system efficiency (ηT), following standard methodologies for evaluating energy performance in water utilities [3], [13]. These values served as the basis for developing technical recommendations to improve energy efficiency in the SPAM Gowongan distribution system. To ensure data reliability, the ultrasonic flowmeter and digital power meter used in this study were confirmed to be recently calibrated, with certification issued within the last year [13]. A one-hour monitoring period was chosen due to stable full-load operation, a practice commonly recommended for reliable pump performance evaluation in water distribution systems [13].

RESULTS AND DISCUSSION

The distribution system of the Gowongan Water Supply System (SPAM Gowongan) features relatively complex geographical characteristics, with service areas spread across medium to high elevation zones. The service area of SPAM Gowongan consists of two main distribution zones: the Pudak Payung Pressure Break Tank (BPT) and the Banyumanik Reservoir. These zones represent distinct hydraulic paths shaped by elevation gradients and gravitational flow control. The Pudak Payung BPT functions to reduce excess pressure caused by elevation, thereby maintaining system stability, while the Banyumanik Reservoir serves as a storage and regulation facility for downstream water distribution. This form of elevation-based zoning is a widely adopted strategy in water supply networks to ensure efficient pressure management and energy use [5]. The spatial layout of the SPAM Gowongan service area is presented in Figure 3.

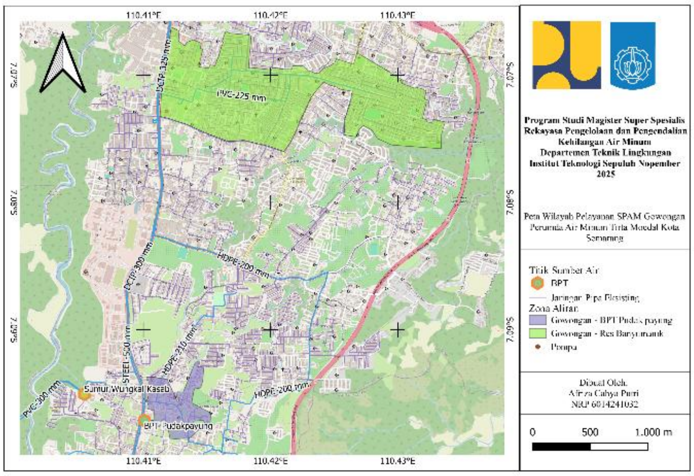

Figure 3. SPAM Gowongan Service Area Map

To support water distribution across these elevation zones, the pumping system plays a critical role in maintaining adequate pressure and flow. The technical specifications of the pump unit operating within the SPAM Gowongan system are summarized in Table 1.

Table 1. Technical Specification Pumps

Pump	Type	Brand	Q (l/s)	Pressure
E4	Submersible	Vansan SS 10210	60	50

After presenting the pump's technical specifications, field measurements were conducted to evaluate the actual performance of the E4 Gowongan pump unit during operation. The measured parameters include flow rate and discharge pressure under real operating conditions. These results are presented in Table 2.

Table 2. Pump Operational Measurement Result

Pump	Q (l/s)	Q (m^3/s)	H (bar)	H (m)	Operating Time (hours/day)
E4	64.25	0.06425	4.8	48.96	24

Based on the operational measurement results, the next step is to calculate hydraulic power as a basis for evaluating pump efficiency. The pumping system operates by converting electrical energy into mechanical energy through a motor, which is then transferred to the pump to generate hydraulic energy [13]. The hydraulic power output is calculated using the fluid density (ρ), gravitational acceleration (g), flow rate (Q), and pump head (H), as formulated in Equation (1):

$$P_w = \rho \times g \times Q \times H \qquad \text{...(1)}$$

Based on Equation (1), the hydraulic power generated by the pump unit at SPAM Gowongan was calculated using the measured flow rate and head values obtained from field data. These calculations are presented in Table 3 and provide a clearer understanding of the pump's ability to convert electrical input into hydraulic energy output under actual operational conditions. This value will serve as a reference for the subsequent calculation of pump efficiency. The results in Table 3 reflect the actual hydraulic energy output produced by the pump under field conditions. his output will then serve as the basis for evaluating the overall efficiency of the pumping system by comparing it with the corresponding electrical input power.

Table 3. Hydraulic Power Calculation Result of the Pump

Pump	**H (m)**	**Q (m^3/s)**	**g (m/s^2)**	**ρ (kg/m^3)**	**Pw (kW)**
E4	48.96	0.06425	9.81	998	30.80

Following the analysis of hydraulic parameters, the evaluation proceeded to the electrical aspects to determine the actual energy consumption of the pumping system. Measurements of electric current (I), voltage (U), and power factor (cos φ) were conducted directly in the field using a digital power meter connected to a data logger system. Based on the results, the input (real) power consumed by the E4 Gowongan pump unit was recorded at 51.07 kW. The detailed electrical parameters are presented in Table 4.

Table 4. Pump Input Power

Pump	**I (A)**	**U (V)**	**cos φ**	**Ph (kW)**
E4	102	500.69	0.78	51.07

As shown in Table 4, the electrical input power consumed by the E4 Gowongan pump was recorded at 51.07 kW, with a power factor (cos φ) of 0.78. Although this value is relatively close to the ideal benchmark of ≥ 0.85 [15], it still indicates that some portion of the supplied electrical energy is not effectively converted into useful work but instead manifests as reactive power. This condition can reduce overall system efficiency. To assess the performance of the pump, the total efficiency was calculated using Equation (2), where Pw represents the hydraulic power output (kW), Ph is the motor input power (kW), and ηT denotes the total pump system efficiency in percent:

$$\eta_T = \frac{P_w}{P_h} \times 100\% \quad \text{....(2)}$$

Based on the measured input and output parameters, the total pump efficiency was calculated using equation (2), resulting in a value of 60.3%, which is slightly above the minimum standard of 60% recommended for pump operations [14]. While this indicates that the system performs within acceptable operational limits, the relatively low power factor of 0.78 suggests that a notable fraction of the electrical energy input is not being effectively utilized. Instead, this energy is lost as reactive power, which can diminish overall system performance and increase operational costs over time. To improve this condition, several technical measures are recommended. First, the Variable Speed Drive (VSD) parameters should be recalibrated to better match actual flow and pressure conditions. Second, consistent mechanical maintenance is necessary to preserve the pump's long-term efficiency. Third, ongoing system monitoring should be implemented to detect any deviations from optimal performance ranges [16]. These actions are expected not only to improve energy efficiency, but also to enhance the reliability and cost-effectiveness of the distribution system in the long run.

In evaluating the efficiency of water distribution operations, Specific Energy Consumption (SEC) is calculated to determine how much electrical energy is required to distribute each unit volume of water. The calculation uses Equation (3), where E represents the electrical energy consumed (in kWh) and V is the volume of water distributed (in m³). A lower SEC value indicates more efficient energy use in the water distribution process [14].

$$SEC = \frac{E}{V} \quad \text{....(3)}$$

Following the evaluation of pump energy conversion efficiency, the next step involves calculating the SEC as a key indicator of energy performance in the water distribution system. SEC is obtained by dividing the total electrical energy consumption by the volume of water delivered. The calculated value is presented in Table 6. This metric helps assess how efficiently electrical energy is utilized in delivering water to end users. The values shown in Table 6 summarize the SEC performance of the pump unit, providing an indication of the system's operational efficiency under current field conditions.

Table 6. Specific Energy Consumption (SEC) Values

Pump	Energy Consumption (kWh)	Volume of Water Distributed (m^3)	SEC Value (kWh/m^3)
E4	36.770	166.536	0.221

Based on Table 6, the SEC value for the E4 Gowongan pump is 0.221 kWh/m³. This value is below the efficiency threshold of 0.4 kWh/m³, indicating that the distribution system operates with relatively efficient energy use. However, when compared to the previously calculated overall pump efficiency, there is still room for improvement through technical optimization or operational adjustments. Although the SEC value of 0.221 kWh/m³ is acceptable, the system's Non-Revenue Water (NRW) rate of 40.29% indicates substantial water loss, which may be caused by leaks, metering inaccuracies, or unauthorized consumption. This high level of NRW means a substantial portion of pumped water (and the energy used to move it) does not reach paying customers, thereby reducing overall energy effectiveness. In other words, even with good pump performance, the actual energy cost per revenue-generating unit of water is much higher. Reducing NRW would thus not only improve financial returns but also enhance energy efficiency metrics at the utility level.

Compared to other water utilities, the SEC value of 0.221 kWh/m³ in the Gowongan system is relatively efficient. For instance, audits in Palangka Raya and Malang reported SEC values above 0.35 kWh/m³ due to oversized or poorly scheduled pumps [9], [10]. In contrast, the use of VSD and proper peak-hour scheduling in Surabaya and Palembang led to SEC values in the range of 0.24–0.28 kWh/m³ [11], [12]. The lower SEC observed in Gowongan is likely a result of optimized load shifting and relatively stable hydraulic conditions, although the impact of NRW still limits the system's true energy-to-output performance.

After determining the level of energy efficiency through the Specific Energy Consumption (SEC) value, the evaluation proceeds by reviewing the electricity consumption pattern based on the tariff structure outlined in Regulation of the Minister of Energy and Mineral Resources Number 7 of

2024 concerning Guidelines for the Calculation and Evaluation of Energy Efficiency in the Public and Industrial Sectors. This assessment is essential to understand how the utilization of electricity by the pumping system not only affects technical efficiency but also directly impacts operational cost efficiency [17]. Therefore, the following discussion examines the distribution of electricity consumption by the E4 Gowongan pump during off-peak (LWBP) and peak hours (WBP), as well as the role of Variable Speed Drive (VSD) technology in optimizing time-based energy usage. The details of electricity consumption categorized by peak and off-peak times for the E4 Gowongan pump from January to April 2025 are presented in Table 7.

Table 7. Pump Energy Use by Load Period

Month	LWBP Usage (kWh)	WBP Usage (kWh)	Ratio
January	37,153.800	7.435	0.167
February	36,892.800	7.431	0.168
March	33,113.200	6.703	0.168
April	35,682.200	7.072	0.165

Based on the data in Table 7, electricity consumption during Off-Peak Hours (LWBP) consistently exceeded 83% each month, with an average LWBP/WBP ratio of 0.167. This indicates that most pump operations occurred during off-peak hours, which is more cost-efficient due to lower LWBP tariffs as regulated by the Ministry of Energy and Mineral Resources Regulation No. 7 of 2024. The implementation of Variable Speed Drive (VSD) technology on the E4 pump unit plays a key role in improving operational efficiency. VSD enables automatic adjustment of motor speed based on real-time pressure and flow requirements, minimizing unnecessary energy use during low demand periods. In this study, the system's control logic effectively shifts load to cheaper energy periods. The VSD's setpoint responsiveness allows the pump to maintain pressure stability without frequent start-stop cycles, which not only improves energy efficiency but also extends equipment lifespan. Similar findings were reported in energy optimization studies in Surabaya and Palembang, where load-based scheduling contributed significantly to lowering SEC values [11], [12].

CONCLUSION

This study evaluated the energy efficiency of the SPAM Gowongan water distribution system through an assessment of pump performance, electricity consumption patterns, and the impact of tariff-based operational strategies. The findings indicate that the E4 pump operates at a total efficiency of 60.3% with a Specific Energy Consumption (SEC) of 0.221 kWh/m³, both of which meet or exceed recommended benchmarks. The implementation of Variable Speed Drive (VSD) technology has significantly contributed to improved energy performance, with more than 83% of electricity consumed during off-peak (LWBP) hours.

Despite these positive outcomes, further improvements are necessary to enhance overall efficiency and reduce operational costs. Recommended actions include optimizing pump scheduling to limit peak-hour usage, conducting regular performance audits, and exploring the integration of renewable energy sources such as solar power.

This study reinforces the value of detailed energy audits in identifying inefficiencies and informing targeted energy management strategies in urban water utilities. The results demonstrate that substantial efficiency gains can be achieved through a comprehensive approach involving pump system optimization, time-based operational planning, and the application of smart control technologies. Metrics such as total pump efficiency and SEC should be continuously monitored and integrated into data-driven decision-making frameworks to sustain long-term system performance.

BIBLIOGRAPHY

[1] International Water Association (IWA), The Water Sector's Contribution to Global Electricity Consumption. 2023.

[2] I. Skoczko, "Energy Efficiency Analysis of Water Treatment Plants: Current Status and Future Trends," Mar. 2025. doi: 10.3390/en18051086.

[3] M. Molinos-Senante and C. Guzmán, “Benchmarking energy efficiency in drinking water treatment plants: Quantification of potential savings,” vol. 176, pp. 417–425, Mar. 2018, doi: 10.1016/j.jclepro.2017.12.178.

[4] M. Molinos-Senante and R. Sala-Garrido, “Evaluation of energy performance of drinking water treatment plants: Use of energy intensity and energy efficiency metrics,” vol. 229, pp. 1095–1102, Nov. 2018, doi: 10.1016/j.apenergy.2018.08.102.

[5] National Urban Water Supply Project (NUWSP), “*Bahan Bacaan Materi Pembekalan* Field Assistants (FA) NUWSP (Reading Material for NUWSP Field Assistants Training),” 2020.

[6] Perumda Air Minum Tirta Moedal Kota Semarang, “*Rencana Kerja dan Anggaran Tahun 2025* (2025 Corporate Work and Budget Plan),” Semarang, 2025.

[7] Direktorat Jenderal Cipta Karya, “*Buku Kinerja BUMD Air Minum 2024* [2024 Performance Report of Regional Drinking Water Companies],” 2025.

[8] A. R. Alam and A. Yuniarto, “*Audit Energi Sederhana Pada Pompa Distribusi IPA 2 Pramuka PAM Bandarmasih Kota Banjarmasin* (Basic Energy Audit of Distribution Pump at Pramuka WTP PAM Bandarmasih, Banjarmasin City),” vol. IX, no. 4, 2024.

[9] G. Asmara, A. Yuniarto, and M. Sundoro, “*Peningkatan Efisiensi Energi pada Sistem Distribusi Sumbersari Perumda Air Minum Tugu Tirta Kota Malang* (Improving Energy Efficiency in Sumbersari Distribution System, PDAM Tugu Tirta, Malang),” 2022.

[10] A. Nur Alhamidiy, A. Masduqi, and B. Wahyu Adhi, “*Studi Optimasi Pompa Distribusi SPAM Kota Palangka Raya untuk Efisiensi Energi* (Optimization Study of Distribution Pumps in Palangka Raya SPAM),” Jurnal Teknik Sipil Giratory UPGRIS, vol. 5, no. 1, 2024.

[11] R. D. Indra, “*Analisis Audit Energi pada Instalasi Pengolahan Air Ngagel I dalam Rangka Peningkatan Efisiensi Energi di PDAM Surya Sembada Kota Surabaya* (Energy Audit Analysis at Ngagel I WTP in PDAM Surabaya),” Master Tesis, Institut Teknologi Sepuluh Nopember, Surabaya, 2023.

[12] N. P. Anindita, “*Analisis Potensi Penghematan Energi pada Sistem Penyediaan Air Minum (SPAM) Borang di PDAM Tirta Musi Kota Palembang* (Potential Energy Savings Analysis in Borang SPAM, PDAM Palembang),” Master Tesis, Institut Teknologi Sepuluh Nopember, Surabaya, 2023.

[13] S. Lang, G. Ludwig, F. P. Pelz, and B. Stoffel, “General Methodologies of Determining the Energy Efficiency Index of Pump Units in the Frame of the Extended Product Approach,” 2013.

[14] Direktorat Jenderal Cipta Karya and USAID IUWASH, “*Pedoman Pelaksanaan Efisiensi Energi di PDAM* (Guidelines for Energy Efficiency Implementation in PDAMs),” no. Pedoman Pelaksanaan Efisiensi Energi di PDAM, 2018.

[15] National Electrical Manufacturers Association, “Motors and Generators,” Rosslyn, 2021. Accessed: Jun. 20, 2025. [Online]. Available: www.nema.org

[16] M. Alif Hidayat and A. Slamet, “*Analisis Peningkatan Efisiensi Energi Pada Sistem Distribusi Air Minum Area Pelayanan Kalidoni Perumda Tirta Musi Kota Palembang* (Energy Efficiency Improvement Analysis in Kalidoni Service Area, PDAM Palembang),” 2024.

[17] Kementerian Energi dan Sumber Daya Mineral, “*Peraturan Menteri Energi dan Sumber Daya Mineral Republik Indonesia Nomor 7 Tahun 2024 tentang Tarif Tenaga Listrik yang Disediakan oleh PT Perusahaan Listrik Negara (Persero)* (Ministry Regulation on Electricity Tariffs by PLN)),” Jun. 2024.