

The Impact of Reduced Non-technical Distribution Losses on GHG Emissions by Implementing Advanced Metering Infrastructure

Meily Priliani^{1)}; I Nyoman Jendra²*

1. PT PLN (Persero) Unit Pelayanan Pelanggan Bali Selatan, Jl. P.B. Sudirman No.2, Dauh Puri Kauh, Kec. Denpasar Bar., Kota Denpasar, Bali 80232, Indonesia
2. PT PLN (Persero) Unit Induk Distribusi Bali, Jl. Letda Tantular No.1, Daging Puri Klod, Kec. Denpasar Tim., Kota Denpasar, Bali 80234, Indonesia

**)Email: meilypriliani@pln.co.id*

ABSTRACT

The distribution losses in the electrical system demonstrate the reliability and efficacy of the network in providing electricity to the customers. The PLN Statistical Report 2022 stated that 20,236 GWh of electricity became losses at PLN's distribution network across Indonesia. Not only causing the financial disadvantage, but these losses are also believed to have an adverse effect on the environment since they raise the amount of greenhouse gas (GHG) emissions because energy losses need to be compensated. Thus, various initiatives are conducted to improve the performance of distribution network system, including in Bali. In attempt to minimize losses, PLN Bali Distribution Unit has gradually implemented Advanced Metering Infrastructure (AMI) technology throughout 2023. This research is supposed to examine the impact of the AMI installation on the value of losses and GHG emissions. Our findings suggest that AMI technology has a positive impact on non-technical losses but an insignificant impact on total losses, defying the widely held belief that it can notably reduce losses. The environmental impact then can be quantified by converting the losses value to GHG emissions.

Keywords: *electricity, distribution losses, greenhouse gases emissions, advanced metering infrastructure*

ABSTRAK

Susut distribusi pada sistem kelistrikan menggambarkan kehandalan dan keefektivan dari jaringan dalam menghantarkan listrik ke pelanggan. Laporan statistik 2022 PLN menyatakan bahwa sebesar 20.236 GWh susut dihasilkan di jaringan distribusi seluruh Indonesia. Tidak hanya menimbulkan kerugian finansial, susut tersebut juga dianggap memberikan efek buruk ke lingkungan karena jumlah emisi gas rumah kaca (GRK) yang meningkat karena kehilangan energi yang harus dikompensasi. Oleh karena itu, berbagai upaya dilakukan untuk meningkatkan performa dari sistem jaringan distribusi, termasuk di Bali. Dalam mengurangi susut, PLN UID Bali secara bertahap telah melakukan implementasi teknologi Advanced Metering Infrastructure di tahun 2023. Penelitian ini dilakukan untuk meninjau pengaruh dari pemasangan AMI terhadap nilai susut dan emisi GRK. Temuan kami menunjukkan bahwa teknologi AMI mempunyai dampak positif terhadap susut non-teknis namun berdampak tidak signifikan terhadap kerugian total, hal ini bertentangan dengan anggapan umum bahwa teknologi ini secara khusus mengurangi susut. Dampak lingkungan kemudian dapat diukur secara kuantitatif dengan mengkonversi nilai susut menjadi emisi GRK

Kata kunci: *listrik, susut distribusi, emisi gas rumah kaca, advanced metering infrastructure*

1. INTRODUCTION

The largest electrical energy provider in Indonesia, PT PLN (Persero), has made it clear that it intends to attain Net Zero Emissions (NZE) by 2060 in order to demonstrate its resolve to meet the country's climate change mitigation goal. By incorporating green aspiration into the Transformation 1.0 program, PLN is committed to meeting this ambition. PLN's Transformation 1.0 focused on four main aspirations, namely lean, innovative, green, and customer focused. The first aspiration is lean that guarantees optimized business processes, enabling extremely efficient business operations and quicker responses. Innovative aspiration is bound to revolutionize every aspect of PLN's business operations from start to finish by transforming the previously dispersed, manual work process into a technology-integrated one. The green aspiration ensures that PLN becomes a pioneer in the energy transition in Indonesia and developed a long-term emissions reduction roadmap. The last aspiration, customer focused, is to establish PLN as the go-to option for customers when it comes to energy solutions. This year, PLN continues the next stage of transformation through Transformation 2.0, where at this stage, the corporate's vision and missions will be realized through "Moonshots" with a focus on Growth, Digital and Net Zero Emissions (NZE)^[1].

Among PLN's initiatives to achieve NZE in 2060 is the development of corporate guidelines for climate change management through policies, in addition to the various other strategic plans that have been formulated and implemented. In 2021, PLN published PT PLN (Persero) Board of Directors Regulation Number 0161.P/DIR/2021 regarding The Strategic Climate Management Policy. This policy, in general, provides the framework for addressing climate change, including mitigation measures. One of the regulated kinds of climate change mitigation in this strategy is energy efficiency in the business activities of the electricity supply, which includes reducing losses in the electricity distribution process.

Losses itself is the difference in electricity (kWh) between the electricity sold to customers and the electricity received on the distribution side after deducting the energy used for private use in the distribution of electricity^[2]. In order to offset losses from inefficient power transmission and distribution, more electricity must be produced. Some countries that have large shares of fossil fuel generation and inefficient grid infrastructure, or a combination of the two, are the predominant culprits of what is called "compensatory emissions"^[3]. These emissions are a result of the additional electricity needed to make up for grid losses, which is frequently produced using fossil fuels.

Nationally in 2022, the energy losses of PLN were 8.72%, consisting of transmission losses of 1.92% and distribution losses of 6.94%, while in PLN's Bali Distribution Unit (UID Bali), the energy losses was 5.22% of total energy production or 297.3 GWh^[4]. Losses in distribution activities can be classified as either technical or non-technical depending on their type. The technical losses refer to the loss of electrical energy during distribution resulting from technical issues, where the reduced energy is converted to heat in the following process; Voltage Network (JTT), Main Substation (GI), Medium Voltage Network (JTM), Distribution Substation (GD), Low Voltage Network (JTR), House Connections (SR) and Measuring and Limiting Devices (APP). On the other hand, the non-technical losses are the losses of electrical energy used by customers and non-customers that are not accounted in electricity sales^[5].

As for the non-technical losses, there are several causes of loss, including electricity theft, meter reading errors, measurement equipment errors and others. In the distribution system, there are many methods for electricity theft, one of which is by using special equipment. In order to minimize electricity theft, prevention is carried out persuasively by informing the public about the

consequences of electricity theft, through the media or by direct socialization. In addition to using persuasive techniques, it also employs corrective measures, such as enforcing strict and precise regulations regarding the use of electricity, or mostly known as P2TL. Discrepancies between the kWh used by customers and those recorded are caused by errors in meter reading. Naturally, the difference will be lessened if the amount used turns out to be higher than what was recorded. One way to address this issue is by offering direction and training to personnel who are engaged in the process of reading meters, as well as by putting meter reading apps and techniques into practice.

PLN UID Bali has taken a number of steps to lower the loss value by 2023, one of which includes replacing Advanced Meter Reading (AMR) technology with Advanced Metering Infrastructure (AMI) technology gradually. The smart grid, which consists of a combination of technology including measurement devices, two-way communication to provide information (energy, voltage, and current) that is nearly real-time, monitoring (quality and condition), and control, includes the AMI smart meter as one of its constituent parts^[6].

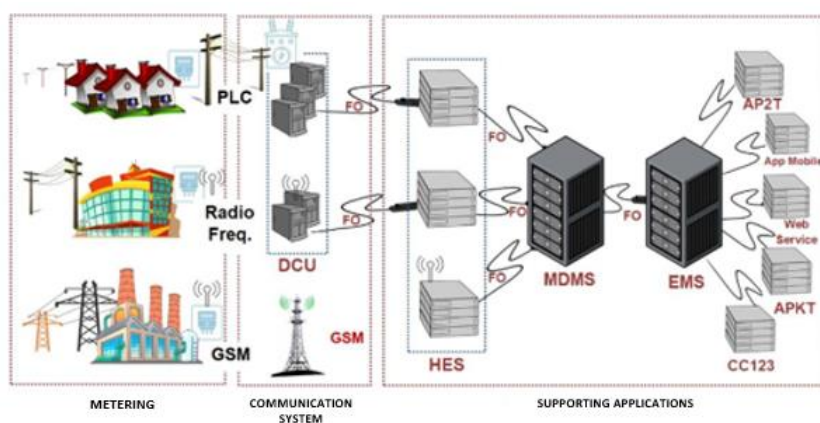


Figure 1. The Scheme of Advanced Metering Infrastructure^[5].

Countries that have successfully used AMI technology on a mass scale, such as Austria, have been able to save up to 55% of energy and the Netherlands has been able to save 15% of energy^[7]. It is intended that the progressive deployment of AMI smart meter technology in 2023 will help to lower distribution losses at PLN, including PLN UID Bali. Theoretically, AMI smart meters can reduce losses, which means the emissions from making up for lost energy will also be decreased. However, when it comes to methods for lowering GHG emissions or delaying the effects of climate change, the initiative to reduce wasted energy like losses—including within PLN—rarely receives attention and is quantified.

Thus, this background served as the foundation for the research that was completed. This study aims to quantify the significance of replacing kWh meters with AMI smart meters, which has been implemented at PLN UID Bali since June 2023, in reducing emissions, as well as to analyze the impact and effectiveness of this change on losses. This will allow the losses reduction program to receive increased attention in the future as a climate change mitigation initiative.

2. METHODS

This research method seeks to evaluate the causal relationships between variables, the correlation in this instance between distribution losses—which are subsequently converted into GHG emission units—and the AMI smart meter technology implementation variable. **Figure 2.** shows the methodology used for the research.

The research began with a preliminary study that involved observing and assessing the most recent strategic concerns in PLN's operations, particularly those pertaining to electricity distribution business activities. In achieving the Company's vision and mission, PLN translates it into short-term, medium-term and long-term strategies and programs, which includes a transformation that has been performed in these three years. Preliminary observations and analysis were also conducted on key performance indicators (KPI) at PLN UID Bali in addition to strategic issues. One of the KPI that is regularly evaluated each year is losses performance; in 2023, the PLN UID Bali loss target is 5.21%^[8]. In the meantime, this year's performance indicators for the digitalization of corporate applications also include the installation of AMI technology. Secondary data corroborating these observations also support the preliminary study. Having a hypothesis and problem based on the preliminary study, it was determined that the use of AMI smart meters could help reduce distribution losses, which are linked to wasted GHG emissions into the environment, in addition to helping achieve digitalization performance targets.

Following the preliminary study, the next step in this research is to develop the purpose of the research, as was previously mentioned in the introduction. Concurrently, the research was undertaken in the PLN UID Bali area and its scope was limited to the period from June 2023, when AMI was implemented, to October 2023, which corresponds to the last month's data that was recorded at the time the research took out.

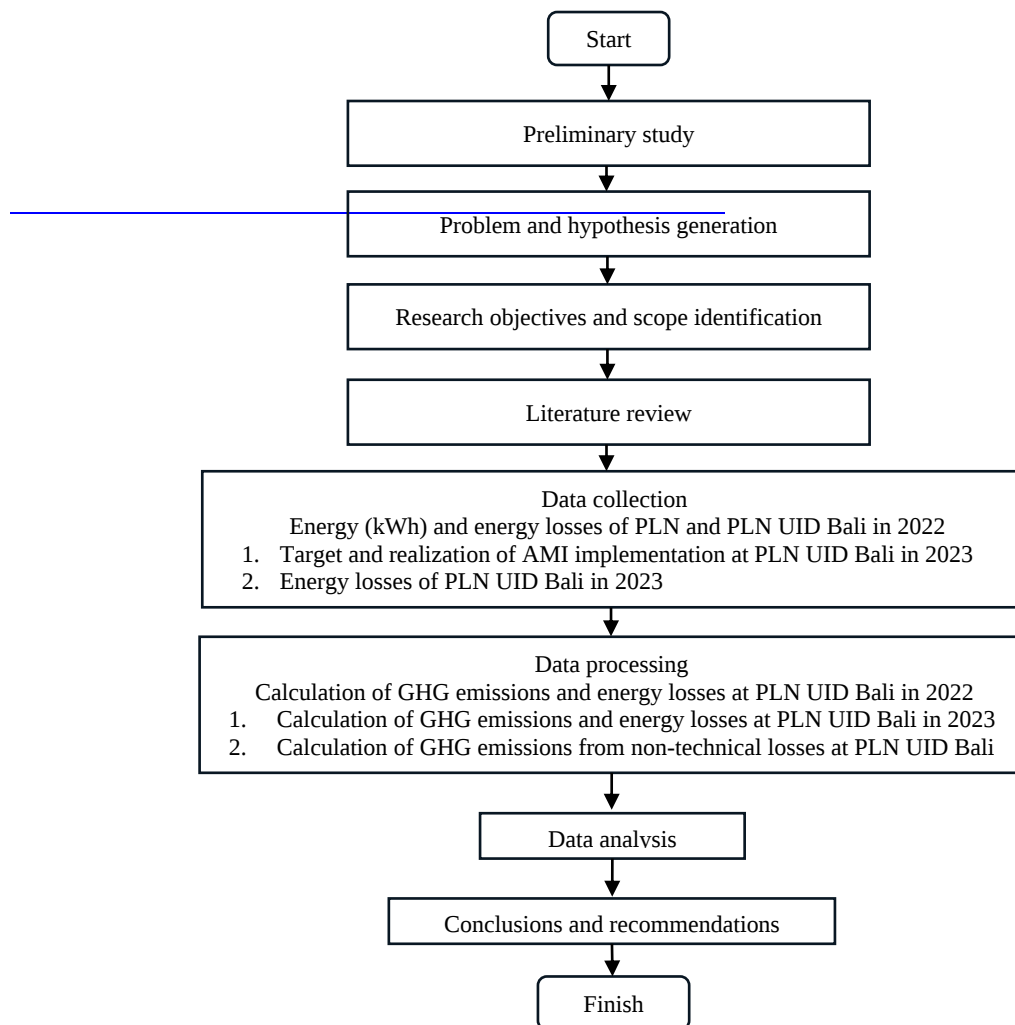


Figure 2. The Flowchart of the Research's Methods

Following the establishment of the objectives and scope, a review of the literature follows to gather timely and pertinent research on the subject and combine it into a coherent synopsis of the body of knowledge already known in the field. Three primary subjects are covered in this research's literature review: losses, GHG emissions, and AMI technology in the energy utility sector. The necessary primary data is then gathered and processed by performing computations in compliance with relevant standards. The first formula used is the distribution losses calculation formula ^[9]:

$$\text{Losses} = \frac{\text{Electricity imported} - \text{Electricity sold} - \text{PSSD}}{\text{Net electricity produced}} \times 100\% \quad (1)$$

Where:

<i>Losses</i>	: <i>Distribution losses (%)</i>
<i>Electricity imported</i>	: <i>Electricity received on the distribution side (kWh)</i>
<i>Electricity sold</i>	: <i>Electricity sold to the customers (kWh)</i>
<i>PSSD</i>	: <i>Electricity for private use in the distribution process (kWh)</i>
<i>Net electricity produced</i>	: <i>Total electricity</i>

In furtherance of calculating distribution losses, GHG emissions are determined by applying the GHG emissions calculation formula to convert energy measured in MWh units into tons of CO₂^[10]:

$$\text{Emissions} = \text{Electricity} \times EF \quad (2)$$

Where:

<i>Emissions</i>	: <i>Mass of CO₂, CH₄, or N₂O emitted (ton CO₂)</i>
<i>Electricity</i>	: <i>Quantity of electricity (MWh)</i>
<i>EF</i>	: <i>CO₂, CH₄, or N₂O emission factor (ton CO₂/MWh)</i>

The emission factor used in this research is the Jamali grid emission factor (Java-Madura-Bali) which has been published by the Government^[11].

The collected primary data are used for running calculations. An analysis of the application of AMI technology, its impact on lowering losses, and its importance on the ensuing GHG emissions can be developed based on calculated results. Finally, the research's last phase is to draw conclusions and suggestions for ongoing development, particularly to meet the targeted business objectives.

3. RESULTS AND DISCUSSIONS

AMI technology has been continuously installed on PLN's customers in Bali by PLN UID Bali since June 2023. This is exemplified by the actual monthly AMI installed in 2023 as opposed to the desired amount. As of October 31, 2023, 504,009 customers had experienced the implementation of AMI technology, reaching 114% of the monthly target, according to the Monitoring Report for the Replacement of AMI PLN UID Bali kWh Meters. While the number of installed AMI as of November 29, 2023, has reached 96.5% of the annual target, PLN UID Bali is anticipated to be able to install AMI on 545,641 customers spread throughout the island by the end of 2023. Although it was only 1.88% customers installed in June, the percentage of customers at PLN UID Bali who have installed AMI technology rose to 29.87% by October 2023.

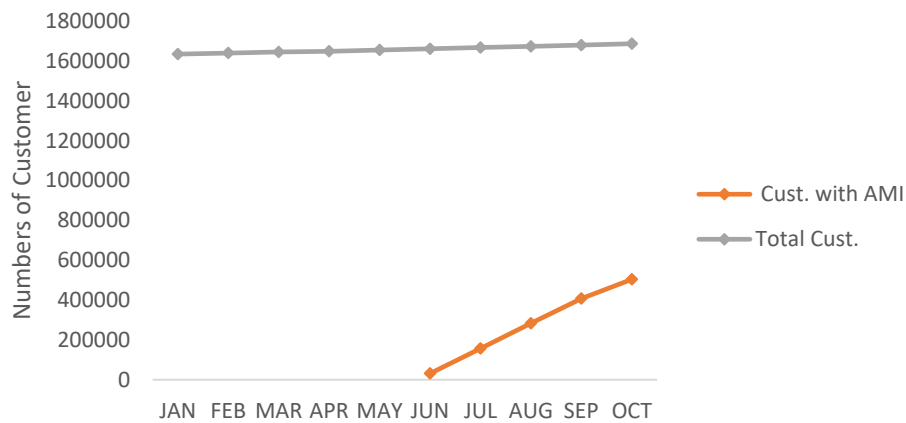


Figure 3. Graph of Customers with AMI Installed in 2023

From June 2023 onwards, the average monthly addition of AMI technology implementation reached 100,802 customers. Losses calculations were executed from 2023 to October by highlighting the losses value in the AMI technology implementation period (month July-October 2023) in order to ascertain the significance of AMI implementation on losses. There is a notable drop in losses as compared to losses in 2023 when historical data on losses in 2022 is compared. Nevertheless, **Figure 4.** illustrates that, despite September and October 2023 seeing a notable increase in AMI installations relative to prior months, the losses value tends to rise in those months when comparing to the number of losses in the period prior to AMI installation.

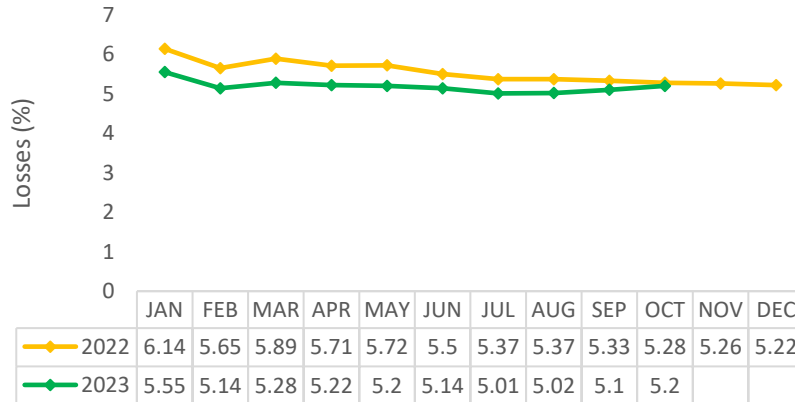


Figure 4. The Value of PLN UID Bali's Losses in 2022 and 2023

It was discovered from earlier literature studies that a wide range of technical and non-technical factors affect losses. Consequently, it is still insufficiently representative to examine the AMI installation variable directly on the cumulative losses value. The actual application of AMI technology is anticipated to reduce the likelihood of errors in kWh recording or improve the precision of the value of electricity sold to consumers; non-technical loss parameters are used to measure these aspects. The following five factors make up PLN UID Bali's non-technical losses: (i) losses resulting from follow-up bills for controlling electricity usage, or TS P2TL; (ii) supply and multipurpose realization; (iii) compensation for subscription security deposit; (iv) discrepancy in LPB-PPOB recognition; and (v) imported kWh.

Based on the data obtained from PLN UID Bali energy transaction team, the number of customers whose average usage is calculated can be decreased so that the documented value of customer electricity usage is much more accurate, as shown in **Figure 5**^[12]. Meter reading in the billing process can be accomplished by using instantaneous AMI data read on HES (head end system) to see customer stands with monthly reading abnormality reports (LBKB) of closed/locked houses.

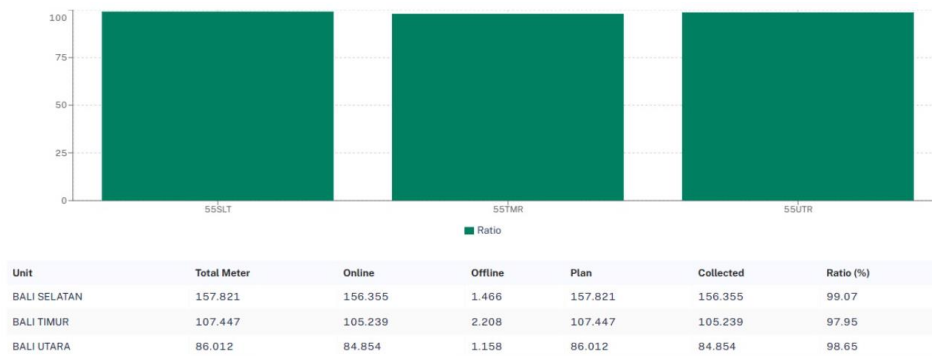


Figure 5. AMI Instant Data Management System

Data on losses in the PLN UID Bali distribution network was taken from the Simple-S application dashboard in order to assess the correlation between more precise readings of the electricity and lower losses. Commencing in October 2023, the 5.2% overall loss amount is comprised of 4.84% technical loss and 0.36% non-technical loss. When compared to the same month period the previous year, when AMI technology was not installed, this value indicates a decrease.

Figure 6. illustrates that the non-technical losses themselves are 256,925 kWh higher in 2022 than in 2023 during the same period in 2023, when there hasn't been a significant installation of AMI. This indicates that although the installation of AMI has reduced non-technical losses, its effect has not been statistically significant in relation to the overall loss value. The non-technical loss component alone only accounts for about 6% of the total kWh losses generated by PLN UID Bali through October 2023.

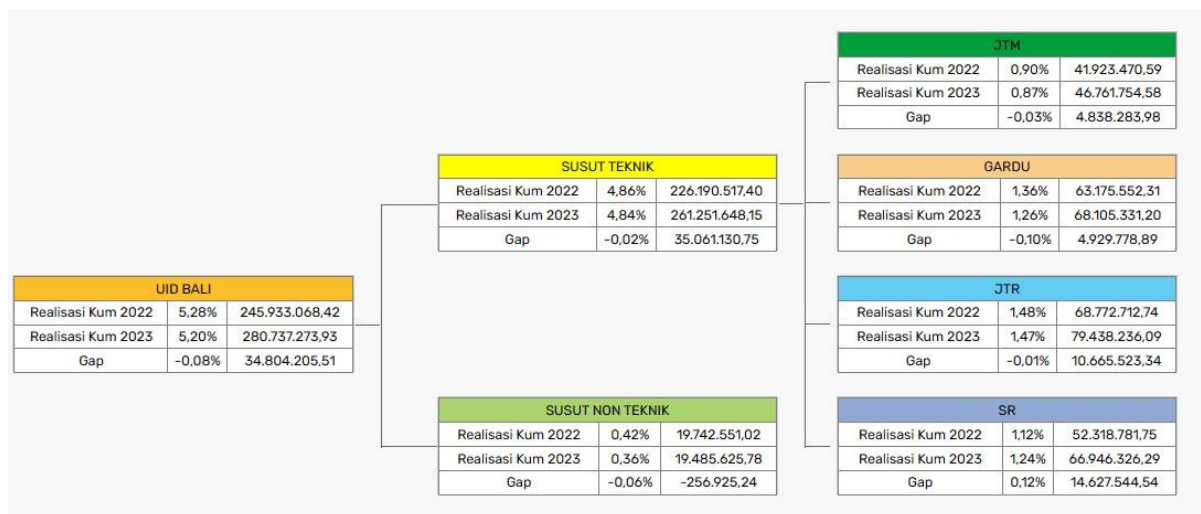


Figure 6. Year-on-year Comparison of Cumulative Losses up to October 2022 and 2023^[13].

In addition to the comparison year over year, a comparison of the losses composition values from 2023's second and third quarters was also conducted. The third quarter of 2023 was the time that AMI technology started to be installed significantly, which is why this period was selected. There is a difference or decrease in losses worth 21,863.19 kWh in the third quarter of 2023 compared to the second quarter of 2023, according to data published on the Simple-S application dashboard for the reduction of the PLN UID Bali distribution network. A relatively slight decrease in losses may be seen in this figure. This occurred as a result of its consideration of the fact that the AMI installation during that time was completed gradually rather than all at once. Consequently, there's a good chance that a portion of the total installed AMIs—perhaps as much as 100%—were not operating at full capacity during the third quarter.

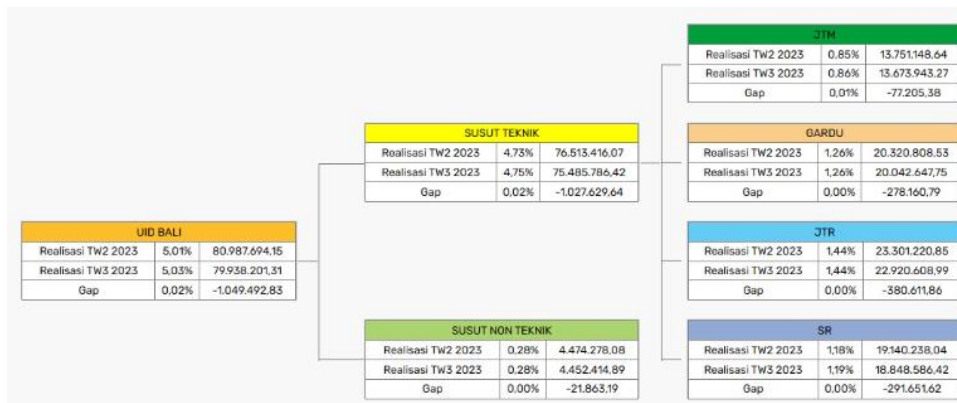


Figure 7. The Comparison of Cumulative Losses for Q2 2023 and Q3 2023 ^[14].

The percentage of non-technical losses in the third quarter of 2023 accounted for only about 5.6% of all kWh losses. It is apparent from **Figures 6** and **Figure 7**'s data, which were extracted from the Simple-S dashboard, that there are only about 5-6% of all losses or 0.2-0.4% of all the electrical energy produced at PLN UID Bali can be attributed to non-technical losses due to their small value.

Equation (2), which is mentioned in the methods section of the paper, determine the significance of losses on GHG emissions that are wasted into the environment. The following table shows a comparison of GHG emission values for each period using the Jamali grid emission factor value, which is equivalent to 0.8 tonnes of CO₂/MWh.

Table 1. The Calculation of GHG Emissions

Value of	Year on Year Comparison		Quarterly Comparison	
	Oct 2022	Oct 2023	TW II 2023	TW III 2023
Electricity produced (kWh)	4,657,823,266	5,316,993,824	1,616,520,841	1,595,572,880
Total losses (kWh)	245,933,068	280,737,274	80,987,694	79,938,201
Non-technical losses (kWh)	19,742,551	19,485,626	4,474,278	4,452,415
GHG emissions of total losses (kg CO ₂)	196,746,455	224,589,819	64,790,155	63,950,561
GHG emissions of non-technical losses (kg CO ₂)	15,794,041	15,588,501	3,579,422	3,561,932

The results of the calculation demonstrate that it remains a direct relationship between the value of GHG emissions and the value of losses incurred. In addition, non-technical losses have themselves declined from the prior year, resulting in a decrease in the amount of GHG emissions generated. In October 2023, 205,540 kg CO₂ less GHG was successfully emitted than in October 2022. In the meantime, when AMI technology started to be installed gradually, there was a reduction in GHG emissions of 17,490 kg CO₂ in the third quarter of 2022 compared to the second quarter of 2023.

It is possible to infer that the application of AMI technology has not been found to be significantly effective in reducing losses and the GHG emissions that result from losses based on the data held and calculations performed. This may occur for many different of reasons, the primary one being that the losses value is dependent upon numerous causative factors, both technical and non-technical factors. About 94% of all losses are caused by technical factors, with non-technical factors contributing to the remaining losses. The second reason is that the percentage of AMI technology installed is still relatively low. There are 1,687,121 PLN UID Bali customers in total as of October 2023; over 70% of these customers have not yet deployed AMI on their electricity installation. Last but not least, despite the figures, the life of AMI technology is still comparatively short. Due to the fact that the installation was done gradually, with an average of 100,802 customers being added each month, not all of the 29.87% of customers who have AMI installed at PLN UID Bali are fully active by October 2023.

On the other hand, it is important to recognize that even though the use of AMI technology in this research only demonstrated a reduction in non-technical losses and did not significantly affect the overall loss value, the amount of GHG emissions that was successfully reduced cannot be understated. One ton of CO₂ is equivalent to a cube that is 27 feet (8.23 meters) tall, wide, and long when converted to make an easier visualization^[14]. According to other sources, a ton of CO₂ is equivalent to 6,000 kilometres driven in a diesel vehicle, 121,643 smartphones charged, or the average emissions of one passenger on a return trip from Paris to New York^[15]. This research discovered that while emissions decreased by 17.5 tons of CO₂ from the second to the third quarter of 2023, non-technical losses decreased by 205.54 tons of CO₂ in October 2023 compared to 2022. Hence, the value of 205.54 tons of CO₂ alone is equivalent to taking 205 round-trip flights from Paris to New York, traveling 1,233,241 kilometres in a diesel vehicle, or charging more than 25 million phones.

The implementation of AMI technology is an excellent starting point in establishing smart grid system in Indonesia. Smart grid can reduce GHG emissions and improve energy efficiency by directly reducing power losses^[16], which is one of the technologies that PLN has pointed out to reach NZE by 2060. Power and distribution networks that are reliable and secure are built on top of efficient electricity system. As a result, emissions will decrease as an efficient electrical network generates less energy to offset energy losses. Since the technical losses account for a larger portion of losses than the non-technical losses, various initiatives must be made to reduce technical losses in addition to implementing AMI in order to maximize the emission value derived from losses.

4. CONCLUSIONS

According to this research, the cumulative non-technical loss value at PLN UID Bali was found to be inversely proportional to the phased implementation of AMI from June to October 2023. There was a decline in the value of non-technical losses year over year when compared to the prior year. Similarly, when converted to GHG emission units, there was a decrease in emissions of 205,540 kg CO₂ or 205.54 tons CO₂. On the other hand, although AMI implementation lowers the

value of non-technical losses, it has no discernible effect on the value of total distribution losses at PLN UID Bali. This is caused by three factors: (i) the technical loss variable is much larger than the non-technical loss, which only accounts for 6% of the total loss value; (ii) the percentage of customers with newly installed AMI reached 29.87% of all PLN UID Bali customers; and (iii) due to gradual installation, the installed amount of AMI technology will not be fully operational for four months, from June to October 2023. Based on these three factors, it is advised that additional research be done to determine the significance of AMI implementation in lowering losses. This research should specifically target customers who have installed AMI for no less than three full months and examine each variable that influences losses. Since the effectiveness of the distribution network or the decrease in losses value will always be directly correlated with the amount of GHG emissions produced, it can be said that the next stage of research is preferred, and the implementation should be done continuously. The mitigation measures taken by PLN, particularly in distribution business activities, will become increasingly important in the future to achieve NZE if PLN UID Bali and other PLN units can progressively improve the value of their losses.

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The first author, Meily Priliani has been actively working as an Account Executive at PT PLN (Persero) UID Bali, UP3 South Bali since 2022. Prior to this, she spent six years in total working for PT PLN (Persero) Headquarters and Tarahan Power Plant, specialized in sustainability management. At Bandung Institute of Technology, she earned a Bachelor of Environmental Engineering degree in 2014 and a Master of Business Administration degree in 2020.



The co-author, I Nyoman Jendra is currently employed as Manager of Measurement Efficiency and Distribution System Quality at PT PLN (Persero) UID Bali. He spent more than four years in his previous role as a Health, Safety, Security, and Environment (HSSE) Manager.