

PT PLN Nusantara Power Muara Karang Power Plant

PT Pembangkitan Jawa Bali currently known as PLN Nusantara Power Muara Karang Power Plant mainly supplies the electricity needs of the Indonesian Capital have highest efficiency Combined Cycle Power Plant in Indonesia which is 61% and has improved its energy performance through EnMS by 18% saved 12.9 million GJ of energy and reducing 793,461 metric tons of CO₂.



Muara Karang Power Plant

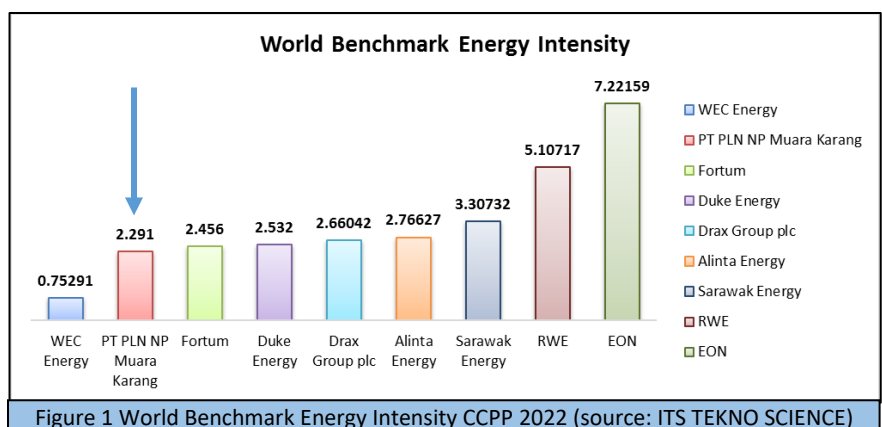
Case Study Snapshot

Industry	Power Generation
Product/Service	Electricity
Location	Jakarta
Energy performance improvement percentage (over the improvement period)	18 % improvement over 3 years (2019 as baseline-year)
Total energy cost savings (over the improvement period)	USD 88.3 Million
Cost to implement Energy Management System (EnMS)	USD 56,149.35
Total energy savings (over the improvement period)	3,604,711 MWh
Total CO₂-e emission reduction (over the improvement period)	793,461.4 Metric Tons

Organization Profile / Business Case

PT Pembangkitan Jawa Bali (PJB) Muara Karang currently known as PLN Nusantara Power Muara Karang Power Plant is a National Vital Object that mainly supplies the electricity needs of the Indonesian Capital (Jakarta). We have been implementing ISO 50001:2011 Since 2015 and then re-certified to ISO 50001:2018 in the year 2020. Scope and boundaries of Energy Management System (EnMS) we implemented on all entities in PLN Nusantara Power Muara Karang Power Plant.

We have 3 entities: Steam Turbine Power Plant Unit 4-5, Combined Cycle Power Plant Block 1, and Combined Cycle Power Plant Block 2 with total capacity 1621 MW. In the year 2021 we commission new generation unit that is Combined Cycle Power Plant Block 3 with higher efficiency to substitute our oldest generation unit Steam Turbine Plant Unit 4-5. This project is one of our main EnMS program. Including our newest generation unit, PT PLN NP Muara Karang Power Plant have total capacity of 2,154 MW **contributing 3.4% of the electricity needs of the Java Madura Bali system**, and from 1979 to 2022 has distributed a total of **224,546.22 GWh** of electricity.



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Our power plant has won two Asian Power Award in 2019 and five times Green Rating PROPER Award from Indonesian Ministry of Environment.

Motivation to Manage Energy – For more than 40 years, PT PLN NP Muara Karang Power Plant has maintained as one of the main electricity supplier for the Indonesian Capital. Nevertheless, we understand the key risk factor as one of the oldest power plant in Indonesia, including the increased competition among newer power plant with higher efficiency and lower production cost, and Indonesia's resolution for Net Zero Emission. Therefore PT PLN NP Muara Karang Power Plant is determined to achieved better efficiency and also lower production cost through the implementation of ISO 50001 – Energy Management System. We integrate ISO 50001:2018 with other management system in our Integrated Management System (IMS), such as ISO 14001, ISO 45001, ISO 9001, ISO 20000-1, ISO 27001, ISO 37001, ISO 55001, and ISO 22301. We are very optimistic that the implementation of EnMs will not only reducing our energy consumption and production cost, but also reducing the net carbon emission which comply with Indonesian policy for Net Zero Emission in the year 2060.



Figure 2 Muara Karang Roadmap 2023-2027



“ISO 50001 not only helps us improve energy and cost efficiency, but also lead us closer toward Net Zero Emission.”

—Maryono, Senior Manager Muara Karang Power Plant

Business Benefits

PT PLN NP Muara Karang Power Plant has made various efforts to save energy by focusing on Significant Energy Uses (SEUs), establishing Net Plant Heat rate as an Energy Performance Indicator (EnPI) and determining a baseline with reference to ISO 50001: 2018.

Economic Benefit

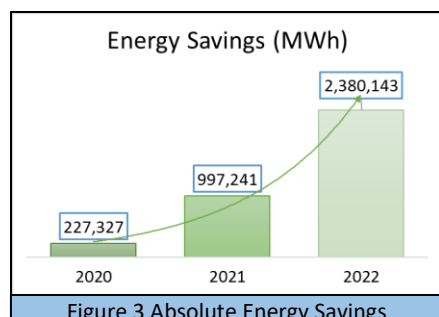


Figure 3 Absolute Energy Savings

The absolute energy savings obtained by CUSUM (Cumulative of Sum) from 2020 to 2022 are 3,604,711 Mega Watt hour or 12,9 Million Giga Joule. From this energy saving we reduce our energy consumption by 18% in 2022 with 2019 as our baseline year. In 2022 there was a very significant increase in energy saving according to the graph in figure 3. This is due to the successful implementation of ISO 50001:2018 with the main energy efficiency program: the construction of Combine Cycle Block 3 with a high efficiency Gas Turbine which has started

operating in mid 2021 which will substitute Steam Turbine Power Plant 45. PT PLN NP Muara Karang Power Plant has successfully achieved a **US\$ 88.3 Million** energy cost saving from 2020 until 2022 and the EnMS program repaid for itself in just 3 years but the benefit will last for longer period. Beside that we also reduce our production cost per kWh of electricity from US\$0.071 in 2019 to US\$0.054 in 2022.

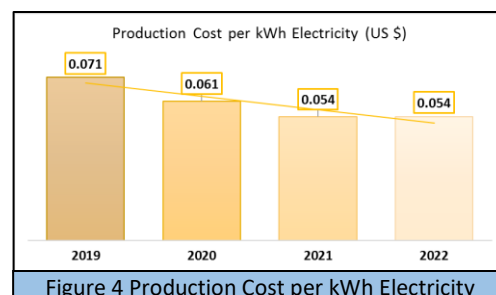


Figure 4 Production Cost per kWh Electricity

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Environment Benefit

PT PLN NP Muara Karang Power Plant succeeded in reducing CO2 gas emissions progressively through EnMS. The construction of Combined Cycle Block 3 as our main energy efficiency program started operating in early 2021 has significantly reduced GHG emissions because Combined Cycle Power Plant Block 3 uses a Gas Turbine from Mitsubishi MF 701F5 that uses the latest dry low NOx technology with a very low emission level of 0.0947 Ton CO₂eq/GJ, included in the best 25% according to Directorate General Regulation (PPKL) P19-20 for Gas Turbine Power Plant and Combined Cycle Power Plant Benchmarking, which is **the lowest emission level for the current Combined Cycle Power Plant class in Indonesia**. In addition, PT PLN NP Muara Karang consistently implements the Environmental Management System (EMS). Proved by obtaining **the ISO 14001:2015 certificate**. The Green Rating PROPER Award (Indonesian award of company environment performance assessment) was won 5 times from 2017 to 2021. Some of the programs that have been carried out by PT PLN NP Muara Karang Power Plant is integrated energy management system in environmental management system (Life Cycle Assessment), and finding the critical points that cause environmental impacts, so that the company is able to overcome impacts on target, **reducing total GHG emissions in 2019-2022 by 793,461.4 tons CO₂eq.**

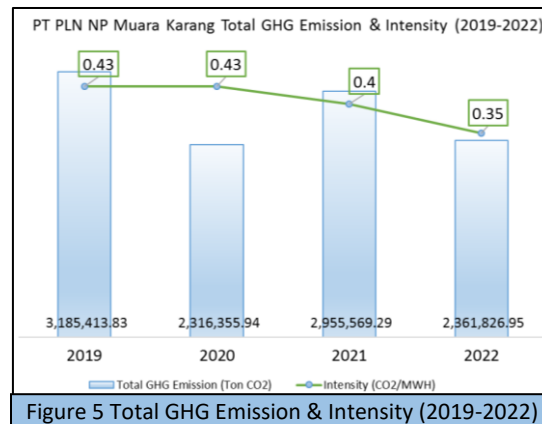


Figure 5 Total GHG Emission & Intensity (2019-2022)

Corporate Achievement

The implementation of EnMS supports us in conducting energy efficiency awareness, sustainability culture, and innovation training among employees in all levels. Our effort in implementing EnMS recognized by PT PLN NP Headquarters and awarded us “Power Plant with The Best EAF Performance”. We also get two Asian Power Award in 2019 on category “Gas Power Project of The Year” and “Power Utility of The Year”. One of these awards was obtained through the innovation of the energy saving programs entitled “Re-Design System Integration of GTG and HRSG CCPP Block 1”. The Innovation is a solution to the problem of loss of production & energy. Last year in 2022, we won the Subroto Award by the Indonesian Ministry of Energy and Mineral Resource (KESDM) on Management Energy at Large Industry category.



Figure 6 Asian Power Award in 2019

Plan

Policy and Commitment

Every plan for implementing the EnMS need the involvement and commitment of every employees in all levels. In achieving that first we integrated ISO 50001:2018 into corporate management system which is Integrated Management System (IMS) PT PLN NP along with other management system certified with PAS 99:2012. PT PLN NP Muara Karang has a EnMS policy signed by the General Manager with a commitment to continuously improve energy performance. To summarize the policy in *figure 7* the following commitment are implement energy management system, formulate strategic plan framework, commitment on financing, conduct management review meeting, and carry out management reports energy to Ministry of Energy and Mineral Resources. We increase our employee skill we train

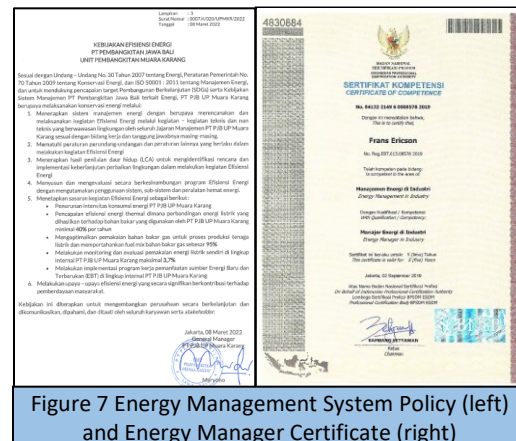


Figure 7 Energy Management System Policy (left) and Energy Manager Certificate (right)

them to get Energy Manager and Energy Auditor certification. To raise awareness and increase knowledge on energy efficiency, we socialize energy policies and energy conservation programs to all employees regularly through Coffee Morning program and Montly Joint Meeting. PT PLN NP Muara Karang Power Plant has long term planning so called Company Long Term Plan called 'RJPU' (see figure 2) which comprise programs for improvement of equipment efficiency and reliability. RJPU is for 5 years which derived annually can be called Company Work Plan and Budget called 'RKAP'.

Energy Review

To execute the process in implementing EnMS PT PLN NP Muara Karang Power Plant formed an energy management team that consists of Certified Energy Manager and Energy Auditor. The energy team conducted energy review as a process of gathering, calculating, analyzing processed data of energy consumption. We are focusing our energy review based on Significant Energy Uses (SEUs), then establishing Net Plant Heat Rate as an Energy Performance Indicator (EnPI) and determining a baseline with reference to ISO 50001: 2018. We were defining 2019 as the base year and the data for analysis was set from the last 3 years. Target EnPI was determined in accordance to PT. PLN NP corporate's key performance indicator. The method we are using are the combination of Energy Audit and regular performance test based on ASME PTC.

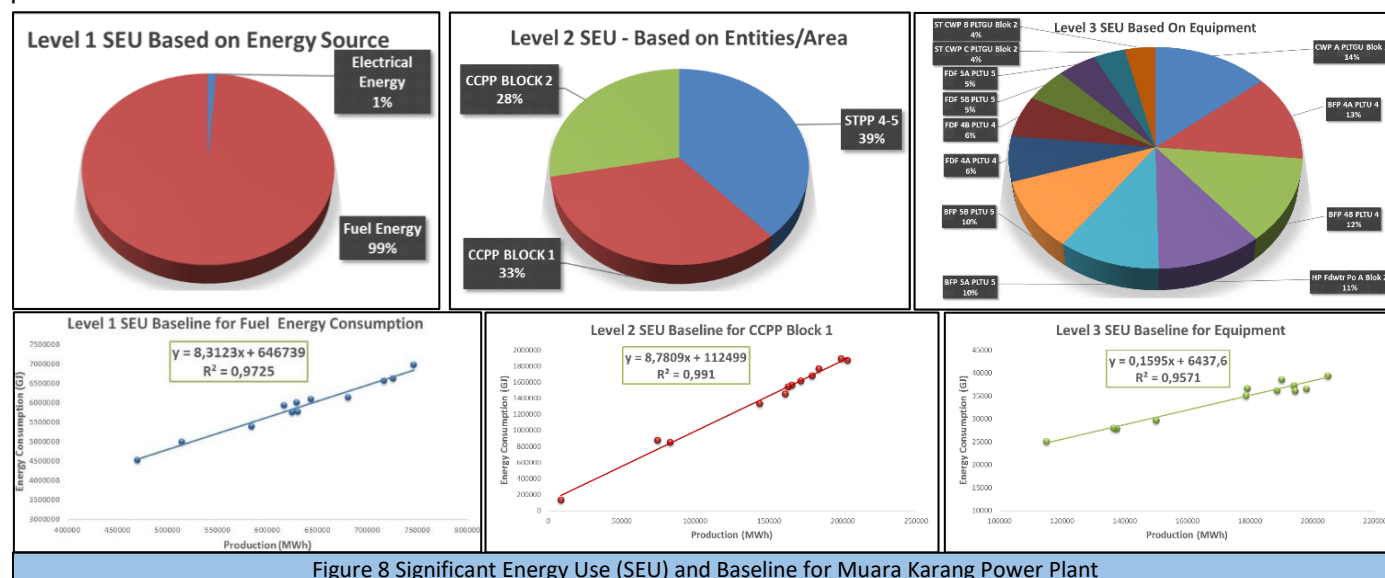


Figure 8 Significant Energy Use (SEU) and Baseline for Muara Karang Power Plant

To determine baseline, we do linear regression to energy consumption vs production data. We measured up to 3 tier levels to analyze the SEU of PT PLN NP Muara Karang Power Plant so the SEUs were known down to the equipment level. For the 1st tier level we set the SEU based on Energy Sources. The composition of the energy used in PT PLN NP Muara Karang power plant consisted of 98.86% fuel and 1.14% electrical energy as shown in the pie chart. We can conclude that significant portion energy that are used are from fuel. Power plant industry used fuel to generate electricity which is another form of energy and because of that we set the 2nd tier level of SEU based on Net Plant Heat rate (NPHR) from each entities/area. We have total of 3 entities in PT PLN NP Muara Karang Power Plant. The 3rd tier level of SEU are based on equipment in every generating unit. From the data based on EnPI we get that the NPHR of our oldest generating unit (Steam Power Plant Unit 4-5) are higher than other generating unit. Therefore, our energy team agreed to have more focus and prioritize on program for compensating the energy efficiency of our oldest unit.



“EnMS guides us to realize our energy efficiency target and increase our awareness and commitment on energy efficiency.”

—Sarita, Operation Manager Muara Karang Power Plant

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Do, Check, and Act

Program and Implementation

Based on the measurements, calculations, and identification of SEUs that have been carried out, as well as referring to the baseline and NPHR as the EnPI unit as explained in the previous elaboration, we get the potential improvement from each level of SEU. From the 1st level SEU we implement the program that will reduce our fuel consumption. It is known that Steam Turbine Plant Unit 4-5 has the lowest thermal efficiency, thus we have our main efficiency program which is Development of CCPP Block 3 (2021) with a Gas Turbine with efficient and environmentally friendly technology to substitute the production of Steam Turbine Plant Unit 4-5. You can see on *figure 9* the development of CCPP Block 3 are our highest investment but also give us highest saving. From the 2nd level SEU we implement program that can raise our generating unit efficiency one of them is Upgrade Combustor Extendor dan Advance Gas Path Turbine GTG 1.1 Combined Cycle Block 1.

No	Program	Program Year	Total Budget (US \$)	Total Savings (US \$)	Emission Reduction (Ton CO ₂ e)
1	Upgrade Combustor Extendor and Advance Gas Path Turbine GTG 1.3	2019	3,372,662	8,841,460	67.632,30
2	Installation of Rooftop Solar Panels	2019	45,333	20,053	244,11
3	Replacement of TL lamp to LED	2019	191,115	49,532	532,27
4	Replacement of mercury lamp to LED	2019	7,487	1,959,668	27.258,97
5	Compressor Washing GTG Block 1	2019	81,924	1,778,952	18.853,76
6	Compressor Washing GTG Block 2	2019	22,600	3,071,783	25.912,82
7	Modification of IGV opening for heat rate improvement Block 2	2019	259,476	4,661,252	40.043,01
8	Upgrade Combustor Extendor and Advance Gas Path Turbine GTG 1.1	2020	7,341,650	4,098,010	50.259,41
9	Re-Design Integration of GTG and HRSG Control Systems of Block 1	2020	8,810	1,501,581	21.876,55
10	Retrofit Debris Filter STG 1.0 Block 1	2020	625,078	3,816,527	43.583,35
11	Replacement combustor basket GTG 2.2	2020	1,182,485	1,607,390	22.718,73
12	Tube Cleaning Condensor STG 2.02	2020	5,333	1,136,352	15.628,24
13	Modified Supply Gland Steam to Reduce StartUp Duration CCPP Block 2	2020	2,000	292,791	4.389,14
14	Construction of CCPP Block 3 with High Energy Efficiency (approximately 61%) and Environmentally Friendly	2021	378,070,295	55,365,889	453.166,98
15	Optimization of CCW Fan Operation	2019	1,900	43,114	510,88
16	Installation of Rooftop Solar Panels Admin Building Phase 2 Muara Karang	2021	205,373	64,610	850,85
TOTAL			391,423,521	88,308,962	793.461,38

Figure 9 Energy Efficiency Program



Figure 10 CCPP Block 3

From the 3rd level SEU we implement program that can reduce electricity consumption for each equipment by optimizing operating pattern for equipment. The following are the program we implement from 2019 until 2022. We measure our total saving and CO₂eq from 2020 until 2022. Beside that we also have already implement energy efficiency program before 2020 such as installation solar panel, changing fluorescent lamp into LED lamp, optimizing AC operation, offline waterwash compressor of gas turbine power plant, and etc. We also do verification and measurement of energy performance with ISO 50015.

Evaluation

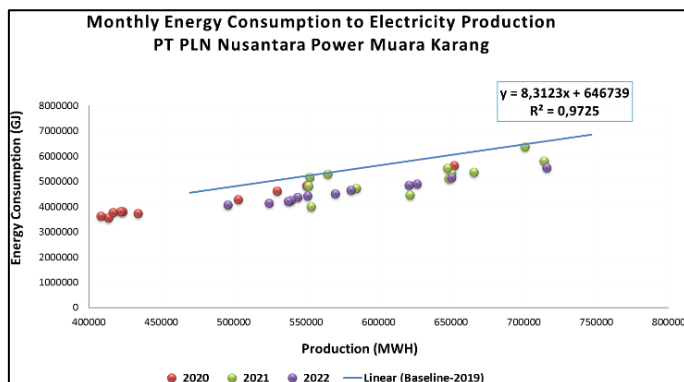


Figure 11 Montly Energy Consumption to Electricity production

our energy performance to see whether the EnPI has reach the target or not. We also make projection and simulation for the current year to see if we can reach the EnPI target set by PT PLN NP Headquarter at the end of year. You can see from *figure 13* we have succeeded to keep NPHR below target every year with average gap of 7% between target and realization. Energy savings and performance improvement are calculated based on total

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consumption in comparison with its baseline. We didn't do normalization because we calculate energy saving from total production and total energy consumption of Muara Karang Power Plant for each year compared to baseline. We socialize our monthly energy performance to all division at Monthly Joint Meeting. Collaborating with other division we look for the best solution to improve our energy performance. Our monthly efficiency performance is reported and validated by the Cost Management Division of PT PLN NP Headquarters. We also hire third party such as PT PLN Puslitbang to ensure our calculation method are in line with ASME PTC guideline. Beside internal audit we also do external audit with third parties PT EMI (Energy Management Indonesia).

$$\text{Energy Savings} = \frac{\text{Energy Expected (baseline)} - \text{Actual Energy Consumed}}{\text{Energy Expected (baseline)}}$$

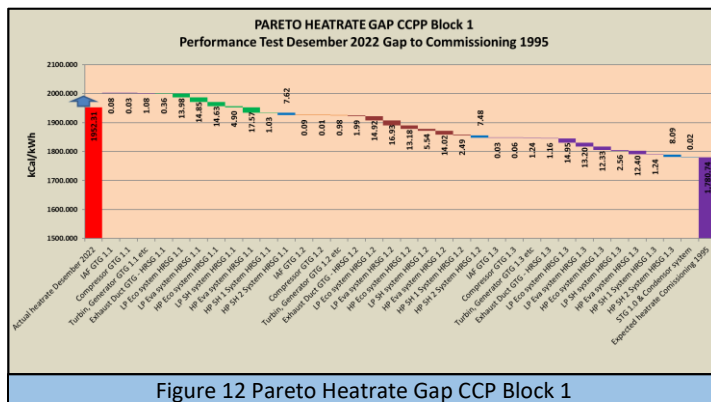


Figure 12 Pareto Heatrate Gap CCP Block 1

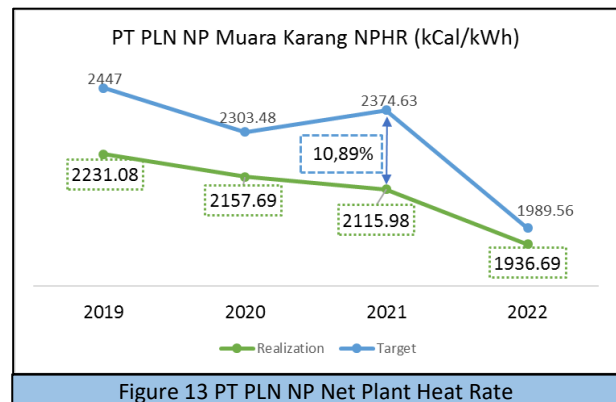


Figure 13 PT PLN NP Net Plant Heat Rate

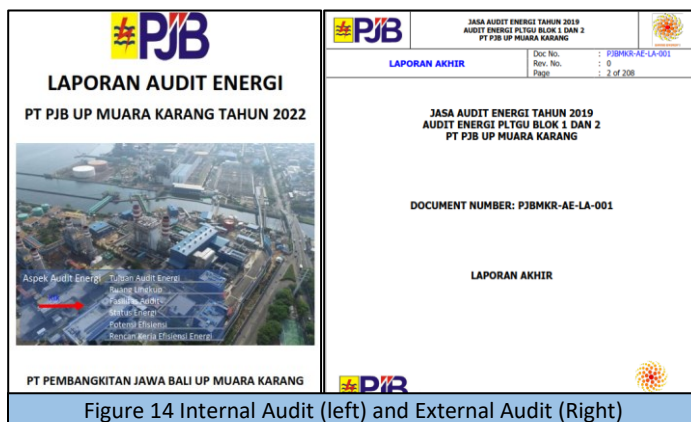


Figure 14 Internal Audit (left) and External Audit (Right)

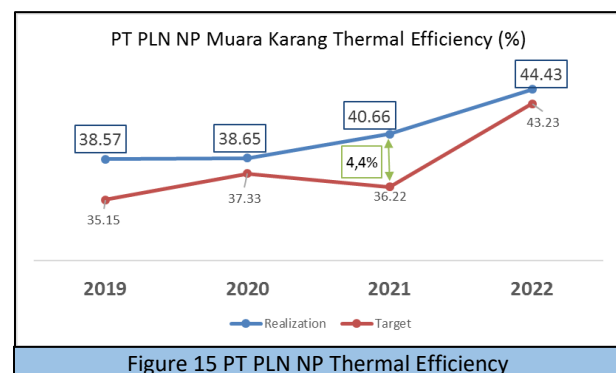


Figure 15 PT PLN NP Thermal Efficiency

Continuous Improvement

It is important to maintain our energy performance by continuous improvement after we do the evaluation. We show from figure 15 that we always make our efficiency target higher than before with year 2021 as exception because we assume Covid-19 pandemic will have higher effect on our production. But we succeeded on improving our efficiency and create a gap between realization and target of 4,4% in 2021. Beside the monthly joint meeting, our energy team also conducted Monthly Management Review meeting called 'RTM' (see figure 16) to evaluate SEU and determine critical operating parameters based on SEU. The management also held a program called BRIGHT (Brilliant Innovation for Brighter Electricity) to capture ideas and innovations carried out in all fields. All program and ideas that has been discussed to



Figure 16 Monthly Management Review Meeting

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be implemented to raise our energy performance are poured into Company Long Term Plan called 'RJPU' (see figure 2) and annually discussed in Company Work Plan and Budget call 'RKAP'. All this to make sure that we keep implementing EnMS and improve our energy performance.

Transparency

The program we do and the result on energy saving by implementing ISO 50001:2018 are reported to and validated by our Government through:

1. Online Energy Management Reporting (POME) by the Indonesian Ministry of Energy and Mineral Resources (KESM). (<https://simebtke.esdm.go.id/sinergi/>)
2. We have reported to Indonesian Ministry of Environment (KLHK) through Assessment Program in Environmental Management (PROPER) and for that we got Green PROPER Award from 2019 until 2022. (<https://proper.menlhk.go.id/>)
3. We also have emission monitoring facility for our power plant called Continuous Emission Monitoring System (CEMS) which are always monitored by Ministry of Environment. (<https://ditppu.menlhk.go.id/simpel/cemsonline>)
4. We reported three times a day our production, energy consumption, and also water consumption to our headquarter and our parent company PT PLN (<https://navitas.ptpjb.com/Naviver/cgi-bin/WebIndex.exe>)

What We Can Do Differently

Lesson Learned

From continuously implementing EnMS ISO 50001:2018, PT PLN NP Muara Karang Power Plant has learned many things beside all the achievement. The program to improve energy performance doesn't have to be something big but can also be something simple such as changing one behavior toward in carrying out activities. Setting company targets down to staff level should be delivered by providing clear direction from management. Other lesson we learn is we need to do external audit more often and from other third parties to gain more insight from another point of view. We learn that by implementing new technology we can significantly increase efficiency by 6% from 38% to 44%, reduce emission, and also reduce production cost of electricity we can increase our power plant efficiency from year to year.

Future Plan

PT PLN NP Muara Karang Plant have a Long-term Plan written in the Energy Efficiency Strategic Plan for 2023 to 2026 and is updated every year. It contains future program that we can do based on energy saving. Some of them are implementing new technology, further reduce energy consumption, further reduce plant heat rate, and implementation of new energy sources. Right now we are planning toward energy transition by increasing our renewable energy production to further support Net Zero Emission. We plan to install more solar panel until 1MWp in 2027. Another thing is co-firing with another fuel for our existing combined cycle power plant. We are considering co-firing with hydrogen fuel which is more environmentally friendly. For our GE Gas Turbines (CCPP Block 1) we can reduce the CO2 emission by 2.8% with only 10% hydrogen (see figure 17) co-firing which doesn't need much extra equipment.

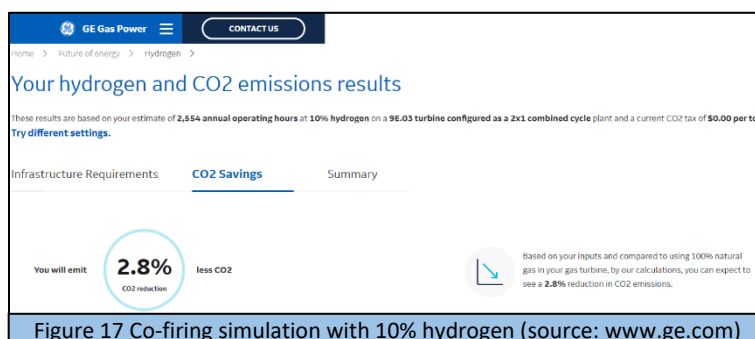


Figure 17 Co-firing simulation with 10% hydrogen (source: www.ge.com)