Identifying Resource Efficiency Opportunities in the Fertilizer Industry in Indonesia: Findings and Recommendations

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DISCLAIMER

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Abbreviations

BFW	Boiler feed water
CSR	Corporate Social Responsibility
EBT	Electronic Benefit Transfer
FGD	Focus Group Discussion
GHG	Greenhouse Gas
GITA	Green Industry and Trade Assessment
IGA	Indonesia Green Award
IGE	Implementing an Inclusive Green Economy
ILO	International Labour Organization
IPAL	Installation wastewater treatment
JBIC	Japan Bank for International Cooperation
LCDI	Low Carbon Development Initiative
MDRS	Modified Dust Recovery System
PAGE	Partnership for Action on Green Economy
PET	Pusri Effluent Treatment
PGRU	Purge Gas Recovery System
PMP	The Indonesian Government's Equity Participation
PSO	Public Service Obligations
PIM	Pupuk Iskandar Muda
PKC	Pupuk Kujang Cikampek
PKG	Petrokimia Gresik
PUSRI	Pupuk Sriwijaya Palembang
RECP	Resource efficiency and cleaner production
SCP	Sustainable consumption and production
SMEs	Small and Medium Enterprises
TEC	Toyo Engineering Corporation
VSD	Variable speed drives
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNITAR	United Nations Institute for Training and Research
WWTP	Wastewater Treatment Plant

Executive Summary

The Indonesian government has recognized the importance of fertilizers and has implemented various policies and initiatives to promote their effective and sustainable use. These include programs aimed at educating farmers about proper fertilizer application, encouraging the use of environmentally friendly fertilizers, and promoting responsible fertilizer manufacturing practices.

Implementing resource efficiency measures can involve using advanced technologies and practices that maximize the efficiency of fertilizer production processes. This includes optimizing energy consumption, reducing water usage, and minimizing the use of raw materials. The industry can reduce its ecological footprint and contribute to a more sustainable and responsible approach to fertilizer production.

This study found that applying resource efficiency techniques in the fertilizer industry can trigger competitiveness, reduce environmental footprint, and assist the government in meeting the climate target. This study finds that some companies have advanced in resource efficiency applications while others are still behind.

Resource efficiency and cleaner production (RECP) integrated with a life cycle perspective towards low carbon development should be the future focus of sustainability for the fertilizer industry in Indonesia.

Introduction

To further understand Indonesia's environmental performance and resource efficiency potential, especially in the fertilizer industry, the United Nations Industrial Development Organization (UNIDO) under the Partnership for Action on Green Economy (PAGE) together with the Indonesian government focal ministry, BAPPENAS (Ministry of National Development Planning) commissioned the Indonesia Cleaner Production Centre (ICPC) to conduct a study to identify resource efficiency opportunities for the fertilizer Industry in Indonesia.

UNIDO and PAGE government focal ministry BAPPENAS (Ministry of National Development Planning) agree to demonstrate the potential benefits of a well-designed and implemented resource efficiency strategy by undertaking a demonstration project in the fertilizer industry in Indonesia.

The initial plan focuses on the energy efficiency component to allow going deep and maximizing energy performance improvement potential in the fertilizer sector. A high-level resource efficiency questionnaire survey has been conducted in 6 selected fertilizer plants to shortlist 4 candidate plants, to which a more detailed questionnaire was sent to guide the final selection of a pilot plant for conducting a resource efficiency demonstration. The 6 fertilizer plants are PT. Pupuk Iskandar Muda (PT. PIM), PT. Pupuk Kujang Cikampek (PT. PKC), PT. Pupuk Sriwijaya Palembang (PT. PUSRI), PT. Pupuk Indonesia (Persero), PT. Petrokimia Gresik (PT. PKG), and PT. Pupuk Indonesia Energi.

After the selection process based on the RECP industry selection criteria, 4 industry candidates were selected as pilot plant for conducting a resource efficiency demonstration in the fertilizer industry.

Resource efficiency assessments at the pilot plant were conducted for four aspects:

- specific energy consumption (SEC), in MMBTU/ton product
- specific greenhouse gas emission, in kg CO_2 eq./ton product
- specific water consumption, in m3/ton product
- percentage of wastewater recycled, %.

1. Resource Efficiency and Cleaner Production (RECP) Profile of Fertilizer Company

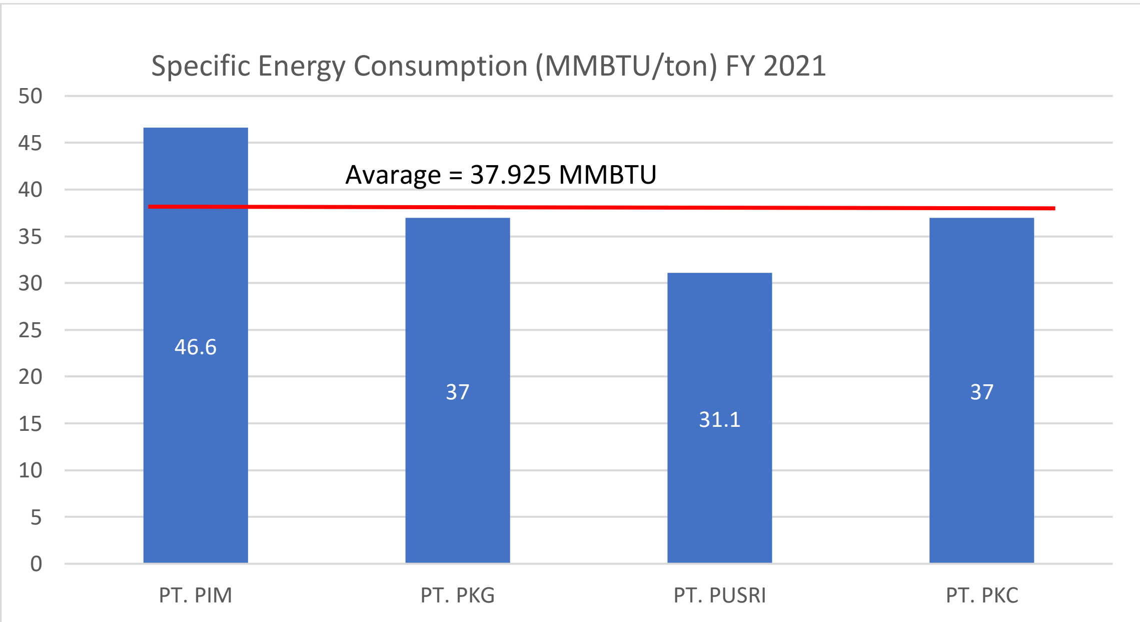
The RECP Profile of each fertilizer company is different depending on the capacity, type of fertilizer product produced, and technology process, including machinery. Likewise, other resources consumption, such as water and steam are also different. The type of fertilizer industry that participated in the study and answered the questionnaire produces urea fertilizer, ammonium sulphate (ZA) fertilizer, and NPK (Nitrogen, Phosphorus and Potassium) fertilizer.

1.1 Specific Energy Consumption (SEC) and Energy Efficiency

In this analysis, the Energy Performance Indicators of each fertilizer industry are compared to the baseline period (in this case 2018). Energy consumption includes energy sources used as raw materials (feedstock) equalized with energy. Specific energy consumption was calculated using MMBTU unit per ton urea.

Based on figure 1, it is shown that specific energy consumption of PT. PIM, 46.6 above of average. PT. PKG - 37, PT. PKC - 37, and PT. PUSRI – 31.1 are below average. The electricity unit is in megawatt per hour. To calculate the specific energy consumption, that electricity unit is converted to MMBTU by following conversion ratio of 3.412 MMBTU/MWh.

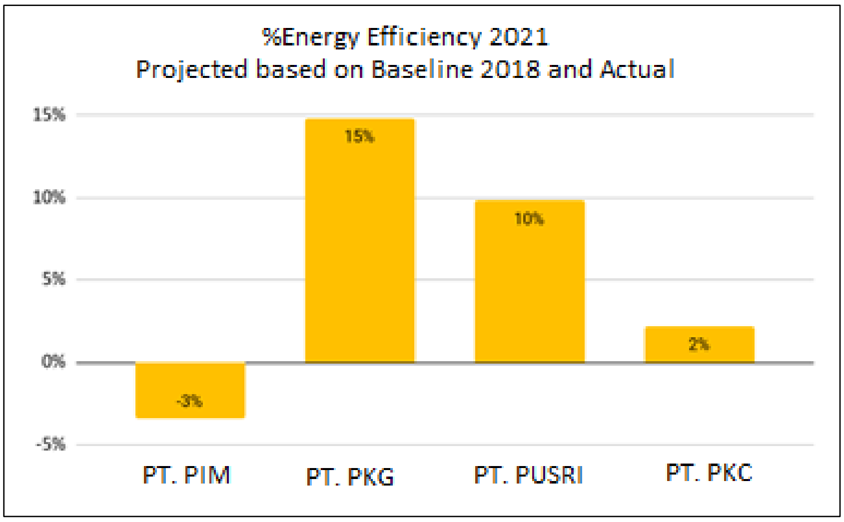
Figure 1. Specific Energy Consumption (SEC) and Energy Efficiency of RECP Pilot Plants



Average SEC for pilot units in 2021 = 37.9 MMBTU/ton

Source: RECP Profile 2021: Pilot Plants

Figure 2. The efficiency of Energy (Projected Based on Baseline vs Actual)



Percentage of improvement in energy efficiency at RECP pilot units in 2021 compared to the baseline year 2018

Source: RECP Profile 2021: Pilot Plants

Most companies showed an improved energy efficiency in 2021 compared to the 2018 baseline despite the COVID-19 pandemic throughout 2020-2021. An improvement of up to 15% was recorded at PT. PKG. It should be noted that PT. PIM has a decreased energy efficiency because there is no production in April 2021.

Meanwhile, PT. PUSRI, the energy efficiency is 10%, followed by PT. PKC 2%. This percentage value is calculated by modelling forecast energy consumption compared to actual energy consumption in 2021. During Jan – Sept 2021, urea production increased, impacting energy intensity.

The percentage of improvement in energy efficiency is calculated based on the baseline year 2018 for Urea production. The improvement in energy efficiency is calculated by comparing the projected energy efficiency (based on specific energy consumption in 2018) with the actual energy efficiency (in 2021).

The RECP study identified energy efficiency that has been implemented at the units, which reached up to 15% at PT. PKG and 10% at PT. PUSRI through efforts such as:

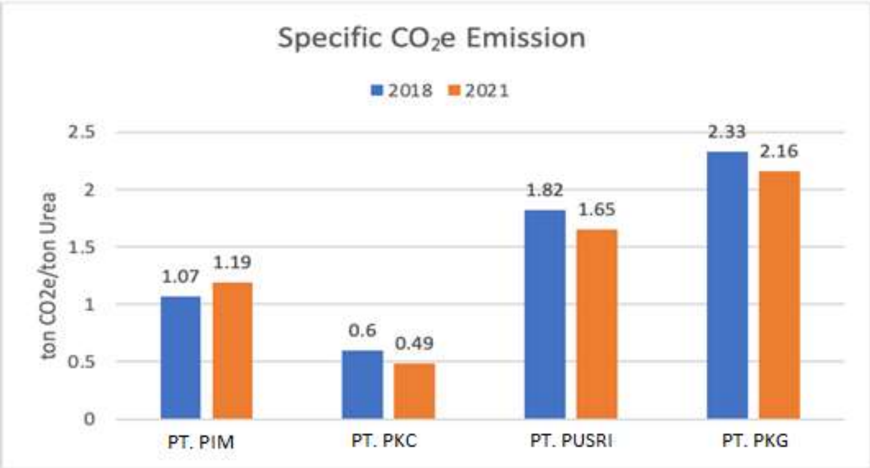
- better process control;
- good housekeeping;
- equipment modification;
- Material and energy efficiency through utilization of useful by-products, and onsite reuse and recycling.

Since the material used in the production is gas, the utilization of by-products and onsite reuse and recycling can also be classified as energy efficiency.

1.2 Specific CO_2e Emission

Specific CO_2e emission is total emissions divided by total urea production. Figure 3 shows that the specific CO_2e emission at PT. PIM has increased from 2018 to 2021. Different from PT. PKC, PT. PUSRI, and PT. PKG, specific CO_2e emissions have decreased from 2018 to 2021. The specific details regarding Scope 3 emissions[1] for PT. PKC, PUSRI, are unspecified. The calculation result of greenhouse emission could be different from the reported greenhouse emission because the energy consumption is sourced from natural gas and CO_2 gas as a by-product from production process.

Figure 3. Specific CO_2e Emission of RECP Pilot Plants



Source: RECP Profile 2021: Pilot Plant

The specific greenhouse gas emission did not reduce significantly. The highest CO_2 emission reduction is seen from PT. PUSRI AND PT. PKG, compared to the 2018 baseline. Although the total CO_2 emission was reduced, at the same time, there was a decrease in urea production compared to 2018.

The current method for calculating CO_2e reduction is based on the absolute CO_2 reduction from CO_2 utilization and not based on the projected reduction calculation using baseline. A few different approaches that can be used to identify a baseline for calculating CO_2 reduction. Some standard methods include:

1. Historical data: This approach uses data from previous years to establish a baseline for current and future CO_2 emissions. This can be useful for identifying trends and patterns over time.
2. Industry averages: This approach compares an organization's emissions to industry averages to establish a benchmark for CO_2 reduction.
3. Best practices: This approach looks at the best practices and emissions levels of leading organizations in the industry to establish a benchmark for CO_2 reduction.
4. Business-as-usual scenario: This approach projects future emissions based on the assumption that an organization will continue with its current practices, without any changes to improve energy efficiency or reduce emissions.
5. Regulatory standards: This approach uses legal standards or regulations as a baseline for calculating CO_2 emissions and reduction.
6. Absolute emissions: This approach establish a benchmark based on the total absolute emissions of a company.

It is important to note that the approach selection depends on the industry, size, nature of the organization, and the goals of the CO_2 reduction calculation.

[1] Scope 3 Emission: There are three scopes to account the greenhouse gas emission based on The Greenhouse Gas Protocol. Scope 3 includes all other indirect emissions that occur in an organization's upstream and downstream activities.

1.3 Specific Water Consumption (SWC)

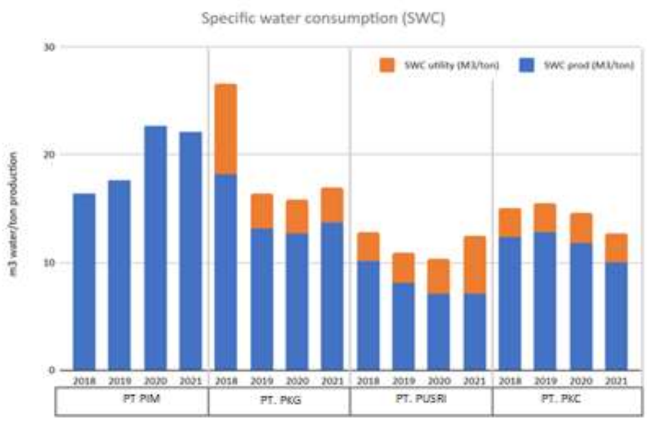
Water is used in production as steam and for utility in the fertilizer industry. Water for steam and chiller requires demineralized water as minerals can cause boiler problems and reduce efficiency. Water is treated through filtration for utility and demineralized for usage in the steam plant.

Calculation of Specific Water Consumption (SWC) is divided into 2 types: 1). SWC utility which is a comparison between demineralized[2] water consumption and product output, 2). SWC production, which is a comparison of filtered water consumption and product output. Demineralized water consumption is used for steam/boiler and chiller (cooling tower) generators.

For the three pilot units that provided utility water consumption data, PT. PKG, PT. PUSRI, and PT. PKC, the specific water consumption for the utility of the three companies have met below the green industry standard (SIH) maximum threshold of 5.5 m3/ton of urea with an average of 3.6 m3/ton. Water usage for production is not an indicator of green industry standards (SIH). Based on the four pilot units, the specific water consumption for urea production is 13.5 m3/ton.

Until this report is published the Green Industry Standard (SIH) has not included targets on water use for production and water recycling for the fertilizer industry. It is a recommendation to include these in future standard revisions.

Figure 4. Specific Water Consumption (2018 - 2021) of RECP Pilot Plants



Source: RECP Profile 2021: Pilot Plant

- 98% Ammonia separation from wastewater for fuel and water recovery
- Water recovery through hydrolysis and stripping process (PT. PUSRI effluent treatment)
- The usage of recycled water to reduce water consumption:
  - 16.27% recycled water at PT. PKG
  - 14% recycled water at PT. PKC

  through the recovery of condensate, cooling water, backwash, and wastewater treatment.

To calculate specific water consumption use limitations and assumptions due to the following data condition:

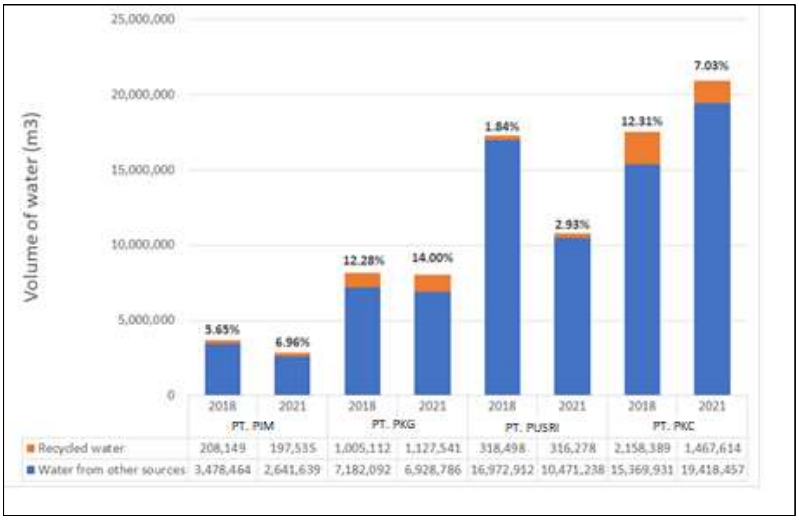
[2] Demineralized water is water that has most, or all its mineral ions removed, demineralized water involves removing dissolved minerals and salts from water to achieve a high level of purity.

1. Data provided by PKG is for the production of urea, ZA and SP36. Data shown here is proportion only to urea production.
2. PIM did not provide differentiation of water consumption for production and utility.
3. The percentage of water recycled is calculated by the amount of water recycled divided by total water from all sources.
4. PKC did not provide 2021 GHG emission data.

1.4 Utilization of Recycled Water

Water use efficiency is one of the efforts to maintain the sustainability of water resources and industrial sustainability. Water efficiency can be obtained from recycled water (wastewater treatment) and reused water (e.g., condensate water, cooling water, backwash).

Figure 5. Recycled Water Utilization (2018 & 2021) of RECP Pilot Plants



Percentage of recycled water and volume of water consumed in the fertilizer pilot units

Source: RECP Profile 2021: Pilot Plant

Based on the graph, in 2021, the recycled water utilization of PT. PKG was around 14% of total water consumption, which can be considered the best practice for other industries. PT. PUSRI is the lowest, 2.93%, meanwhile PT. PIM, 6.96% and PT. PKC, 7.03%, both the percentage of total recycle water utilization almost the same.

2. Conclusion and Recommendation

Table 1. Recapitulation of Pilot Plants RECP Profile

Items	PT. PIM	PT. PKG	PT. PUSRI	PT. PKC	SIH	IBM
Specific Energy Consumption (MMBTU/ton)	46.6	37.0	31.0	36.96*	37	
Specific Water Consumption (m^3/ton)	22.11	16.51	12.45	12.75	5.5****	
Specific CO2e emission*** (t-CO2e/ton)	N/A	0.334	0.410	0.237*	1.6	0.43
Percentage of Wastewater recycled (%)	4.38	3.74	2.93	11.70	N/A	90%

Source: RECP Profile 2021: Pilot Plant

*Data based on PKC 2021 Environmental Management Performance Summary (DRKPL). Specific CO_2 emission based on 11.86 kg CO_2e/50 kg urea)
**Data Financial Year 2021 was not available. Data is calculated based on the average of 2018-2020.
*** Green Industry Standard set the threshold for the specific water consumption only for utility. Data provided by the pilot units are total water consumption which combines water for production and utility.

Table 3 summarises the RECP profile of the assessed participants based on the RECP study result. The data from four companies as a pilot can be used as an internal benchmark. The performance of the four pilot industries was summarized in the RECP profile of the assessed pilots in comparison with the Green Industry Standard (SIH) threshold limit and industry benchmark (IBM) for urea production. The specific data, also known as data intensity, were calculated based on the annual consumption and production. As a benchmark, the upper threshold for the Ministry of Industry's Green Industry Standard (SIH) and global industrial benchmark for urea production are provided.

Based on the baseline analysis findings in the four RECP pilots, the recommendations are as follows:

- ❑ Energy efficiency programs have not been implemented comprehensively, although some industries have achieved sub-standard specific energy. There are already industries that can meet the standards to be used as benchmarks/good industry practices.
- ❑ Water efficiency programs are not evenly distributed, even though the specific water consumption is below the standard. There are already those who can meet the standards to be used as benchmarks/good industry practices.
- ❑ CO_2e reduction calculation is based on total utilization, not based on total reduction. So, it is necessary to review SIH limits based on total CO_2 reduction (energy efficiency, emissions, and utilization)
- ❑ The use of recycled water has not been included in the Green Industry Standard
- ❑ Pupuk Indonesia SR 2020: "For efficiency, PT. Pupuk Indonesia (Persero) is gradually increasing the use of coal and reducing the use of natural gas for heating and steam, considering that coal has a lower price, so that production costs can be reduced. "– This approach will have an impact on GHG emissions, should be reconsidered.

2.1 Technology Recommendation

Technical recommendations in the form of technology for specific purposes that can improve resource efficiency (environmental and social), among others:

- Factory revitalization
- CO_2 exhaust gas utilization
- Operational data digitization system
- Innovation in industrial waste monitoring equipment (gas and liquid waste emissions)
- Improved WWTP performance and improved water recycling facilities
- Increasing the use of renewable energy (biomass) for the production process and solar PV (for offices)
- Improved interconnection between factories
- Knowledge sharing between industries for equal implementation – equalization of technology used
- Standard implementation with the same GHG calculation approach

2.2 Management Recommendation

In implementing the production process in the fertilizer industry, several management recommendations that can improve resource efficiency (environmental and social) include; Implementation of energy management and audit systems, employee training and development related to environmental management, Implementation of environmental management systems throughout the fertilizer industry, implementation of heat/steam recovery systems throughout the fertilizer industry, and Comprehensive and integrated data collection system.

2.3 Financing Recommendation

Long-term technology replacement options require substantial funding, so a long-term corporate strategy is needed. Synergy is needed with financial institutions related to sustainable funding mechanisms to accelerate the implementation of resource efficiency and cleaner production that can reduce significant greenhouse gas emissions in Indonesian fertilizers (stakeholders: BAPENAS, Ministry of Industry, Ministry of Energy, and Mineral Resources, MoEF, Pupuk Indonesia (Persero).

The funding mechanism can be synergized with the road map for sustainable finance phase II (2021 – 2025) issued by the OJK. Some examples of implementing of sustainable finance include financing for new and renewable energy projects (financing electricity sourced from hydropower, geothermal power, hydropower, solar power, biogas power, biomass, and other renewable energy sources, energy efficiency, and others). - Green Taxonomy.

2.4 LCA (Life Cycle Analysis) Recommendation

The fertilizer industry can expand the boundary system from Gate-to-Gate to Cradle-to-Grave example:

- Develop alternative industrial-scale products to replace urea that is not based on fossil fuels which will one day run out and at the same time reduce the effects of greenhouse gases.
- Potential application of recycled packaging through a program to return unused packaging to producers as a form of implementation of expanded producer responsibility (EPR).

I. Background

The study of RECP in the fertilizer industry sector was carried out to support the Ministry of National Development Planning/BAPPENAS in implementing low-carbon development policies and a green economy to demonstrate the potential and benefits of a well-designed and implemented resource efficiency strategy by undertaking a pilot project in the fertilizer industry in Indonesia. This activity focuses on the energy efficiency component for high-level assessment, scale up the potential to improve the fertilizer sector's energy performance and analysis the greenhouse emission profile.

Under the PAGE framework, UNIDO developed the Green Industry and Trade Assessment (GITA) report in 2019 to strengthen the implementation of the low carbon development initiative (LCDI). It measures the country's industrial environmental performance in terms of air, and water pollution, industrial waste, resource efficiency in energy, water, and material efficiency, and clean technology application in Industrial production. GITA finds that the industry is the topmost energy consumer in Indonesia. In the industrial sector, Non-metallic mineral products (cement, ceramics, glass, and lime), chemical, petrochemical, and non-ferrous metals are the largest energy consumers. 80% of the energy losses of most significant energy users come from the heating system and on-site power plants except for pulp and paper, textile, and basic chemical industries. The country is more resource-efficient in terms of usage of material resources and less water-efficient compared to the Asia-Pacific regional average. GITA also conducts case studies on Cement, Fertilizer, Pulp and Paper, and Food and beverage sectors and recommends doing resource efficiency demonstrations to identify the cost savings potential of introducing resource efficiency measures.

The methodology for demonstrating Resource Efficiency and Cleaner Production (RECP) in pilot plants are literature review, survey, statistics, desktop study, and calculations. The following steps and approaches of study methodologies:

- Literature review: Conducting a literature review involves gathering and analyzing relevant published materials, scientific articles, research papers, and case studies related to RECP.
- Survey: distributing questionnaires to all fertilizer companies which attended the RECP Kick-Off Meeting. Six companies were selected based on the completeness of data given by the companies, and a further step was to select four companies as the pilot unit. This selection process required more detailed data and deep-dive analysis.
- Statistics: Utilizing statistical data can be crucial in understanding the current state of the industry or sector being studied.
- Desktop study: A desktop study involves conducting research, analysis, and data collection using available resources, reports, databases, national and international standards as a benchmark.
- Calculation using RECP methodology: Applying a specific RECP methodology involves using established frameworks and tools to quantify the potential resource savings, emissions reductions, and economic benefits of implementing cleaner production practices.
- Online meetings with pilot companies and stakeholders: Engaging with relevant stakeholders is essential for gathering input, sharing information, and building consensus on RECP initiatives.
- Demonstration of RECP in pilot plants: involving setting up pilot plants or small-scale facilities to implement and test resource efficiency and cleaner production practices, including site visit to pilot plants to discuss and consultation a resource efficiency option that can be implemented in short- and long-term planning in pilot units. The RECP options included energy, material, water, and operational optimization. The RECP option intends to generate

attractive upgrade opportunities from a plant with management support in implementing cost-effective projects, funding projects, and setting benchmarks to encourage broad uptake.

- Report: final report and policy executive summary.

Four selected companies as pilot units:

Company	Location	Production	Market
PT. Pupuk Iskandar Muda (PIM)	Lhokseumawe - North Aceh	Urea, Ammonia	Aceh, North/West Sumatra, Riau, Kepri, & Jambi
PT. Petrokimia Gresik (PKG)	Gresik, East Java	Urea, Ammonia	Sumatra & Java
PT. Pupuk Sriwidjaja (PUSRI)	Palembang, South Sumatra	Urea, Ammonia	Sumatra & West Kalimantan
PT. Pupuk Kujang Cikampek (PKC)	Cikampek, West Java	Urea, Ammonia	West Java

Resource Efficient and Cleaner Production (RECP): What is it?

RECP was introduced in 2009 by the United Nations Industrial Development Organization (UNIDO) and the United Nations Environment Programme (UNEP) as an umbrella term that brings together comparable practices that had proven themselves in preceding periods and showed great synergy, including Cleaner Production; Eco-Efficiency; Waste Minimization; Green Productivity; Pollution Prevention; and Toxics Use Reduction. RECP relates to sustainable consumption and production, green industry, sustainable tourism development, industrial energy efficiency, innovation, and competitiveness. These objectives are closely aligned with the 2030 Sustainable Development Goals (SDGs), specifically SDG 12 (Ensure sustainable consumption and production patterns), SDG 9 (Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation), and SDG 8 (Promote sustained, inclusive, and sustainable economic growth, full and productive employment, and decent work for all).

A sustainable process is implemented to improve the efficiency of natural resource utilization (including materials, water, and energy). This increased efficiency enables a more productive utilization of natural resources, reducing waste, liquid waste, and air emissions. Moreover, it is expected that this approach will contribute to enhancing the environmental quality for the community, including workers, consumers, and local communities, as the environment is effectively maintained. The focus should be identifying low-hanging fruit opportunities (i.e., "good housekeeping") and investment opportunities.

Figure 6. Resource Efficient & Cleaner Production

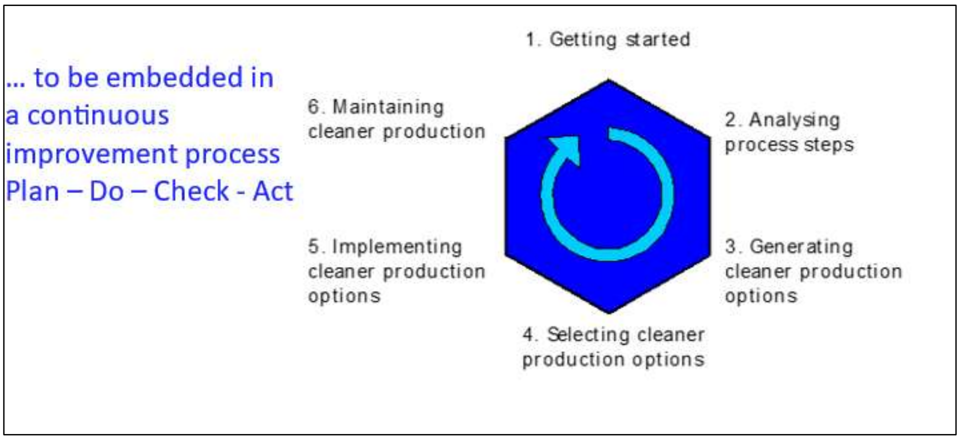
Source: UNIDO RECP Programme

RECP practices allow substituting materials and using renewable or recycled materials to avoid hazardous raw materials, product redesign to make disassembly easier, extend service life, reduce consumer maintenance requirements, and enable industrial symbiosis.

RECP Method

RECP preparation includes top management commitment, RECP team formation (better including personnel from different departments, and RECP profiling/baseline. For baseline, it needs data on material, water, and energy use as well as waste, wastewater, and GHG emission.

Figure 7. RECP Method

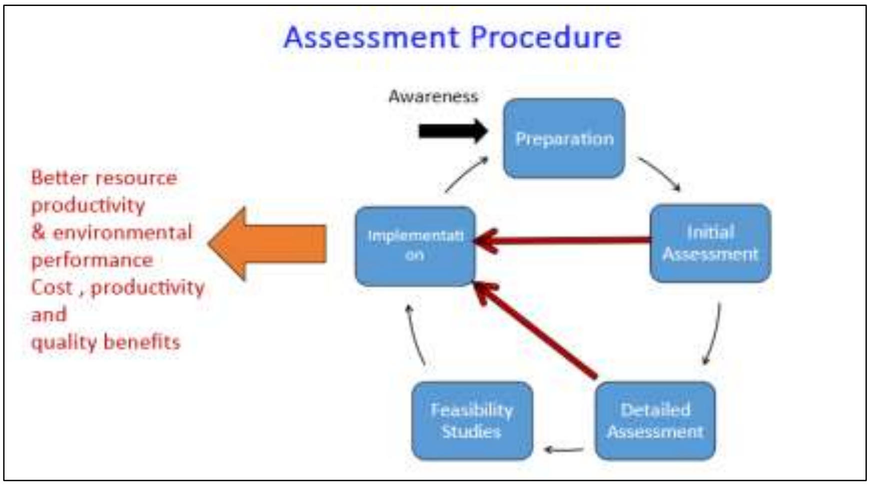


Source: UNIDO RECP Programme

Initial assessment includes analysis on:
- flow diagram (to identify where material/energy/water is consumed and the source of wastage),
- Plant layout (to identify areas of inefficiency and wastage)

From this assessment, immediate RECP options (eight practices) can be identified; these options can be implemented immediately. Some options that need more evaluation were also identified to be assessed in detail. Detailed assessment needs more than the flow diagram; material and energy balance is required to determine the root causes of inefficiency and waste. RECP options are generated based on the assessment. Some options can be directly implemented, while other requiring higher investment needs a feasibility study. A feasibility study looks at the economic, technical, and environmental aspects of the RECP options. Implementing the RECP options needs an implementation plan, monitoring, and mainstreaming RECP in the company management and operation (continuous improvement).

Figure 8. Assessment Procedure



Source: UNIDO RECP Programme

Importance of Implementing RECP

As the economy grows, resource use and environmental impact also increase rapidly (during the 20th century, global resource use increased eightfold).

Decoupling the resource use and environmental impacts from economic growth means that the economic growth rate will be much higher than the growth rate of water, material, and energy consumption and waste, emission, and effluent generation. The ultimate aim is to decrease the resource use and pollution generation in absolute terms.

In other side, industrial activities have an impact on the generation of pollutants so that the carrying capacity of the environment are reduced.

This requires shift in production and consumption system through the application of resource-efficient and cleaner production methods. This is in line with the green economy, defined as low-carbon, resource efficient, and socially inclusive.

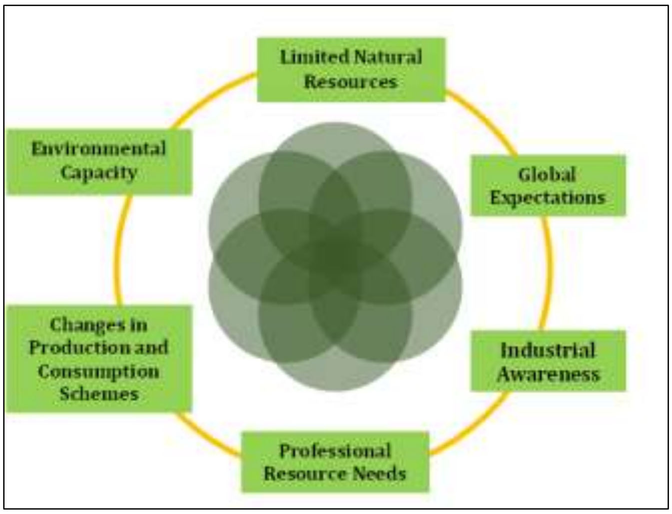
Since 2015, UNIDO, together with the Ministry of Environment implemented RECP Programme in Indonesia, based on the result of RECP activities implementation at pilot plants, identified the following benefits of RECP implementation[3]:

- Improve resouce efficiecncy Meningkatkan effisiensi sumber daya
- Reduce enviromental foot print
- Enchancing company's branding

[3] Publication of RECP success stories, ICPC (ppbn.or.id)

- Increase awareness of work enviromental and Occupational Health and Safety/"Keselamatan dan Kesehatan Kerja" (K3)
- Better understanding on production process and waste
- Increased capacity to manage and minimize resource consumption, waste and pollution

Figure 9. RECP Implementation



Source: UNIDO RECP Programme

In the RECP methodology, there are eight practices:

- Good housekeeping is simple, no-cost, or low-cost practice, such as the creation and implementation of Standard Operation Procedures (SOP), turning off equipment when not in use, etc.
- Input material: it is input material change, i.e., change fossil fuel to renewable energy, change hazardous chemicals into safer alternatives, etc.
- Product modification: Product modification can be done, for example, increasing product lifetime or enabling the product to be recycled after its lifetime is over.
- Technology Change, better process and equipment modification: Changes can be implemented in terms of better process control, e.g., implementing automatic control, equipment modification, e.g., improving insulation, fixing leaks, and technology change e.g. changing an old compressor with a new efficient one.
- Recycling: It can be onsite reuse and recycle (e.g., water reuse, heat recovery) or offsite (production of useful by-product, e.g., waste heat to neighbouring company, waste material as other company's raw material)

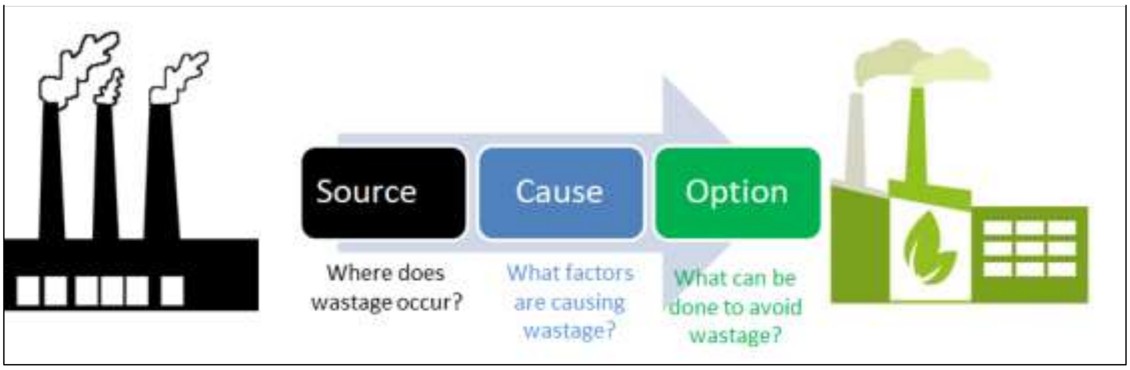
Figure 10. 8 (eight) Elements of RECP Implementation

Source: UNIDO RECP Programme

RECP Problem Solving Logic

In order to work on any inefficiency or wastage, RECP techniques identify the following:
Source: where does the inefficiency/wastage occur?
Cause: what factors are causing the inefficiency/wastage?
Option: what can be done to avoid/reduce inefficiency/wastage?
This differentiates RECP from the "end-of-pipe" action, which addresses on how to treat the generated waste.

Figure 11. RECP Problem

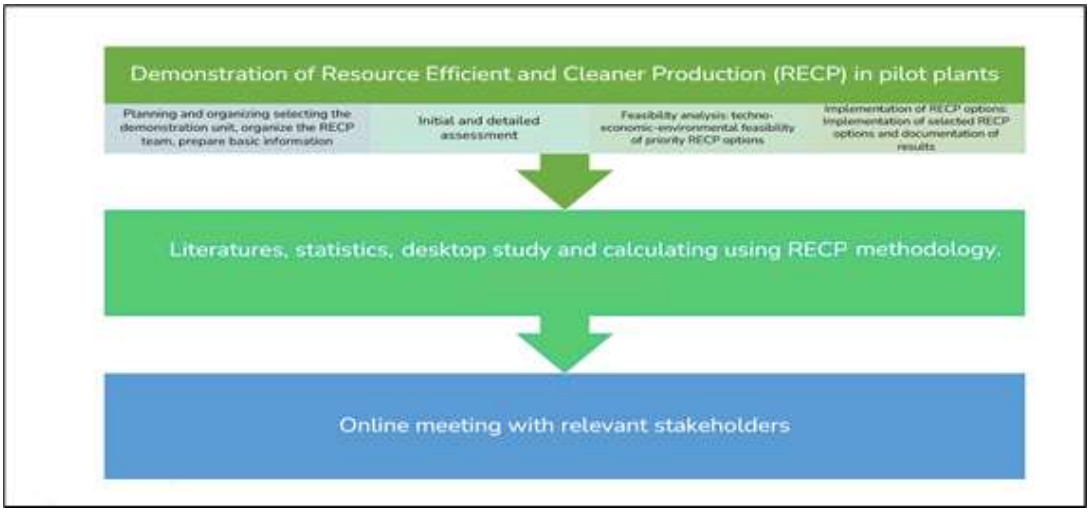


Source: UNIDO RECP Programme

II. Methodology of the Study

The study combined an industrial survey of the fertilizer industry, a desktop study, a literature study, focus group discussions with stakeholders of the fertilizer industry in Indonesia and a site visit to the pilot plant. The project was conducted amidst the COVID-19 pandemic (in 2021) and therefore, most of the activities were conducted through online platforms.

Figure 12. Methodology of Study



A survey was distributed to **nine** leading fertilizer companies in Indonesia, consisting of 5 (five) state-owned companies (SOE) or *Badan Usaha Milik Negara (BUMN)* under PT. Pupuk Indonesia (Persero) Group, and 4 (four) private companies. **Six** of the nine companies responded to the questionnaire and were screened to be selected as the pilot/demonstration units. **Four companies were selected as pilot units for detailed resource efficiency and cleaner production (RECP) assessment**. These companies were PT. Pupuk Iskandar Muda (PIM), PT. Pupuk Kujang Cikampek (PKC), PT. Pupuk Sriwidjaja (PUSRI), and PT. Petrokimia Gresik (PKG).

III. Desk Review, RECP Study, and Result

3.1 Desk Review

<u>Profile of Fertilizer Industry in Indonesia</u>

The fertilizer industry in Indonesia is dominated by State-owned enterprises (BUMN), which are members of the PT. Pupuk Indonesia Group. Desk review was conducted based on published data which finds 9 fertilizer industries consisting of 4 private fertilizer industries and 5 BUMN industries members of PT. Pupuk Indonesia (Persero).

The list of industries is as follows:

- PT. Pupuk Indonesia Group <u>(State-Owned Enterprise/SOEs)</u>
    1. PT. Petrokimia Gresik ("Program Penilaian Peringkat Kinerja Perusahaan Dalam Pengelolaan Lingkungan Hidup"/Public Disclosure Program for Environmental Compliance (PROPER)[4] GOLD,)
    2. PT. Pupuk Kalimantan Timur (PROPER GOLD 2019)
    3. PT. Pupuk Kujang (PROPER GREEN)

[4] There are five ratings: Gold Rating & Green Rating, Beyond Compliance, Eco-Innovation
Blue Rating, Compliance, Red & Black Rating, Non-Compliance

4. PT. Pupuk Sriwijaya Palembang (PROPER GREEN)
5. PT. Pupuk Iskandar Muda (PROPER BLUE)

- Private Fertilizer Company
  1. PT. Sentana Adidaya Pratama (Riau and Gresik)
  2. PT. Agri Indomas (Palembang)
  3. PT. Agri Timur Mas (Gresik)
  4. PT. Saraswanti Anugerah Makmur (Sidoarjo)

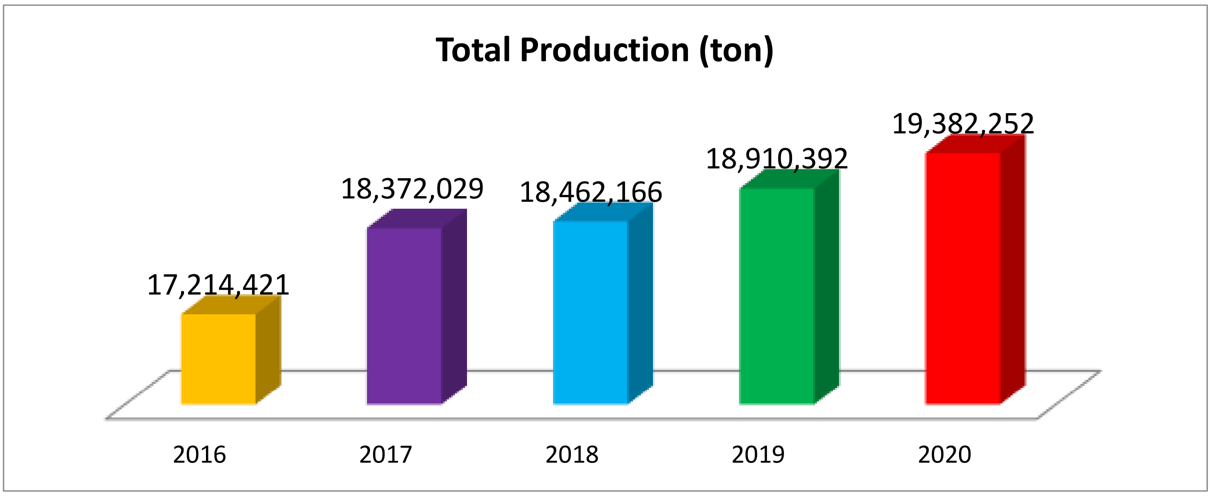
Most of the fertilizer industry produces NPK fertilizers as the domestic market share mostly uses NPK. The desk review on fertilizer development in Indonesia found that production, raw material consumption (water, energy, materials), and environmental performance data are available from PT. Pupuk Indonesia Group members. This study conducted a survey through a questionnaire to minimize the gap between data availability and actual data.

PT. Pupuk Indonesia (Persero)

The following section describes the profile of PT. Pupuk Indonesia (Persero):

Pupuk Indonesia Group achieved record production in 2020. Total production reached 19.4 million tons or 117.78% of the target set by the Shareholders. This is the Company's highest achievement, despite having the difficult challenges of the Covid-19 pandemic, as shown in Figure 13 below. PT. Pupuk Indonesia Energy has been working for more than seven years with 60 employees, supplying electricity and steam for unit needs.

Figure 13. Total production of PT. Pupuk Indonesia Group



Source: *Sustainability Report* – PT. Pupuk Indonesia (Persero), 2021

Performance of Pupuk Indonesia Group in the lenses of Economic, environmental and social indicator:

Economic Performance

Regarding operational performance, throughout 2020, Pupuk Indonesia Group succeeded in realizing the production of 19.4 million tons, or 102.50% of the previous year's realization. Compared to the target of 16.5 million tons, the achievement of fertilizer and non-fertilizer products was 117.78%. The performance of the production process is also more efficient because the ratio of urea gas consumption is only 26.9 MMBTU/ton or 97.43% from 2019. This realization is 95.63% of the set target. Regarding sales, the realization for non-subsidized fertilizers or non-Public Service Obligations (PSO) reached 4.9 million tons or 126.86% of the realization in 2019. This achievement also reached 139.79% of the set target.[5]

The good performance results were influenced by the increase in market demand for urea and NPK, both from within the country and abroad. Meanwhile, the distribution of PSO fertilizer was only 96.80% of the previous year's realization, considering that the additional allocation for the additional subsidized fertilizer was only effective for distribution in November 2020. However, the result was still above the target of 106.05%.

In line with the increase in sales volume, the company recorded a rise in revenue that amounted to IDR71.88 trillion or reaching 101.07% from the previous year's realization. The realization is 100.14% compared with the target. This achievement was supported by the sales performance of non-PSO fertilizers that exceeded the realization in 2019 and the target in 2020. At the same time, the company managed to make selling expenses efficiency up to IDR 1.19 trillion, only 84.80% from the previous year and reaching 92.20% of the 2020 budget.

In terms of profit, the achievement of profit for the current year was IDR 2.33 trillion or reached 77.69% compared to 2019 and reached 89.79% of the target. The lower profit in 2020 compared to 2019 was influenced by the increase in the cost of trade revenues, while the lower profit achievement compared to the 2020 target was due to other expenses higher than the budget.

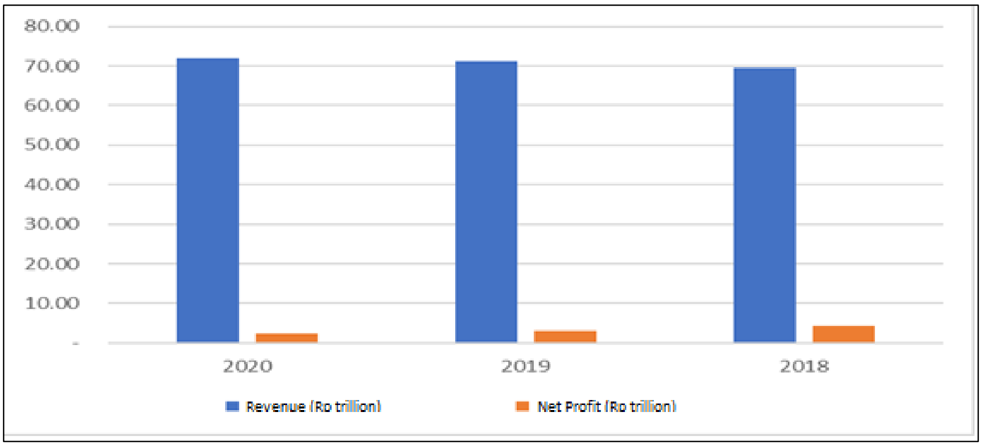
In addition, the Company's liquidity, which is shown through cash flow from operating activities, is also in a good state. In 2020, the realization was IDR 16.07 trillion or 186.82% of the achievement 2019. This was supported by the high cash receipts from customers, which amounted to IDR 77.49 trillion or 105.75% from the previous year.

From the aspect of the company's ability to cover loans from creditors, namely the Debt to EBITDA indicator, it was realized at 3.7 times in 2020, experiencing a performance improvement compared to 2019 was 4.5 times. This happens because there is a repayment of loans to creditors. These achievements in the economic field certainly provide a special spirit amid various challenges of the economic downturn due to the pandemic.

The economic performance of PT. Pupuk Indonesia (Persero) in the sustainability report can be seen in figures 14, and 15 below.

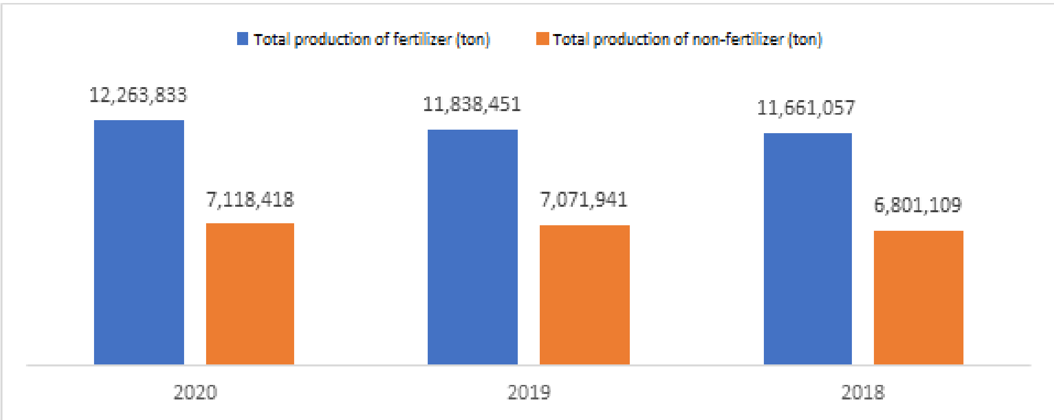
[5] Source*: Sustainability Report* – PT. Pupuk Indonesia (Persero), 2021

Figure 14. Revenue and Net Profit of PT. Pupuk Indonesia (Persero)



Resource: Sustainability Report – PT. Pupuk Indonesia (Persero), 2021

Figure 15. Total Production of Fertilizer and Non-Fertilizer PT. Pupuk Indonesia (Persero)



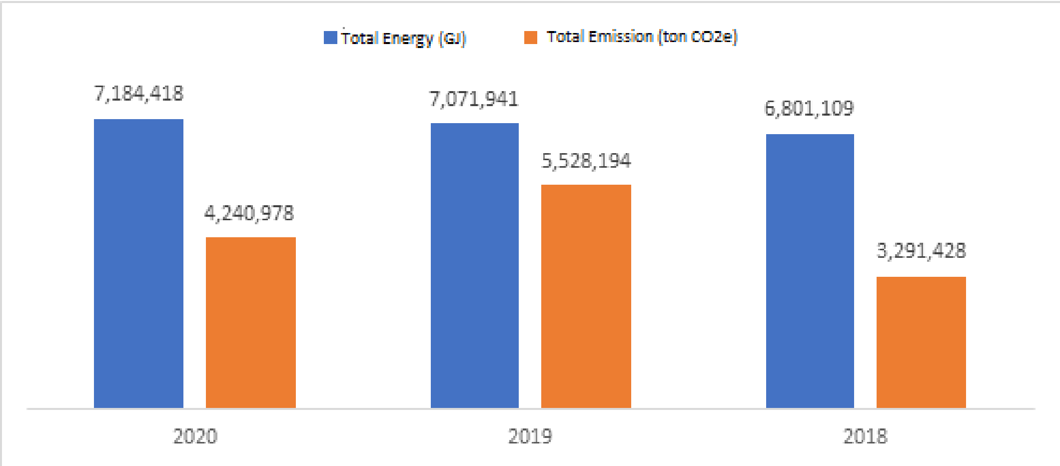
Resource: Sustainability Report – PT. Pupuk Indonesia (Persero), 2021

Environmental Performance

One of the environmental performance achievements received in 2020 was the PROPER "Gold" for PT. Pupuk Kalimantan Timur dan PT. Petrokimia Gresik, PROPER "Green" for PT. Pupuk Kujang Cikampek and PT. Pupuk Sriwidjaja Palembang, and PROPER "Blue" for PT. Pupuk Iskandar Muda from the Ministry of Environment and Forestry. This achievement illustrates the efforts of PT. Pupuk Indonesia (Persero) to maintain above environmental sustainability standards the government sets. In addition, the company reduced Total Energy, namely energy use per ton of product, in the reporting year. This decrease resulted from a reduction in energy consumption of 17,446,752 GJ. In line with the decline in energy, 23% reduction in greenhouse gas emissions compared to the previous year. Reducing energy consumption and emissions is a form of commitment and seriousness in preserving the environment.

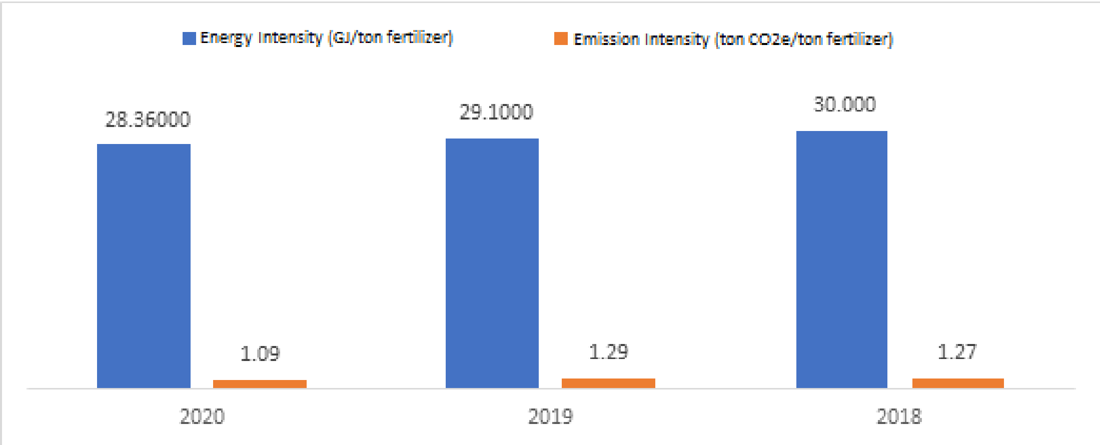
The environmental performance of PT. Pupuk Indonesia (Persero) in the sustainability report can be seen in figure 16, and 17 below:

Figure 16. Total Energy and Emission of PT. Pupuk Indonesia (Persero)



Resource: Sustainability Report – PT. Pupuk Indonesia (Persero), 2021

Figure 17. Energy Intensity and Emission Intensity of PT. Pupuk Indonesia (Persero)



Resource: Sustainability Report – PT. Pupuk Indonesia (Persero), 2021

Social Performance

The implementation of Corporate Social Responsibility (CSR) in 2020 was focused on overcoming the impact of the pandemic by continuing programs that have been running well. PT. Pupuk Indonesia (Persero) provides a stimulus for small and medium enterprises (SMEs) affected by the COVID-19 pandemic. In addition, the company offers relaxation for partnership recipients in rescheduling instalments and reconditioning. This is in line with the policy of the Ministry of State-Owned Enterprises as the shareholder of PT. Pupuk Indonesia (Persero). Currently, the company has 1,002 fostered partners with a loan value of IDR 87,4 billion. PT. Pupuk Indonesia (Persero) distributed CSR funds of IDR 51,1 billion in the reporting year, and Community Development Program funds of IDR 43.48 billion (32%) were distributed to the poverty alleviation sector.

Private Fertilizer Company

The following brief information on four private companies:

1. PT. Sentana Adidaya Pratama, (SADP), Riau and Gresik

PT. Sentana Adidaya Pratama (SADP) was established in 1999, with fertilizer trading being its first business using the brand, Mahkot. PT SADP is a subsidiary of Wilmar Group Indonesia, one of the largest agribusiness companies in the world, especially in the field of CPO and its derivatives.

In the early stages of its development, Pupuk Mahkota imported and distributed all quality and affordable fertilizers needed by plantations and agriculture, especially oil palm plantations, such as straight fertilizer, namely KCl (Potassium chloride) fertilizer, and Rock phosphate fertilizer.

In its journey triggered by the high demand for NPK fertilizer (compound fertilizer) as well as the increasing knowledge of plantation users on effective and efficient balanced fertilization management, PT SADP answered the challenge by building its own NPK factory (steam granulation) located in Dumai Industrial state, Riau.
In 2002, the rapid development of oil palm plantations became one of the driving forces of the national economy in the crown fertilizer answer to continue to expand the construction of NPK plants as an active role in the progress of the Indonesian economy. Until now, it has 6 NPK Fertilizer plants with a capacity of more than 1 million Mt/year (Source, Mahkota Fertilizer, PT. Sentana Adidaya Pratama (SADP) website).

2. PT. Agri Indomas, Palembang
PT. Agri Indomas is a subsidiary of the Wilmar Group.

3. PT. Agri Timur Mas, Gresik
PT. Agri Timur Mas had been closed.

4. PT. Saraswanti Anugerah Makmur (SAMF), Sidoarjo

PT. Saraswanti Anugerah Makmur Tbk (SAMF), was established in East Java Province in 1998, based on the Deed of Establishment No. 15 dated June 18, 1998, Notary by Titiek Lintang Trenggonowati, S.H., in Surabaya, and has been approved by the Minister of Justice of the Republic of Indonesia, Decree No. C2-17.036 HT.01.01.TH.98 dated October 5, 1998, and registered at the Regional Office of the Ministry of Trade of East Java Province No. 159/BH.12.01/I/99 dated January 13, 1999.

The company is engaged in the production and distribution of non-subsidized NPK fertilizers. It has 3 (three) subsidiaries with 5 (five) plants spread across East Java, North Sumatra, and Central Kalimantan.

To reach and facilitate consumers to obtain information about fertilizers, SAMF has 12 marketing offices spread across 12 cities in Indonesia in Banjarbaru, Balikpapan, Makassar, Pontianak, Sampit, Yogyakarta, Jakarta, Surabaya, Pekanbaru, Jambi, Medan, and Palembang.

With the issuer code SAMF, PT. Saraswanti Anugerah Makmur, Tbk started a new step by becoming a public company and listing on the Indonesia Stock Exchange on March 31, 2020, with a total of

775,000,000 shares offered to the public or 15.12% of the capital placed and fully paid capital after the Initial Public Offering. This new step taken by the company succeeded in raising funds amounting to IDR 93 billion, which was intended for capital expenditure and other working capital needs.

3.2 RECP Study

Questionnaire and Feedback

The questionnaires were distributed to 9 fertilizer industries in Indonesia, seven fertilizer industries from BUMN (State-Owned Enterprises), and two from the private sector.

Five of nine fertilizer industries responded, all from the BUMN. The fertilizer industry that contributed to this survey was PT. Pupuk Indonesia, a holding company that oversees fertilizer industry units and supports industrial units. 3 fertilizer industry units answered the survey, namely PT. Pupuk Kujang Cikampek, PT. Pupuk Iskandar Muda, and PT. Pupuk Sriwijaya Palembang. In addition, one supporting industry PT. Pupuk Indonesia Energi.

The following is a list of industries that received the questionnaire:

Table 2. List of Industries for the Surveys

No	Industry Name	Category	*Core business*	Response Questionnaire
1	PT. Pupuk Iskandar Muda	BUMN	Fertilizer	Yes
2	PT. Pupuk Kujang Cikampek	BUMN	Fertilizer	Yes
3	PT. Pupuk Sriwijaya Palembang	BUMN	Fertilizer	Yes
4	PT. Pupuk Indonesia (Persero)	BUMN	Holding	Yes
5	PT. Petrokimia Gresik	BUMN	Fertilizer	Yes
6	PT. Pupuk Kaltim	BUMN	Fertilizer	No
7	PT. Pupuk Indonesia Energi	BUMN	Energy	Yes
8	PT. Sentana Adidaya Pratama	Private	Fertilizer	No
9	PT. Harina Chemicals Industri	Private	Fertilizer	No

RECP Pilot Plants were selected based on the following Selection Criteria:

- Included in the industrial unit of fertilizer production.
- Industries that sent responses to the questionnaire were sent via email.
- Submitted monthly baseline water consumption, energy, and production output data from 2018 to Sept-2021.
- Industries that keep the communication either via email or other forms of communication.
- Committed to follow-ups such as field visits.

Overall Conclusion

The fertilizer industry understands that environmental sustainability is a factor that needs to be prioritized in running a business. Each industrial unit already has an environmental management plan. Efforts to improve environmental sustainability include implementing energy efficiency, using renewable energy, and reducing waste. However, some are still constrained in their implementation related to investment and very dependent on the typical implementation. Some of the obstacles for some industries include the lack of infrastructure, trained personnel, lack of regulation, and lack of supervision and implementation. The lack of environmental sustainability management includes waste and air pollution.

Baseline data analysis of energy/feedstock, carbon, and water.

Energy Performance Indicator:

- Energy Performance Indicators for each fertilizer industry compared to the baseline period (for this study in 2018)
- The fertilizer industry generally uses natural gas as a raw material and energy source
- Energy consumption mentioned includes energy sources used as raw materials (feedstock), which are equalized with energy

Resource Efficient and Cleaner Production (RECP) Pilot Plant

1. **Pilot Plant Profiling**

PT. Pupuk Iskandar Muda

PT. Pupuk Iskandar Muda (PT. PIM) is a subsidiary of PT. Pupuk Indonesia (Persero) is engaged in the urea fertilizer industry and other chemical industries, and the first urea fertilizer factory in Indonesia was built by the national contractor PT. Rekayasa Industri. This was the first large-scale project entrusted by the Government to a national contractor. The company was established based on the Notarial Deed of Soeleman Ardjasasmita SH no. 54 on 24 February 1982, under the name of PT. Pupuk Iskandar Muda. The determination of the location for the construction of the PT. PIM at Lhokseumawe - North Aceh is based on the availability of natural gas reserves as a source of raw materials, water intake facilities, and the existence of port facilities as a place for loading and unloading factory equipment, also a very strategic location for export destination countries..

The construction of the PIM-1 plant was completed in 1984 with a total investment of US$ 308.4 million, while the PIM-2 plant was completed in 2005 with a total investment of US$ 310.2 million. PT. PIM's factory consists of:

- Prill Urea Plant Unit (Urea Plant 1) with a production capacity of 570,000 tons/year, using Japan's Mitsui Toatsu technology.
- Ammonia Plant Unit (Ammonia Plant 1) with a production capacity of 386,000 tons/year using American Kellogg technology.
- Urea Granule Plant Unit (Urea Plant 2) with a production capacity of 570,000 tons/year, using Toyo Access technology from Japan.
- Ammonia Plant Unit (Ammonia Plant 2) with a production capacity of 396,000 tons/year using American Kellogg technology.

The Company's Articles of Association have been amended several times, related to changes in the capital following the B.R.AY Notary Deed. Mahyastoeti Notonegoro, S.H. No. 01 dated January 02, 2012, Notary Deed of Lumassia, SH No. 10 dated January 19, 2012, and the Notary Deed of Lumassia, SH No. 02 dated February 07, 2012, based on Government Regulation no. 54 dated December 22, 2011, regarding the participation of the State capital of the Republic of Indonesia into the share capital of PT. Pupuk Iskandar Muda was subsequently transferred entirely to the company's share capital (Persero) PT. Pupuk Sriwidjaja, so that the composition of the share capital of PT. Pupuk Sriwidjaja (Persero) is 99.99955%) and 0.00045% Employee Welfare Foundation.

PT. Pupuk Iskandar Muda with 576 employees has been operating for more than 36 years producing urea fertilizer.

PT. Pupuk Kujang Cikampek

PT. Pupuk Kujang was established on June 9, 1975, with funds of US$ 260 million, a loan from the Government of Iran amounting to US$ 200 million, and the Indonesian Government's Equity Participation (PMP) of US$ 60 million. The company repaid loans to the Government of Iran in 1989.

The construction of the first Kujang Fertilizer factory, which was later named the Kujang 1A Factory with a production capacity of 570,000 tons/year of urea and 330,000 tons/year of ammonia, was carried out by the main contractors Kellogg Overseas Corporation (USA) and Toyo Engineering Corporation (Japan).

The construction of the Kujang 1A Factory was successfully built for 36 months. It was inaugurated by the President of the Republic of Indonesia on December 12, 1978. PT. Pupuk Kujang is a subsidiary of BUMN Pupuk in Indonesia, namely PT. Pupuk Indonesia Holding Company. In line with its development in the age of the plant getting older than before, it has consequences for higher maintenance costs and increased downtime. Overcoming these problems requires significant funds, especially for replacing and reconditioning some core equipment. To anticipate this problem, PT. Pupuk Kujang has prepared an action plan to continue business continuity. One of the plans that have been implemented is the replacement of the urea reactor in 2001 and the construction of the Kujang 1B Plant.

The construction of the Kujang 1B Factory, with a production capacity of 570,000 tons/year of urea and 330,000 tons/year of ammonia, was carried out by the main contractor Toyo Engineering Corporation (TEC) Japan, and supported by 2 (two) domestic contractors, namely PT. Rekayasa Industri and PT. Inti Karya Persada Teknik. The Kujang 1B Factory construction took 36 months, starting from October 1, 2003, to September 6, 2005, apart from the equity owned by PT. Pupuk Kujang, the funding for this project was obtained from a loan from the Japan Bank for International Cooperation (JBIC) amounting to JPY 27,048,700,000. The inauguration of the Kujang 1B Factory was carried out by the President of the Republic of Indonesia on April 3, 2006.

PT. Pupuk Kujang Cikampek has been operating for more than 46 years producing urea and NPK fertilizers with 1,024 employees since December 2021.

PT. Pupuk Sriwijaya Palembang

PT. Pupuk Sriwidjaja Palembang (Pusri) is a company that was established as a pioneer in producing urea fertilizer in Indonesia on 24 December 1959 in Palembang, South Sumatra, under the name PT. Pupuk Sriwidjaja (Persero). Pusri started its business operations to implement and support government policies and programs in the economy and national development, particularly in the fertilizer and other chemical industries. Pusri's long history as a pioneer in national fertilizer producers for more than 50 years has proven our ability and commitment to carry out important tasks assigned by the government.

Apart from being a national fertilizer producer, Pusri also carries out trading business, providing services and other businesses related to the fertilizer industry. Pusri is responsible for implementing the distribution and marketing of subsidized fertilizers to farmers to implement the Public Service Obligation (PSO) to support the national food program by prioritizing the production and distribution of fertilizers for farmers throughout Indonesia. The sale of non-subsidized urea fertilizer to fulfil the fertilizer needs of the plantation, industrial and export sectors is part of the company's other activities outside the responsibility for implementing the Public Service Obligation (PSO).

As a company responsible for the continuity of the national fertilizer industry, Pusri has undergone various changes in management and authority that are closely related to government policies. Since April 18, 2012, the Ministry of SOEs inaugurated PT. Pupuk Indonesia (Persero) as the name of the new parent fertilizer company, replacing the name PT. Pusri (Persero).

PT. Pupuk Indonesia (Persero) is the main and controlling shareholder of Pusri, with ownership of 99.9998%. Meanwhile, the ultimate owner of Pupuk Indonesia is the Government of the Republic of Indonesia, which owns all (100.00%) of Pupuk Indonesia (Persero) shares. Pusri officially operates under the name PT. Pupuk Sriwidjaja Palembang continues to use the Pusri brand and trademark.
The construction of factory facilities from PUSRI I, II, III, IV, V, and IB is carried out in stages. Each factory was built with careful planning under the Five-Year Development Plan launched by the Government of Indonesia to meet the growing national fertilizer demand..

Pusri I (1963 - 1986)
Pusri I is a symbol of a milestone in Indonesia's fertiliser industry's history. Built on an area of 20 hectares, PUSRI I is the first fertilizer factory in Indonesia built on 14 August 1961 and started operations in 1963 with an installed capacity of 100,000 tons of urea and 59,400 tons of ammonia per year. PUSRI IB has replaced PUSRI I Factory's role due to age and declining efficiency.

Pusri II (1974 - 2017)
Pusri II is the oldest factory operated by Pusri, built-in 1974 and still running until 2017.

Pusri III
The planning process for PUSRI III began when the government inaugurated the operation of PUSRI II as a measure to anticipate the increasing demand for fertilizers. As a follow-up to the government's decision, on May 21, 1975, the Minister of Industry, M Jusuf, inaugurated the erecting of the first pillar for the construction of the Pusri III Factory. The Pusri III plant has a production capacity of 1,100 metric tons of ammonia per day, or 330,000 a year, and 1,725 metric tons of urea a day, or 570,000 metric tons a year.

Pusri IV
Through Decree No. 17 dated April 17, 1975, the President of the Republic of Indonesia has assigned the Minister of Industry to immediately take preparatory steps to construct the Pusri IV factory. On August 7, 1975, the beginning construction of PUSRI IV. The first piling of the PUSRI IV factory was

carried out in Palembang by the Minister of Industry M Jusuf on October 25, 1975. Pusri IV was built in 1977 with the same production capacity as PUSRI III, with a production capacity of 1,100 metric tons of ammonia a day, or 330,000 metric tons a year, and 1,725 metric tons of urea a day or 570,000 metric tons a year.

Pusri IB

The PUSRI IB factory is factory-built as a replacement for the PUSRI I factory, which has been declared inefficient. On January 15, 1990, was the Early Start Date to start the Process Engineering Design Package activities. On May 1, 1990, was the effective date of the construction implementation and was inaugurated by the President of the Republic of Indonesia on December 22, 1994. PUSRI IB has a production capacity of 446,000 tons of ammonia per year and 570,000 tons of urea per year. This factory applies energy-efficient ammonia and urea manufacturing process technology with an efficiency of 30% more efficient than existing PUSRI factories. The scope of Pusri IB includes one unit of ammonia plant with a capacity of 1,350 tons per day or 396,000 tons per year. One unit of urea plant with a capacity of 1,725 tons per day or 570,000 tons per year and one unit of utility, offsite and auxiliary.

Pusri IIB

The Pusri II-B Factory replaces the Pusri-II Factory over 40 years old. The Pusri II-B plant uses KBR Purifier Technology for the Ammonia Plant and TOYO and Pusri's ACES 21 technology as Co Licensor for the Urea Plant. In addition to being environmentally friendly, it also saves gas on raw materials, with a ratio of gas consumption per tonne of the product of 31.49 MMBTU/Ton of Ammonia and 21.18 MMBTU/Ton of Urea. Compared to the existing Pusri II Plant, which has a gas consumption ratio per tonne of the product of 49.24 MMBTU/Ton Ammonia and 36.05 MMBTU/Ton Urea, gas consumption will be saved by 14.87 MMBTU per ton of urea. The Pusri IIB factory has the largest capacity compared to other factories. The capacity of the Ammonia Plant is 2,000 tons/day (660,000 tons/year), and the Urea Plant's capacity is 2,750 tons/day (907,500 tons/year).

PT. Petrokimia Gresik

PT. Petrokimia Gresik consistently takes various strategic steps to improve the company's quality. Providing excellent service, producing high-quality products while advancing the welfare of its people is the key to Petrokimia Gresik's success to become a superior company that the country can be proud of. The main objective of PT. Petrokimia Gresik is to advance the national agricultural sector, which is one of the factors and indicators of the progress of a nation's economy. PT. Petrokimia Gresik has a significant role in realizing and improving national food security. With the creation of national food security, people's welfare will increase so that Indonesia can be more advanced.

Total water uses for the production process in 2020 is 31,917,109 m3 / Total water use for the production process in 2020 was 31,917,109 m3. The total water recycled and reused in 2020 was 1.82% of the entire river water intake.

Energy Intensity in the Production Process of PT. Petrokimia Gresik in 2020 for fertilizer 3.32 GJ/ton and non-fertilizer 5.74 GJ/ton. The reduction of GHG emissions in 2020 was 19,700-ton CO_2.
The company obtained a GREEN PROPER from the Republic of Indonesia's Ministry of Environment (KLHK) and obtained ISO 14001:2004 Environmental Management System certification.

The total consolidated sales value in 2020 was Rp26,571.1 billion. Consolidated net profit was IDR 1.41 trillion. Economic Value Obtained Rp 26.614 billion. Distribution of economic value of IDR 25.198 billion.

PT. Petrokimia Gresik received the Green PROPER award on 8 January 2020.

2. **Priority for environmental sustainability**

The fertilizer industry agrees that environmental sustainability is a priority. This circumstance is marked by a good understanding of how to run an environmentally sustainable business. In addition, the fertilizer industry also understands well the options available to increase environmental sustainability in the business.

The fertilizer industry already has an environmental management plan that does not cause environmental pollution, such as air pollution and water pollution, that does not exceed the threshold according to applicable regulations. Efforts are made by continuously monitoring and reporting on chemical pollution and air pollution. In addition, the relevant agencies also check the reporting and monitoring of wastewater and air emissions in each fertilizer industry.

3. **Opportunity to improve environmental sustainability**

Energy Efficiency

The fertilizer industry is interested in saving energy and is looking to reduce energy use. This is evidenced by the investment in new equipment/processes to reduce energy use in recent years. Even the fertilizer industry has differing views that energy efficiency is difficult to implement. However, implementing energy efficiency depends on investment, which depends on the typical energy efficiency options applied.

New and Renewable Energy

The fertilizer industry has also shown interest in using new and renewable energy (EBT). However, the implementation depends on the type of solution carried out. Some typical implementations of the application of renewable energy require high investment. The application of renewable energy in the fertilizer industry is not a problem with the existing electricity system.

Waste Reduction

The fertilizer industry is very interested in efforts to reduce the waste generated. This is evidenced by replacing processes to reduce waste in the last year period. Fertilizer customers are very interested in the actions of the fertilizer industry to carry out environmental activities such as pollution management, energy efficiency, use of renewable energy, waste management, and others.

[PT. Pupuk Indonesia] Digitalization of operational data

[PT. Pupuk Kujang Cikampek] Set up a new plant, a CO_2 liquid plant to reduce GHG emissions from the NH3 plant

[PT. Pupuk Indonesia Energi] Installed demo PV module with installed capacity 8 kWp for an office building

4. **Barriers to Improvement of environmental sustainability**

Based on the results of the discussion during the field visit, several obstacles were identified that caused the low environmental performance improvement:

a. Lack of infrastructure (water treatment, electric system, etc.)

There are two opinions regarding the relationship between the lack of infrastructure compared to improvement environmental performance. The most important to improve environmental performance require creativity and innovation that cannot be limited by existing infrastructure.

b. Lack of experts in environmental management

Training related to environmental sustainability needs to be done to increase knowledge and make the right decisions in managing the company's environment.

c. Lack of regulation (pollution, energy use)

The lack of regulation should not be used as an excuse/problem for the industry not to make environmental improvements. The company has an environmental responsibility, including all stakeholders from employees, surrounding communities, investors and customers, to ensure environmental control and management.

d. Lack of supervision and enforcement of regulations

Making improvements to the environment should not only be aimed at environmental compliance. But beyond competitive and industrially sustainable.

e. Number of orders and customer payments

Almost all fertilizer industries answered that orders and customer payments could not limit environmental sustainability activities. The fertilizer company that answered is owned by a BUMN that orders and pays regularly. State-owned fertilizer companies were developed to support national food security. The government also subsidizes the types of fertilizers produced; some are non-subsidized. The responsibility for sustainable environmental activities lies with the industry, which can achieve this through the implementation of manufacturing innovations.

The response of the fertilizer industry regarding the impact of the lack of environmental sustainability can be concluded as follows:

- Liquid waste has an impact on river water pollution.
- The by-product of urea production can damage the human respiratory system and marine ecosystems.

- Waste generated from production activities such as liquid waste, air emissions, B3 waste, and domestic waste.
- CO_2 (greenhouse gas) emissions from GTG (Gas Turbine Generator) and Gas Boiler activities.

Respondent opinions compile in the following box:

[PT. Pupuk Indonesia] Liquid waste generated from production activities contaminates the river.

[PT. Pupuk Kujang Cikampek] Pollution of water, air, and GHG emissions but the impacts are still below its threshold value.

[PT. Pupuk Indonesia Energi] GHG emission from Generator Turbine Gas (GTG) and Gas Boiler.

[PT. Pupuk Indonesia] Liquid waste generated from production activities contaminates the river

[PT. Pupuk Iskandar Muda] Waste by-products of urea production that can damage human respiration and damage marine ecosystems.

[PT. Pupuk Indonesia Energi] GHG emission from Generator Turbine Gas (GTG) and Gas Boiler.

5. **Enhancing environmental sustainability**

The increase in environmental sustainability efforts that are expected to be carried out in the future can be concluded as follows:

- Develop new low-carbon emission sustainable products.
- Maintain operating parameters; the industries can control the amount of waste and the potential for environmental pollution.
- Carry out environmental management to overcome the impacts released by industry, such as installing Wastewater Treatment Plant (IPAL), PET (Pusri Effluent Treatment) to manage liquid waste, installing MDRS (modified dust recovery system) to absorb urea dust in the prilling tower, silencers to reduce noise, PGRU (Purge Gas Recovery System) to recycle exhaust gas so that it can be used as fuel and raw materials. Collaborate with licensed third parties to manage Toxic and Hazardous Waste (LB3) and cooperate with local Final Disposal Sites (TPA) for domestic waste.
- Increase biodiversity around the factory and complex by planting various trees and breeding different types of protected animals.
- Using a co-generation scheme, reuse exhaust gas from GTG to generate steam.
- Comply with regulations issued by the relevant ministries, implement energy and environmental management.

Improvement and innovation activities conducted compiling in the following box:

PT. Pupuk Sriwijaya Palembang introduced Environmental management to overcome the impacts of the industry by installing wastewater treatment plant (WWTP), PET (Pusri Effluent Treatment) to manage liquid waste, installing MDRS (modified dust recovery system) to absorb urea dust at the prilling tower, silencer to reduce noise, PGRU (*Purge Gas Recovery System*) to recycle exhaust gas so it can be used for fuel and raw material. The company is cooperating with licensed third parties to manage hazardous waste and cooperating with local landfill management for domestic waste.

PT. Pupuk Indonesia develops a new sustainable product to reduce carbon emissions.

PT. Pupuk Iskandar Muda maintains operating parameters to control the amount of waste and potential environmental pollution.

PT. Pupuk Indonesia Energi uses a cogeneration scheme, re-uses the GTG Exhaust Hot Gas to generate steam.

PT. Pupuk Kujang Cikampek complies with the regulations set by the relevant ministries, implement energy and environment management clean production system.

3.3 RECP **Performance**

RECP Performance in Fertilizer Industry

The RECP Profile of each fertilizer company is different depending on the capacity and type of fertilizer product produced. Likewise, other resource consumption, such as water and steam are also different. The type of fertilizer industry that answers the questionnaire is the fertilizer industry that produces urea, ammonium sulphate (ZA) fertilizers, and NPK fertilizers (Nitrogen, Phosphorus, and Potassium).

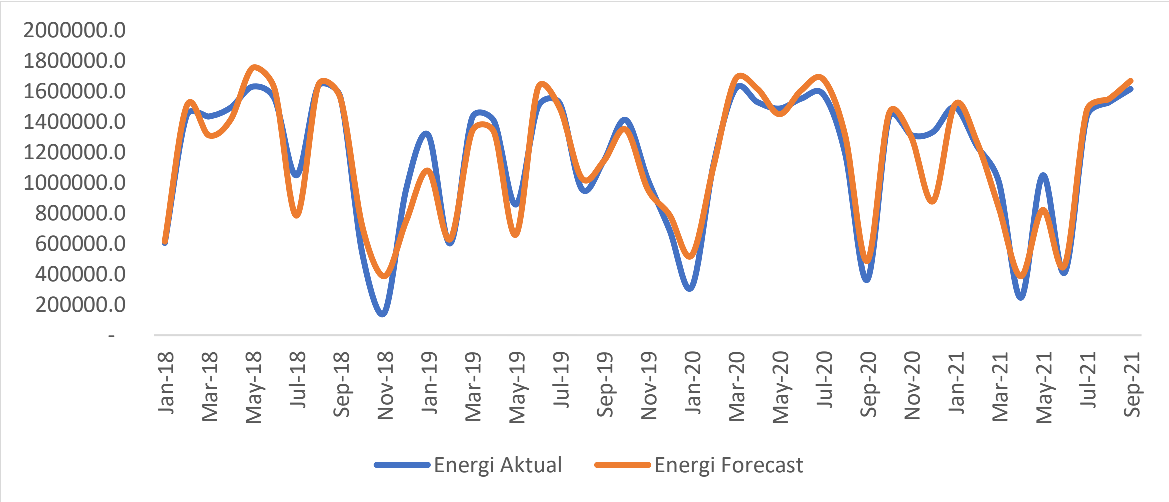
Most fertilizer companies have used recycled water to reach approximately 10% of the total water used. The use of water for the fertilizer industry, which produces urea, ammonium sulphate and NPK fertilizers, is an average of 24,500,000 M3 per year. Meanwhile, electricity usage reaches 381,000 MWh per year, which impacts increasing greenhouse gases (GHG) with an average of 278,000 MWh per year. The industry can reduce greenhouse gas emissions because the CO_2 produced can be used as raw material for making urea fertilizer.

a. PT. Pupuk Iskandar Muda

Energy Consumption

The energy consumption forecast model taken from 2018 data is used as a baseline to project energy consumption for the following year using the urea production variable. The difference between the actual energy consumption and the projected consumption indicates the relative energy saving. The following graph shows the actual energy consumption compared to the forecast energy consumption.

Figure 18. Graph - Actual vs Forecast Energy Consumption (MMBTU)



Based on the 2018 baseline data, a prediction model for 2021 (Jan – Sept) is made. Furthermore, the predicted energy consumption model in 2021 is compared with the actual energy consumption. Energy consumption in 2021 slightly exceeds forecast energy consumption (-0.49%). The results of the comparison between the prediction model and actual consumption in 2021 can be seen in the following table:

Table 3. Forecast vs Actual Energy Consumption

	2021 *Forecast*	**2021 Actual**	**Savings**	**Percentage (%)**	**Unit**
Energy	9,966,976	10,015,513	-48,537	-0.49	MMBTU
Energy Cost	59,801,855	60,093,075	-291,220		$

Note: energy cost ≈ $6/MMBTU

Baseline 2018 vs Reporting 2021

During the Jan-Sept 2021 period, urea production decreased by 8.49% compared to the 2018 baseline in the same period. The decrease in urea production was followed by a 19.20% decrease in energy use in the same period. The following table compares actual energy consumption and actual urea production in 2018 as the baseline and 2021 as the reporting period.

Table 4. Baseline 2018 vs Reporting 2021

	2018 Actual	**2021 Actual**	**Savings**	**Percentage (%)**	**Unit**
Energy Consumption	12,396,043	10,015,513	2,380,531	19.20	MMBTU
Urea Production	335,276	249,774	28,451	8.49	ton
Specific Energy Consumption	38.80	40.10	-1.30	-3.35	MMBTU/ton-urea

Note: no urea production reported on April 2021

Forecast Model Rating

The variable used to predict energy consumption through simple linear regression is urea production during the 2018 period. Urea production is a significant determinant variable for predicting energy consumption which can be seen from the p-value of 0.0000 (well below the error rate limit of 0.1). Urea production capability based on data in 2018 can predict the energy use of 0.91 91% (more than 50% as a limit). It can be said that the 2018 forecast data model is suitable for forecasting energy use in the next period. The assessment of the 2018 forecast data model can be seen in the following table:

Table 5. Forecast Model Rating

Variables	MMBTU per unit	p-value	R-square	F-stat
Constant	386,705	0.0015	0.91	103.11
Urea production	25.97	0.0000		

Greenhouse Gas (GHG) Emissions

Greenhouse gas (GHG) emissions are limited to CO_2 emissions from heat energy (fuel combustion) and electrical energy for production. The following table compares greenhouse gas emissions in 2018 (Jan-Sept period) with 2021 in the same period. The decrease in GHG emissions by 61.571 tons- CO_2e in 2021 is more due to reduced fuel use and urea production. If specific GHG emissions are calculated, an increase from 1.07 tons- CO_2/ton urea in 2018 to 1.19 tons- CO_2/ton urea in 2021 (-0.12 tons- CO_2/ton urea) can be found.

Table 6. Greenhouse Gas Emissions

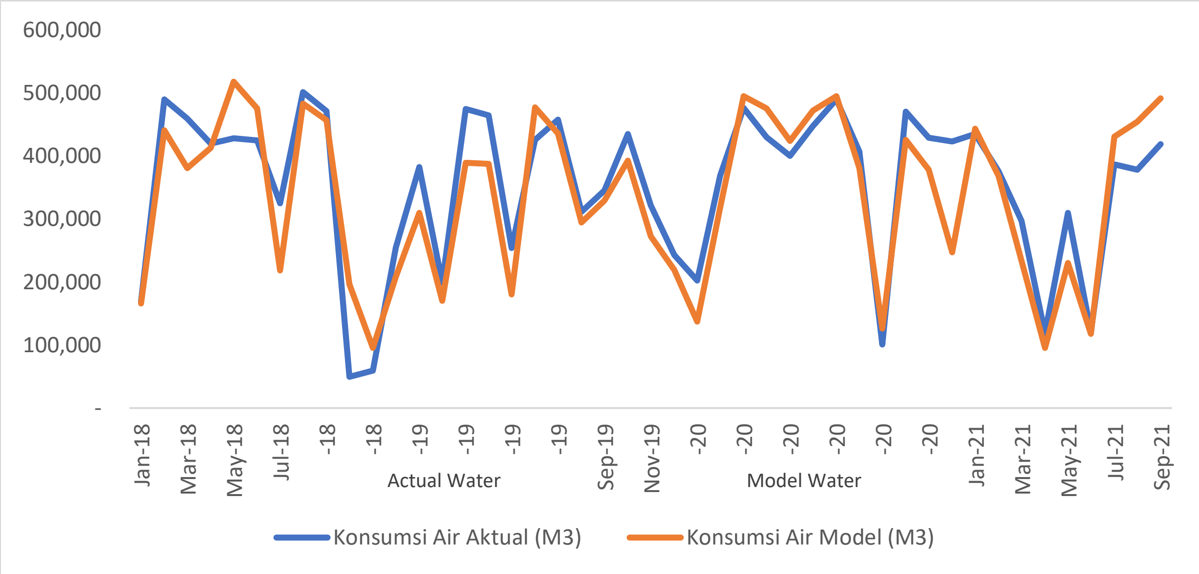
Energy Source	Unit	Kg CO_2/MMBTU	2018	2021	Change (ton-CO_2e)
Natural Gas	MMBTU		6,748,844	5,588,447	
Greenhouse Gas Emissions	Ton- CO_2e	53.06	358,094	296,523	61,571
Greenhouse Gas Emissions	Ton- CO_2/ton urea		1.07	1.19	-0.12

Note: The calculation results may differ due to the energy sources used other than natural gas and the amount of CO_2 gas used as raw material for urea.

Water Consumption

The water consumption forecast model takes 2018 data as a baseline to project water consumption in the following year using the urea production variable as a predictor. The difference between actual and projected/forecast consumption indicates relative water savings. The following graph shows actual water consumption with projected water consumption. Actual water use tends to follow projections in 2021 (January - September period).

Figure 19. Actual Water Consumption vs Forecast (M3)



Actual Water Consumption vs Model

Actual water consumption in 2021 (January – September period) is below the forecast model for the same period. The forecast model is obtained from the regression of urea production data on water consumption in 2018 as a baseline. The following table shows water consumption based on forecast with actual water consumption in 2021. Actual water consumption decreased slightly by 0.87% compared to the forecast model in 2021. Water consumption savings were 25,049 M3 or around US$32,563 for the period January – September 2021 (assuming water costs US$ 1.3/M3). Water use efficiency can reduce wastewater treatment costs, reduce chemicals, and reduce energy.

Table 7. Actual Water Consumption vs Model

	2021 Forecast	2021 Actual	Savings	Percentage (%)	Unit
Water Consumption	2,864,222	2,839,174	25,049	0.87	M^3
Water cost	3,723,4896	3,690,92	32,563		US$

Note: Assumption of water cost is $1.3/M3

Baseline 2018 vs Reporting 2021

During the January - September 2021 period, urea production decreased by 25.50% compared to the 2018 baseline in the same period. The decrease in urea production was followed by a 22.99% decrease in water use in the same period. The following table compares actual water consumption and actual urea production in 2018 as the baseline and 2021 as the reporting period. Water intensity increased slightly in the 2021 by 3.36%, from 11 M3/ton-urea to 11.37 M3/ton urea.

Table 8. Baseline 2018 vs Reporting 2021

	2018 Actual	2021 Actual	Savings	Percentage (%)	Unit
Water Consumption	3,686,613	2,839,174	847,440	22.99	M^3
Urea Product	335,276	249,774	85,502	25.50	Ton
Specific Water Consumption	11.00	11.37	-0.37	-3.36	M^3/ton-urea

Forecast Model Rating

The variable used to predict water consumption through simple linear regression is urea production during the 2018 period. Urea production is a determining variable that has a significant effect on predicting energy consumption which can be seen from the p-value of 0.0001 (less than the 0.1 limits). The ability of urea production to predict water use can be seen from the R-square value of 80% (above the 50% standard). The assessment of the 2018 forecast data model can be seen in the following table:

Table 9. Forecast Model Rating

Variables	M^3 per unit	p-value	R-square	F-stat
Constant	95,393	0.0490	0.81	43.53
Urea Production	8.03	0.0001		

Recycled Water

Water use efficiency is one of the efforts to maintain water resources and industrial sustainability. Water efficiency can be obtained from recycled water (water from wastewater treatment) and reused water (e.g., condensate water, cooling water, backwash). The utilization of recycled water is 197,535 M3 in 2021 (January – September period), lower than 2018 as the baseline. Meanwhile, water consumption in 2021 increased compared to water consumption in 2018. The following table compares the use of recycled water in 2018 (Jan-Sept period) with 2021 in the same period.

Table 10. Recycled Water Utilization

	2018 Actual	2021 Actual	Unit
Water Consumption	3,686,613	2,839,174	M^3
Recycled Water	208,149	197,535	M^3
Recycled Water Utilization	5.65	6.96	%

b. PT. Pupuk Kujang Cikampek

Energy Consumption

Using the urea production variable, the energy consumption forecast model takes 2018 as a baseline to project energy consumption for the following year. The difference between the actual and projected energy consumption indicates the relative energy saving.

Actual energy consumption in 2020 is relatively higher than projected energy consumption in the same period. However, it is different in the 2021 period, where actual energy consumption is lower than projected. The following graph shows the actual energy consumption compared to the projected energy consumption.

Figure 20. Actual vs Projected Electrical Energy Consumption (MMBTU)

Based on the 2018 baseline data, a prediction model for 2021 (Jan – Sept) can be made. Furthermore, the forecast model for energy consumption in 2021 is compared with the actual energy consumption in 2021. The savings made by the company is 2.89% or around 514,332 MMBTU $ 3,085,994) compared to the forecast model. The results of the comparison between the prediction model and the actual energy consumption in 2021 can be seen in the following table:

Table 11. Model vs Actual Energy Consumption

	2021 Model	2021 Actual	Savings	Percentage (%)	Unit
Energy	17,825,980	17,311,648	514,332	2.89	MMBTU
Cost	106,955,880	103,869,886	3,085,994		$

Note: $6/MMBTU, period Jan-Sept 2021

Baseline 2018 vs Reporting 2021

During the January – September 2021 period, there was an increase in urea production by 14.55% compared to the 2018 baseline in the same period. The rise followed the increase in urea production in the use of electrical energy by 10.79% in the same period. The difference in the increase in urea production and energy consumption resulted in a decrease in energy intensity from 23.67 MMBTU/ton-urea to 22.89 MMBTU/ton-urea. The following table compares actual electricity consumption and actual urea production in 2018 as the baseline and 2021 as the reporting period.

Table 12. Baseline 2018 vs Reporting 2021

	2018 Actual	2021 Actual	Savings	Percentage (%)	Unit
Energy Consumption	15,625,999	17,311,648	-1,685,649	-10.79	MMBTU
Urea Production	660,272	756,362	-96,090	-14.55	Ton
Specific Energy Consumption	23.67	22.89	0.78	3.29	MMBTU/ton-urea

Note: Comparison in the same period Jan-Sept

Forecast Model Rating

The variable used to predict energy consumption through simple linear regression is urea production during the 2018 period. Urea production is the determining variable for predicting energy consumption which can be seen from the p-value of 0.0000 (less than 0.1). The ability of urea production to indicate the use of electrical energy can be seen from the coefficient of determination/R-square 84.6% (above 50%). The assessment of the suitability of the 2018 forecast data model can be seen in the following table:

Table 13. Forecast Model Rating

Variable	MMBTU per unit	p-value	R-square	F-stat
Constant	214,579	0.3603	0.85	55.10
Urea Production	2.84	0.0000		

Greenhouse Gas Emissions

Greenhouse gas (GHG) emissions are limited to CO_2 emissions sourced from heat energy (fuel combustion) and electrical energy for the production process. The following table compares greenhouse gas emissions in 2018 (January - June period) with 2021 in the same period. The reduction in GHG emissions in 2021 is due to the utilization of CO_2 by manufacturing liquid CO_2.

Table 14. Greenhouse Gas Emissions

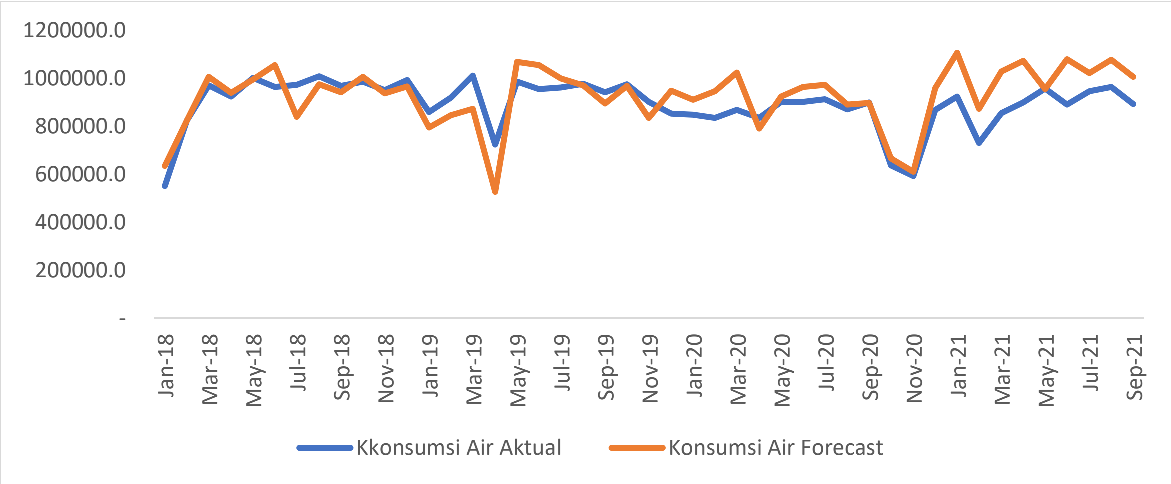
Energy Source	Unit	CO_2 kg per MMBTU	2018	2021	Change (tCO_2e)
Natural Gas	MMBTU		2,968,990	3,269,612	
Greenhouse Gas Emissions	Ton- CO_2	53.06	266,826	247,110	19,716
Specific Greenhouse Gas Emissions	Ton CO_2/ton urea		0.60	0.49	0.11

Note: The calculation results may differ due to the energy sources used other than natural gas and the amount of CO_2 gas used as raw material for urea.

Water Consumption

Using the urea production variable, the water consumption forecast model taken from 2018 data is used as a baseline to project water consumption for the following year. The difference between actual water consumption and projected consumption indicates relative water savings. The following graph shows actual water consumption with projected water consumption. Actual water use tended to be lower than projected in 2021 (Jan – Sept period).

Figure 21. Actual vs Projected Water Consumption (M3)



Model vs Actual Water Consumption

Actual water consumption in 2021 (January – September period) is below the forecast model for the same period. The forecast model is obtained from the regression of urea production data on water consumption in 2018 as a baseline. The following table shows water consumption based on forecast water consumption with actual water consumption in 2021. Actual water consumption decreased by 18% compared to the forecast model in 2021. Water consumption savings were 1,678,805 M3 or around US$ 2,182,446 for the period January – September 2021 (assuming water costs $1.3/M3). Water use efficiency can reduce wastewater treatment costs, reduce chemicals, and reduce energy.

Table 15. Model vs Actual Water Consumption

	2021 Forecast	2021 Actual	Savings	Percentage (%)	Unit
Water Consumption	4,325,358	5,521,520	-1,196,162	-27.65	M^3
Water Cost	5,622,966	7,177,976	-1,555,010		US$

Note: Assumed water cost $1.3/M3

Baseline 2018 vs Reporting 2021

During the Jan-Sept 2021 period, urea production increased by 14.55% compared to the 2018 baseline in the same period. However, the increase in urea production was followed by a 1.6% decrease in water use in the same period. The following table compares actual water consumption and actual urea production in 2018 as the baseline and 2021 as the reporting period.

Table 16. Baseline 2018 vs Reporting 2021

	2018 Actual	2021 Actual	Savings	Percentage (%)	Unit
Water Consumption	8,187,204	8,056,327	130,877	1.60	M^3
Urea Production	660,272	756,362	-96,090	-14.55	Ton
Specific Water Consumption	12.40	10.65	1.75	14.10	M3/ton-urea

Forecast Model Rating

The variable used to predict water consumption through simple linear regression is urea production during the 2018 period. Urea production is a determining variable for predicting energy consumption which can be seen from the p-value of 0.001 (less than 0.1). The ability of urea production to predict water use can be seen from the coefficient of determination (R-square) of 79% (above 50%). The assessment of the 2018 forecast data model can be seen in the following table:

Table 17. Forecast Model Rating

Variables	M3 per unit	p-value	R-square	F-stat
Constant	137,213	0.3175	0.79	37.32
Urea Production	10.56	0.0001		

Recycled Water

Water use efficiency is one of the efforts to maintain water resources and industrial sustainability. Water efficiency can be obtained from recycled water (water from wastewater treatment) and reused water (e.g., condensate water, cooling water, backwash). The following table compares the use of recycled water in 2018 (Jan-Sept period) with 2021 in the same period.

Table 18. Utilization of Recycled Water

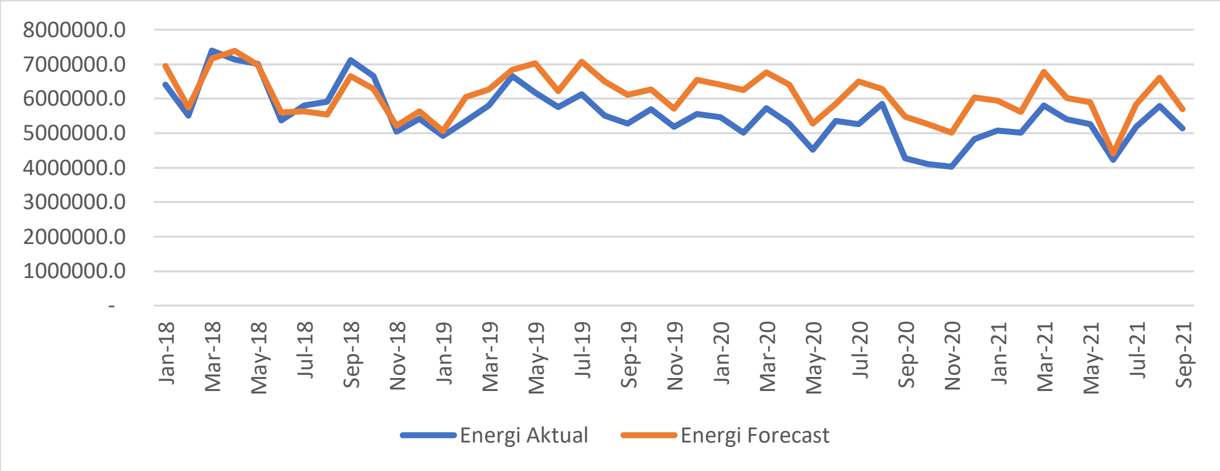
	2018 Actual	2021 Actual	Unit
Water Consumption	8,187,204	8,056,327	M3
Recycled Water	1,005,112	1,127,541	M3
Recycled Water Utilization	12.28	12.64	%

c. PT. Pupuk Sriwijaya Palembang

Energy Consumption

The energy consumption forecast model takes data from 2018 as a baseline to project energy consumption for the following year using the urea production variable. The difference between the actual energy consumption and the projected consumption indicates the relative energy saving. The actual energy consumption is relatively lower than the projected energy consumption in the next period. This indicates savings from mid-2019. The following graph shows actual energy consumption compared to projected energy consumption.

Figure 22. Actual vs Projected Energy Consumption (MMBTU)



Note: Actual energy consumption (MMBTU) is a combination of electrical energy (kWh) converted into MMBTU and thermal energy (MMBTU).

Based on the 2018 baseline data, a prediction model for 2021 (Jan – Sept) can be made. Furthermore, the predicted energy consumption model in 2021 is compared with the actual energy consumption. In 2021 (Jan – Sept period), the potential savings will be 11.22% or approximately 5,925,791 MMBTU ($35,554,748 assuming a natural gas price of $6/MMBTU). The results of the comparison between the prediction model and actual consumption in 2021 can be seen in the following table:

Table 19. Model vs Actual Energy Consumption

	2021 Model	2021 Actual	Savings	Percentage (%)	Unit
Energy	52,807,582	46,881,791	5,925,791	11.22	MMBTU
Energy Cost	316,845,494	281,290,746	35,554,748		$

Note: $6/MMBTU

Baseline 2018 vs Reporting 2021

During the Jan-Sept 2021 period, urea production decreased by 10.43% (10,788,710 MMBTU) compared to the 2018 baseline in the same period. A reduction followed the decrease in urea production in energy use of 18.71% in the same period. The following table compares actual energy consumption and actual urea production in 2018 as the baseline and 2021 as the reporting period.

Table 20. Baseline year vs Reporting Year

	2018 Actual	2021 Actual	Savings	Percentage (%)	Unit
Energy Consumption	57,670,501	46,881,791	10,788,710	18.71	MMBTU
Urea Production	1,684,271	1,508,519	175,752	10.43	ton
Specific Energy Consumption	34.24	31.08	3.16	9.23	MMBTU/ton

Forecast Model Rating

The variable used to predict energy consumption through simple linear regression is urea production during the 2018 period. Urea production is the correct determinant variable for predicting energy consumption which can be seen from the p-value of 0.0000 (much more than 0.1). The ability of urea production to predict energy use can be seen from the coefficient of determination (R-square) of 85% (above 50%). The company uses 1,251,441 MMBTU of energy without producing urea (baseload). The assessment of the 2018 forecast data model can be seen in the following table:

Table 21. Forecast Model Rating

Model Variables	MMBTU per unit	p-value	R-square	F-stat
Constant	1,251,441	0.0926	0.85	55.94
Urea Production	27.54	0.0000		

Greenhouse Gas Emissions

Greenhouse gas (GHG) emissions are limited to CO_2 emissions sourced from heat energy (fuel combustion) and electrical energy for the production process. The following table compares greenhouse gas emissions in 2018 (Jan-Sept period) with 2021 in the same period. The decrease in GHG emissions in 2021 is mainly due to a reduction in urea production by 10.43% and a decrease in fuel by 18.71%, between 2018 as the baseline and 2021 (Jan – Sept period). The results of the calculation of greenhouse gases may be different due to the company's action to utilize CO_2 exhaust gas as a source of raw material for the manufacture of urea.

Table 22. Greenhouse Gas Emissions

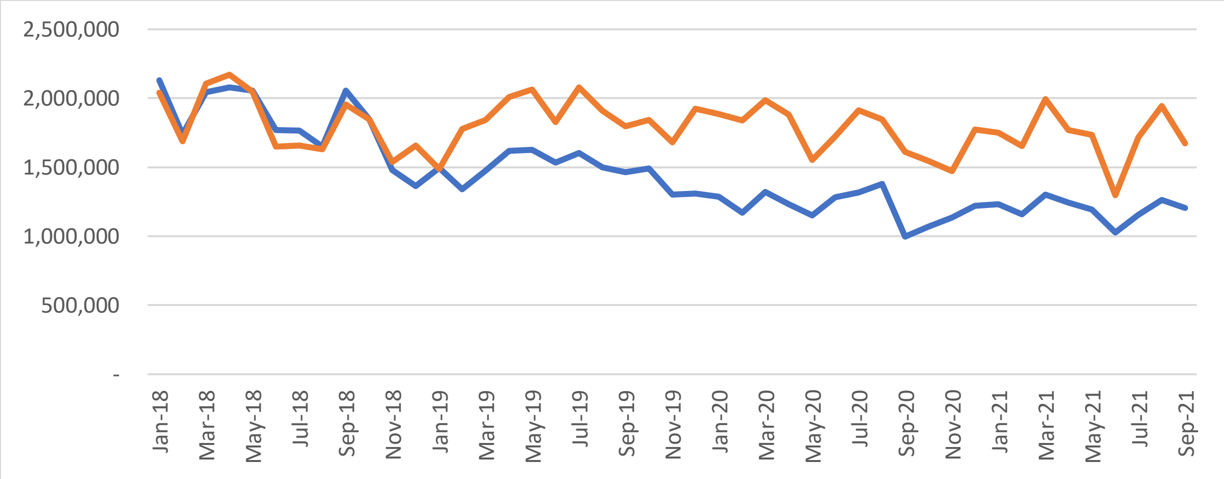
Tracked Energy Sources	Units	CO2 kg per unit	2018	2021	Change (tCO2e)
Natural Gas	MMBTU		57,670,501	46,881,791	
Greenhouse Gas Emissions	Ton- CO_2	53.06	3,059,997	2,487,548	572,449
Specific Greenhouse Gas Emissions	Ton- CO_2/ton urea		1.82	1.65	0.17

Note: The calculation results may differ due to the energy sources used other than natural gas and the amount of CO_2 gas used as raw material for urea.

Water Consumption

Using the urea production variable, the water consumption forecast model taken from 2018 data is used as a baseline to project water consumption for the following year. The difference between actual water consumption and projected consumption indicates relative water savings. The following graph shows actual water consumption with projected water consumption. Actual water use tended to be lower than projected in 2021 (Jan – Sept period).

Figure 23. Actual vs Projected Water Consumption (M3)



Model vs Actual Water Consumption

Actual water consumption in 2021 (Jan – Sept period) is below the forecast model for the same period. The forecast model is obtained from the urea production data regression on water consumption in 2018 as a baseline. Actual water consumption in 2021 decreased by 30.54% (4,743,378 M3) compared to forecast water consumption in 2021. The following table shows water consumption based on the forecast model with actual water consumption in 2021. Water use efficiency can reduce wastewater treatment costs, reduce chemical substances, and energy reduction.

Table 23. Model vs Actual Water Consumption

	2021 Model	2021 Actual	Savings	Percentage (%)	Unit
Water Consumption	15,530,894	10,787,516	4,743,378	30.54	M3
Water Cost	20,190,162	14,023,770	6,166,391		$

Note: $ 1.3/M3

Baseline 2018 vs Reporting 2021

During the Jan-Sept 2021 period, there was a decrease in urea production by 10.43% compared to the 2018 baseline in the same period. However, the reduction in urea production was followed by a 37.61% decrease in water use in the same period. The following table compares actual water consumption and actual urea production in 2018 as the baseline and 2021 as the reporting period.

Table 24. Baseline 2018 vs Reporting 2021

	2018 Actual	2021 Actual	Savings	Percentage (%)	Unit
Water Consumption	17,291,410	10,787,516	6,503,894	37,61	M^3
Urea Production	1,684,271	1,508,519	175,752	10.43	Ton
Specific Water Consumption	10.27	7.15	3.12	30.38	M^3/ton

Forecast Model Rating

The variable used to predict water consumption through simple linear regression is urea production during the 2018 period. Urea production is a determining variable for predicting the production of water consumption, which can be seen from the p-value of 0.001 (less than 0.1). The ability of urea production to predict water use can be seen from the coefficient of determination (R-square) of 78% (above 50%). The assessment of the 2018 forecast data model to predict water use can be seen in the following table:

Table 25. Forecast Model Rating

Variables	M3 per unit	p-value	R-square	F-stat
Constant	371,340	0.1621	0.78	35.99
Urea Production	8.08	0.0001		

Recycled Water

Water use efficiency is one of the efforts to maintain water resources and industrial sustainability. Water efficiency can be obtained from recycled water (water from wastewater treatment) and reused water (e.g., condensate water, cooling water, backwash). The utilization of recycled water increased by 2.93% in 2021 compared to 2018 at 1.84% as a baseline. The following table compares the use of recycled water in 2018 (Jan-Sept period) with 2021 in the same period.

Table 26. Utilization of Recycled Water

	2018 Actual	2020 Actual	Unit
Water Consumption	17,291,410	10,787,516	M3
Recycled Water	318,498	316,278	M3
Recycled Water Utilization	1.84	2.93	%

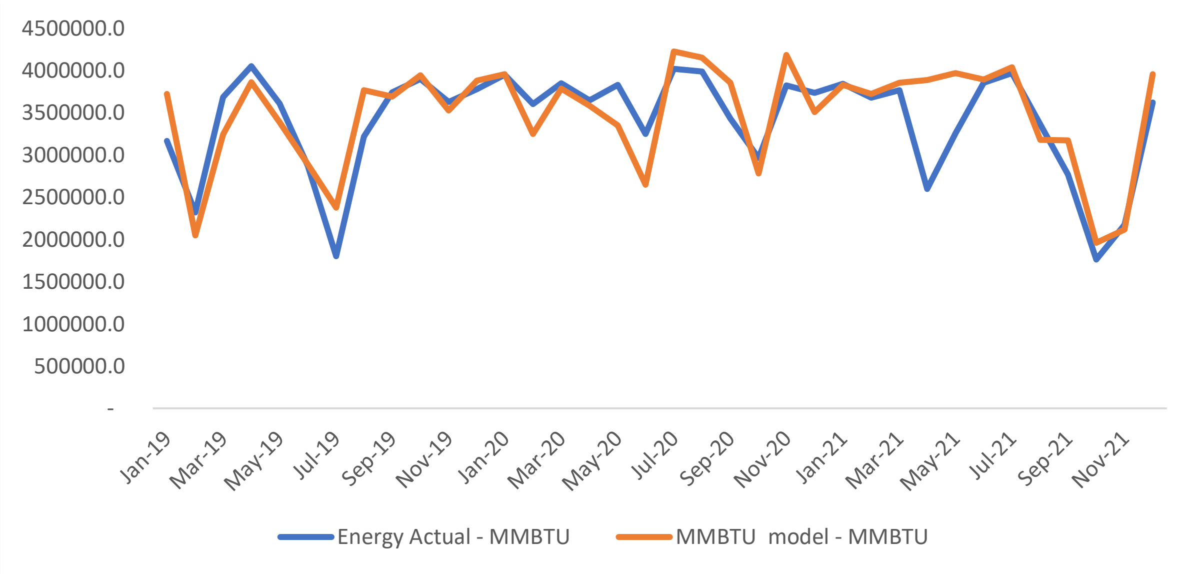
d. PT. Petrokimia Gresik

Energy Consumption

The energy consumption forecast model takes data from 2019 as a baseline to project energy consumption for the following year using the urea production variable. The difference between the actual energy consumption and the projected consumption indicates the relative energy saving.

The actual energy consumption in 2021 is relatively similar to the projected energy consumption pattern in the same period. However, it is different in the March-April 2021 period, where actual energy consumption is lower than projected. The following graph shows the actual energy consumption compared to the projected energy consumption.

Figure 24. Actual vs Projected Energy Consumption (MMBTU)



Based on the 2019 baseline data, a prediction model for 2021 (Jan – Dec) can be made. Furthermore, the predicted energy consumption model in 2021 is compared with the actual energy consumption. The results of the comparison between the prediction model and actual consumption in 2021 can be seen in the following table:

Table 27. Model vs Actual Energy Consumption

	2021 Model	2021 Actual	Savings	Percentage (%)	Unit
Energy Consumption	41,592,259	38,656,886	2,935,372	7.06	MMBTU
Cost	249,553,552	231,941,317	17,612,235		$

Note: $6/MMBTU, period Jan-Sept 2021

Baseline 2019 vs Reporting 2021

During the Jan-Dec 2021 period, urea production increased by 4.56% compared to the 2019 baseline in the same period. However, the increase in urea production was followed by a 2.83% decrease in energy use in the same period. The following table compares actual energy consumption and actual urea production in 2019 as the baseline and 2021 as the reporting period.

Table 28. Baseline 2019 vs Reporting 2021

	2019 Actual	2021 Actual	Savings	Percentage (%)	Unit
Energy Consumption	39,784,322	38,656,886	1,127,436	2.83	MMBTU
Urea Production	906,472	947,860	-41,388	-4.56	ton
Energy Intensity	43.89	40.78	3.11	7.08	MMBTU/ton

Note: Comparison in the same period Jan-Dec

Forecast Model Rating

The variable used to predict energy consumption through simple linear regression is urea production during the 2019 period. Urea production is the determining variable for predicting energy consumption which can be seen from the p-value of 0.0002 (less than 0.1). The ability of urea production to predict energy use can be seen from the coefficient of determination (R-square) of 80% (above 50%). The assessment of the 2019 forecast data model can be seen in the following table:

Table 29. Forecast Model Rating

Model Variables	MMBTU per unit	p-value	R-square	F-stat
Baseline usage	1,079,784	0.0207	0.80	36.55
Urea production	30.21	0.0002		

Greenhouse Gas Emissions

Greenhouse gas (GHG) emissions are limited to CO_2 emissions sourced from heat energy (fuel combustion) and electrical energy for the production process. The following table compares greenhouse gas emissions in 2019 (Jan-Jun period) with 2021 in the same period. The increase in GHG emissions in 2021 is due to the rise in fuel use due to a rise in urea production.

Table 30. Greenhouse Gas Emissions

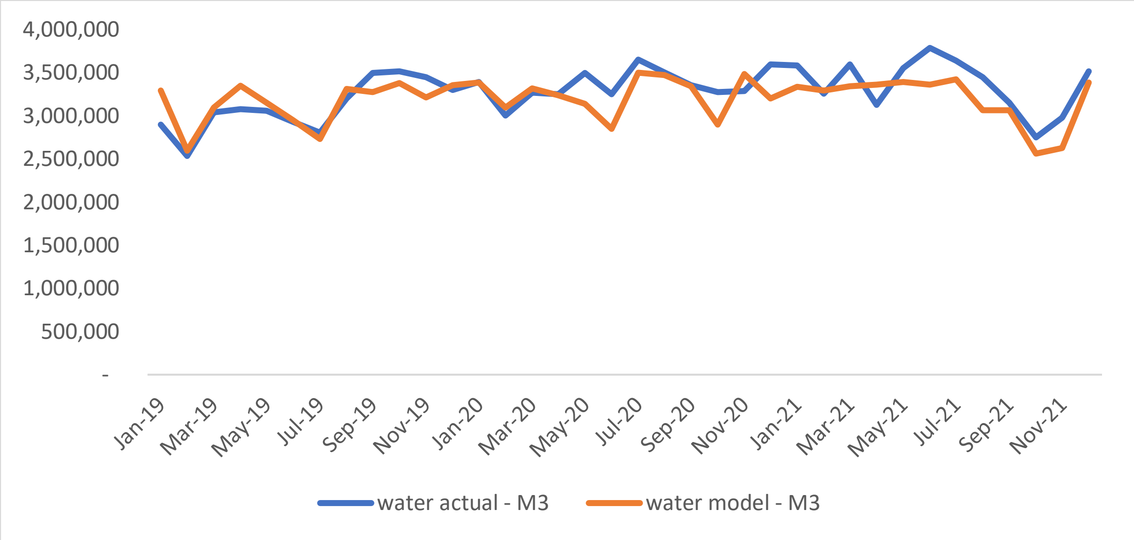
Energy Source (Jan – Jun)	Unit	CO2 kg per unit	2019	2021	Change (ton CO2)
Natural Gas Consumption	MMBTU		19,704,506	20,999,294	
GHG Reporting		53.06	116,205	184,323	-68,118
GHG Emissions	t- CO_2/ton urea		2.33	2.16	

Note: The calculation results may differ due to the energy sources used other than natural gas and the action of utilizing CO_2 gas as raw material for urea.

Water Consumption

Using the urea production variable, the water consumption forecast model taken from 2019 data is used as a baseline to project water consumption in the following year. The difference between actual water consumption and projected consumption indicates relative water savings. The following graph shows actual water consumption with projected water consumption. Actual water use tended to be lower than projected in 2021 (Jan – Dec period).

Figure 25. Actual vs Projected Water Consumption (M3)



Model vs Actual Water Consumption

Actual water consumption in 2021 (Jan – Dec period) is slightly above the forecast model for the same period. The forecast model is obtained from the urea production data regression on water consumption 2019 as a baseline. The following table shows water consumption based on the model's actual water consumption in 2021. Actual water consumption increased by 5.63% compared to the forecast model in 2021. Water consumption increased by 2,150,273 M3 or around $2,795,355 for Jan – Dec 2021 (assuming water costs $1.3 /M3).

Table 31. Model vs Actual Water Consumption

	2021 Model	2021 Actual	Savings	Percentage (%)	Unit
Water Consumption	38,195,786	40,346,059	-2,150,273	-5.63%	M3
Water Cost	49,654,522	52,449,877	-2,795,355		$

Note: Assumed water cost $1.3/M3

Baseline 2019 vs Reporting 2021

During the Jan-Dec 2021 period, urea production increased by 4.56% compared to the 2019 baseline in the same period. The increase in urea production was followed by an 8.21% increase in water use in the same period. In the 2021 period, there will be an increase in water intensity from 41.13 M3/ton urea to 42.57 M3/ton urea. The following table compares actual water consumption and actual urea production in 2019 as the baseline and 2021 as the reporting period.

Table 32. Baseline 2019 vs Reporting 2021

	2019 Actual	2021 Actual	Savings	Percentage (%)	Unit
Water Consumption	37,285,807	40,346,059	-3,060,252	-8.21	M3
Urea Production	906,472	947,860	-41,388	-4.56	Ton
Water Intensity	41.13	42.57	-1.44	-3.50	M3/ton urea

Forecast Model Rating

The variable used to predict water consumption through simple linear regression is urea production during the 2018 period. Urea production is a determining variable for predicting energy consumption which can be seen from the p-value of 0.001 (less than 0.1). The ability of urea production to predict water use can be seen from the coefficient of determination (R-square) of 79% (above 50%). The assessment of the 2018 forecast data model can be seen in the following table:

Table 33. Forecast Model Rating

Model Variables	M3 per unit	p-value	R-square	F-stat
Baseline usage	2,195,628	0.0000	0.75	27.27
Product	12.50	0.0005		

Recycled Water

Water use efficiency is one of the efforts to maintain water resources and industrial sustainability. Water efficiency can be obtained from recycled water (water from wastewater treatment) and reused water (e.g., condensate water, cooling water, backwash). In the period Jan – Jun 2019, the utilization of recycled water was 12.31%. However, in the period Jan – Jun 2021, the utilization of recycled water was 7.03%. The following table compares the use of recycled water in 2019 (January-June period) with 2021 in the same period.

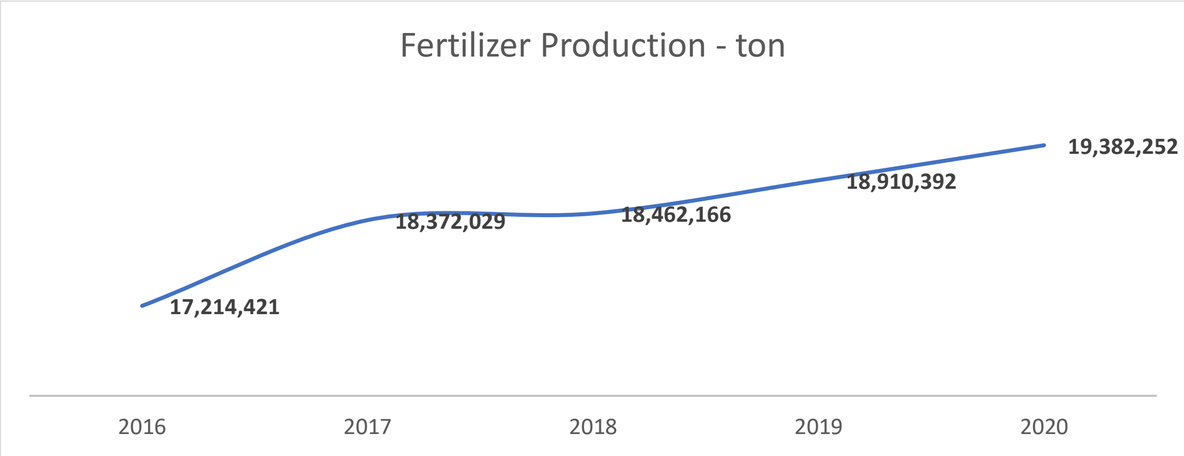
Table 34. Utilization of Recycled Water

	2019 Actual	2021 Actual	Unit
Water Consumption	17,528,320	20,886,071	M3
Recycled Water	2,158,389	1,467,614	M3
Utilization	12.31	7.03	%

3.4 Conclusion

The fertilizer industry is one of the many industrial sectors that require a lot of energy and water. The use of water and electricity in the fertilizer industry increases with the increasing demand for fertilizers. Therefore, to meet water and electricity needs, the fertilizer industry builds river water treatment units into clean water using coagulation, flocculation, and filtration.

Figure 26. Graph - Indonesian Fertilizer Production 2016 - 2020



Source: Pupuk Indonesia Group Annual Report, 2021

The resource consumption includes energy and water consumption, as well as the production output of each unit of the fertilizer industry demo, which the study conducted as follows:

1. **PT. Pupuk Iskandar Muda**

Table 35. Total urea production vs energy and water consumption of PT. Pupuk Iskandar Muda

Item	2018	2019	2020	2021(-Sept)	Unit
Urea production	361,815	337,546	402,108	249,774	Ton
Energy Consumption	14,037,237	13,839,638	14,939,806	10,015,513	MMBTU
Water Consumption	5,933,329	5,936,846	9,139,030	5,521,520	M3
Specific Energy Consumption	38.80	41.00	37.15	40.10	MMBTU/ton
Specific Water Consumption	16.40	17.59	22.73	22.11	M3/ton
Specific GHG Emissions	1.07			1.19	t-CO2/ton
Utilization of recycled water	5.65			6.96	% total water

From the comparison of the 2018 baseline with the 2021 reporting period, it can be concluded as follows:

- There was an increase in energy intensity from 38.80 MMBTU/ton urea in 2018 to 40.10 MMBTU/ton urea in 2021 or around -1.30 MMBTU/ton urea (-3.35%). If the average urea production is 367,200 tons of urea per year, then the energy increase of PT. Pupuk Iskandar Muda is -477,360 MMBTU per year or equivalent to $ -2864,160 per year (assuming the natural gas price is \$6/MMBTU). In April 2021, PT. Pupuk Iskandar Muda did not produce urea fertilizer, so specific energy consumption increased in 2021.

(Note: Based on SIH No. 27 of 2018, the specific heat energy consumption is a maximum of 38 MMBTU/ton-urea for technologies before 1995 and a maximum of 33 MMBTU for technologies before 1995).

- There was a slight increase in water intensity from 11.00 M3/ton urea in 2018 to 11.37 M3/ton urea in the 2021 reporting period, or around -0.37 M3/ton urea (-3.36%). If the average urea production is 1,589,976 tons per year, PT. Pupuk Iskandar Muda wastes water at 588,291 M3 per year.

  (Note: Based on SIH No. 27 of 2018, the maximum specific water consumption is 5.5.M3/ton urea)
- There was an increase in GHG emissions from 1.07-ton CO_2/ton urea) in 2018 to 1.19-ton CO_2/ton urea) in 2021 or around -0.12-ton CO_2/ton urea (-11.2%). The GHG emission is still below the threshold requirement of SIH No. 27 of 2018. If the average urea production is 1,589,976 per year, the GHG emission from PT. Pupuk Iskandar Muda's production activities are -190.797-ton CO_2 per year.

  (Note: Based on SIH No. 27 of 2018, the maximum specific GHG emission is 1.6 ton- CO_2e/ton-urea).
- Renewable energy, such as solar energy, has yet to be carried out at PT. Pupuk Iskandar Muda.

  (Note: Based on SIH No. 27 of 2018, there is no requirement for the amount of renewable energy).
- Utilization of recycled water at PT. Pupuk Iskandar Muda is 197,535 M3 or around 6.96% of the total production water use in 2021.

  (Note: Based on SIH No. 27 of 2018, there is no requirement for the amount of recycled water. In some RECP practices in the textile industry, the amount of recycled water utilization is between 10%-40%)

2. PT. Pupuk Kujang Cikampek

Table 36. Total urea production vs energy and water consumption of PT. Pupuk Kujang Cikampek

Item	2018	2019	2020	2021(-Sept)	Unit
Urea Production	896,721	865,181	843,492	756,362	Ton
Energy Consumption	21,403,826	22,043,479	21,254,902	17,311,648	MMBTU
Specific Energy Consumption	23.87	25.48	25.20	22.89	MMBTU/ton
Water Consumption	11,118,623	11,061,304	9,971,119	8,056,326	M3
Specific Water Consumption	12.40	12.78	11.82	10.65	M3/ton
Specific GHG Emissions	0.60			0.49	t-CO2/ton
Utilization of recycled water	12.28			12.64	% total water

From the comparison of the 2018 baseline with the 2021 reporting period, it can be concluded as follows:

- There was a decrease in energy intensity from 23.67 MMBTU/ton of urea in 2018 to 22.89 MMBTU/ton of urea in 2021, or around 0.78 MMBTU/ton of urea. If the average urea production is 868,500 tons of urea per year, then the energy savings made by PT. Pupuk Kujang Cikampek is 677,430 MMBTU per year or equivalent to $ 4,064,580 per year, assuming a natural gas price of $6/MMBTU.
  (Note: Based on SIH No. 27 of 2018, the specific heat energy consumption is a maximum of 38 MMBTU/ton-urea for technologies before 1995 and a maximum of 33 MMBTU for technologies before 1995).
- There was a decrease in water intensity from 12.40 M3/ton urea in 2018 to 10.65 M3/ton urea in the 2021 reporting period, or around 1.75 M3/ton urea. If the average urea production is 868,500 tons of urea per year, then the water savings made by PT. Pupuk Kujang Cikampek is 1,519,875 M3 per year.
  (Note: Based on SIH No. 27 of 2018, the maximum specific water consumption is 5.5.M3/ton urea)
- There was a decrease in GHG emissions from 0.60-ton CO_2/ton urea) in 2018 to 0.49-ton CO_2/ton urea) in 2021 or around 0.11-ton CO_2/ton urea. If the average urea production is 868,500 per year, then the savings in GHG emissions resulting from the production activities of PT. Pupuk Kujang Cikampek is 95,535 tons of CO_2 per year.
  (Note: Based on SIH No. 27 of 2018, the maximum specific GHG emission is 1.6 ton-CO_2e/ton-urea).
- The use of renewable energy, such as solar energy, has not been carried out at PT. Pupuk Kujang Cikampek.
  (Note: Based on SIH No. 27 of 2018, there is no requirement for the amount of renewable energy).
- Utilization of recycled water at PT. Pupuk Kujang Cikampek is 1,127,541 M3 or around 12.64% of the total use of production water in 2021.
  Note: Based on SIH No. 27 of 2018, there is no requirement for amount of recycled water. Some RECP practices in the textile industry, the amount of recycled water utilization is between 10%-40%).

3. PT. Pupuk Sriwijaya Palembang

Table 37. Total urea production vs energy and water consumption of PT. Pupuk Sriwijaya Palembang

Item	2018	2019	2020	2021(-Sept)	Unit
Urea Production	2,170,100	2,202,318	2,051,701	1,508,519	Ton
Energy Consumption	73,502,708	66,713,034	58,378,342	45,961,318	MMBTU
Water Consumption	11,118,623	11,061,304	9,971,119	7,543,295	M3
Specific Energy Consumption	33.87	30.29	28.45	30.47	MMBTU/ton
Specific Water Consumption	12.78	10.93	10.36	12.45	M3/ton
Specific GHG Emissions	1.82			1.65	t-CO2/ton
Utilization of recycled water	1.84			2.93	% total water

From the comparison of the 2018 baseline with the 2021 reporting period, it can be concluded as follows:

- There was a decrease in energy intensity from 33.87 MMBTU/ton of urea in 2018 to 30.47 MMBTU/ton of urea in 2021, or around 3.40 MMBTU/ton of urea. Suppose the average urea production is 2,140,000 tons of urea per year. In that case, the energy savings made by PT. Pupuk Sriwijaya Palembang is 7,276,000 MMBTU per year, or equivalent to $ 43,656,000 per year (assuming the natural gas price is $6/MMBTU).

  (Note: Based on SIH No. 27 of 2018, the specific heat energy consumption is a maximum of 38 MMBTU/ton-urea for technologies before 1995 and a maximum of 33 MMBTU for technologies before 1995).
- There was a decrease in water intensity from 12.78 M3/ton urea in 2018 to 12.45 M3/ton urea in the 2021 reporting period, or around 0.33 M3/ton urea. If the average urea production is 2,140,000 tons of urea per year, then the water savings made by PT. Pupuk Sriwijaya Palembang is 706,200 M3 per year.

  (Note: Based on SIH No. 27 of 2018, the maximum specific water consumption is 5.5.M3/ton of urea)
- There was a decrease in GHG emissions from 1.82-ton CO_2/ton urea) in 2018 to 1.65-ton CO_2/ton urea) in 2021 or around 0.17-ton CO_2/ton urea. Suppose the average urea production is 2,140,000 tons of urea per year. In that case, the GHG emission savings resulting from the production activities of PT. Pupuk Sriwijaya Palembang is 363,800 tons of CO_2 per year.

  (Note: Based on SIH No. 27 of 2018, the maximum specific GHG emission is 1.6 ton- CO_2e/ton-urea).
- The use of renewable energy, such as solar energy, has not been carried out at PT. Pupuk Sriwijaya Palembang.

  (Note: Based on SIH No. 27 of 2018, there is no requirement for the amount of renewable energy).
- Utilization of recycled water at PT. Pupuk Sriwijaya Palembang is 316,278 M3 or around 2.93% of the total production water use in 2021.

  (Note: Based on SIH No. 27 of 2018, there is no requirement for the amount of recycled water. Some RECP practices in the textile industry, the amount of recycled water utilization is between 10%-40%)

4. PT. Petrokimia Gresik

Table 38. Total urea production vs energy and water consumption of PT. Petrokimia Gresik

Item	2018	2019	2020	2021	Unit
Urea production	581,735	906,472	1,003,843	947,860	Ton
Energy Consumption	27,126,099	39,784,322	44,097,649	38,656,886	MMBTU
Water Consumption	4,910,265	7,359,124	8,382,785	7,578,280	M3
Specific Energy Consumption	24.28	17.48	16.28	16.97	MMBTU/ton
Specific Water Consumption	8.44	8.12	8.35	7.99	M3/ton
Specific GHG Emissions	0.26	0.26	0.37	0.33	t-CO2/ton

Utilization of recycled water	11.90	11.59	12.44	7.03	% total water

From the comparison of the 2018 baseline with the 2021 reporting period, it can be concluded as follows:

- There was a decrease in specific energy consumption from 47.89 MMBTU/ton urea in 2018 to 40.78 MMBTU/ton urea in 2021 or around 7.11 MMBTU/ton urea (14.85%). If the average urea production is 955,000 tons of urea per year, then the energy savings made by PT. Petrokimia Gresik is 6,790,000 MMBTU per year, or equivalent to $ 40,740,300 per year (assuming the natural gas price is $6/MMBTU).
  (Note: Based on SIH No. 27 of 2018, the specific heat energy consumption is a maximum of 38 MMBTU/ton-urea for technologies before 1995 and a maximum of 33 MMBTU for technologies before 1995).
- There was a decrease in specific water consumption from 8.44 M3/ton urea in 2018 to 7.99 M3/ton urea in the 2021 reporting period or around 0.45 M3/ton urea (5.33%). If the average urea production is 955,000 tons of urea per year, then the water savings made by PT. Petrokimia Gresik is 429,750 M3 per year.
  (Note: Based on SIH No. 27 of 2018, the maximum specific water consumption is 5.5.M3/ton urea)
- There was an increase in specific GHG emissions from 0.26-ton CO_2/ton urea) in 2018 to 0.33-ton CO_2/ton urea) in 2021 or around -0.07-ton CO_2/ton urea (-26.92%). Suppose the average urea production is 955,000 tons of urea per year. In that case, the increase in GHG emissions resulting from the production activities of PT. Petrokimia Gresik is -66,850 tons CO_2 per year.
  (Note: Based on SIH No. 27 of 2018, the maximum specific GHG emission is 1.6 ton-CO_2e/ton-urea).
- The use of renewable energy, such as solar energy, has been implemented for lighting installations.
  (Note: Based on SIH No. 27 of 2018, there is no requirement for the amount of renewable energy).
- Utilization of recycled water at PT. Petrokimia Gresik is 1,467,614 M3 or around 7.03% of the total use of production water in 2021 (Jan-Jun).
  (Note: Based on SIH No. 27 of 2018, there is no requirement for the amount of recycled water. In some RECP practices in the textile industry, the amount of recycled water utilization is between 10%-40%).

The environmental performance results summarized in section 3.4 were compared with international benchmarking, in this case using the fertilizer industry in India. Some parameters meet the international benchmark, and some do not meet, the results can be seen in the following table:

Table 39. International benchmarking and benchmarking of fertilizer industry in India

Average	PT. PIM	PT. PKC	PT. PSP	PT. PKG	Bench Marking Fertilizer Industry in India	International Bench Marking
Specific Energy Consumption (MMBTU/ton-urea)	21.26	24.36	30.77	18.76	37	30.32
Specific Water Consumption (M3/ton-urea)	19.73	11.91	11.63	8.23	5.5	4.6
Specific GHG Emissions (ton CO_2/ton urea)	1.13	0.55	1.74	0.31	1.6	0.43
Utilization of recycled water (%)	6.31	12.46	2.39	10.74	10 - 40	90

Note: The use of recycled water is 10 – 40% using the textile industry benchmarking that follows the RECP programme. International benchmarking using fertilizer industry in India.

3.5 Final Conclusion

Based on data analysis from 2018 to 2021, we can conclude that:

1. PT. Petrokimia Gresik, as a demonstration, made efforts to use the highest energy efficiency of the other three industries, which was 18.76 MMBTU/ton-urea.
2. PT. Petrokimia Gresik was a demonstration that carried out the highest water use efficiency of the other three industries, which was 8.23 M3/ton-urea.
3. PT. Petrokimia Gresik as a Pilot Plant that makes efficient efforts and utilizes CO_2 gas from the other three companies so that the greenhouse gas produced is the lowest, 0.31 ton-CO_2/ton-urea.
4. PT. Pupuk Kujang Cikampek, as a Pilot Plant made efforts to utilize the highest recycled water from the other three industries, which was 12.46% of the water used for the production process.
5. PT. Petrokimia Gresik carries out renewable energy from solar energy for lighting.

IV Performance Indicator Based on RECP Study in Fertilizer Industry and Implementation of Options

4.1 Energy

Specific Energy Consumption (SEC) and Energy Efficiency

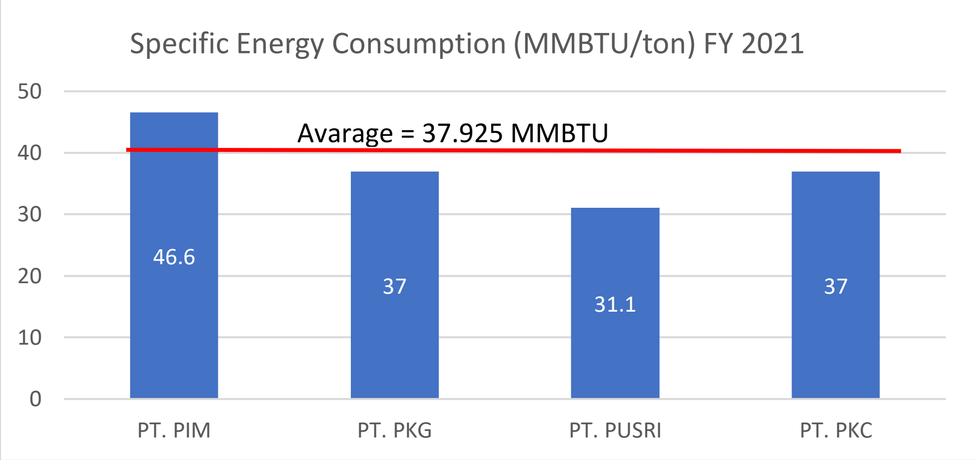
<u>Specific Energy Consumption (SEC)</u>

In order to reach the goal of reducing greenhouse gas (GHG) emissions by 80–95% by 2050 compared to 1990 levels, the industry has to improve its energy efficiency. Improving energy efficiency is the most promising measure to mitigate climate change.

SEC is defined as the ratio of kWh of energy consumed to the unit weight of the product produced by this energy consumption. It is represented by kilowatt hour per kilogram (kWh/kg) or kilowatt hour per pound (kWh/lb). SEC is used as an energy performance indicator to evaluate or measure the performance of energy efficiency. Energy consumption includes energy sources used as raw materials (feedstock), which are equalized with energy.

SEC is calculated as a ratio of energy used for producing a product. Based on the baseline data of PT. PIM, PT. PKC, PT. PUSRI and PT. PKG from 2019-2021, the average SEC is 37.9 MMBTU/ton. To calculate the specific energy consumption, that electricity unit is converted to MMBTU by following the conversion ratio of 3.412 MMBTU/MWh.

Figure 27. Specific Energy Consumption of PT. PIM, PT. PKC, PT. PUSRI and PT. PKG



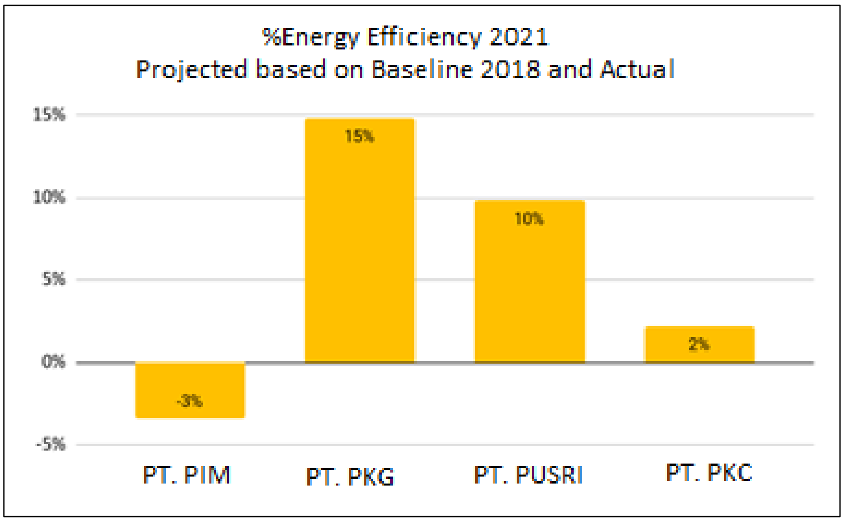
Average SEC for pilot units in 2021 = 37.9 MMBTU/ton

Source: RECP Profile Pilot Plants -2021

Energy Efficiency

Energy efficiency for Pilot Plants for this RECP study is shown below:

Figure 28. Energy Efficiency Baseline vs Actual



Source: RECP Profile 2021: Pilot Plant

Most companies showed improved energy efficiency in 2021 compared to the 2018 baseline despite the COVID-19 pandemic condition throughout 2020-2021. An improvement of up to 15% was recorded at PT. PKG. It should be noted that PT. PIM has a decreased energy efficiency because there is no production in April 2021. Meanwhile, PT. PUSRI, the energy efficiency is 10% followed by PT. PKC 2%. This value of percentage is calculated by model forecast energy consumption compared by actual energy consumption in 2021. During the period Jan – Sept 2021, production of urea was increased that impacted to decreasing of energy intensity.

The percentage of improvement in energy efficiency is calculated based on the baseline year 2018 for Urea production. The improvement in energy efficiency is calculated by comparing the projected energy efficiency (based on specific energy consumption in 2018) with the actual energy efficiency (in 2021).

Since the company doesn't have a data on energy efficiency, therefore the calculation of energy efficiency using the following approach:

Improvement in energy efficiency = **Data projected - data actual**

Percentage of improvement in energy efficiency = $\dfrac{\textbf{Data projected - data actual x 100}}{\textbf{Data actual energy}}$

The formula used to obtain energy efficiency data for four pilot plants as shown at table 40.

Table 40. Energy Efficiency Calculation Approach

PT PIM	2018 Actual	2021 Projected	2021 Actual	Increase/Decrease	Percentage (%)	Unit
Energy Consumption	12,396,043	9,234,807	10,015,513	-780,706	-8%	MMBTU
Urea Production	335,276		249,774	-85,502		Ton
Specific Energy Consumption	36.97		40.10	-1.3		MMBTU/ton-urea
Pupuk Kujang Cikampek					Percentage (%)	Unit
Energy Consumption	15,625,999	17,903,089	17,311,648	591,441	3%	MMBTU
Urea Production	660,272		756,362	96,090		Ton
Specific Energy Consumption	23.67		22.89	0.78		MMBTU/ton-urea
PUSRI					Percentage (%)	Unit
Energy Consumption	57,670,501	51,652,642	46,881,791	4,770,851	9%	MMBTU
Urea Production	1,684,271		1,508,519	-175,752		ton
Specific Energy Consumption	34.24		31.08	3.16		MMBTU/ton
Petrokimia Gresik					Percentage (%)	Unit
Energy Consumption	39,784,322	41,600,808	38,656,886	2,943,922	7%	MMBTU
Urea Production	906,472		947,860	41,388		ton
Energy Intensity	43.89		40.78	3.11		MMBTU/ton

Source: RECP Profile Pilot Plants 2021

In practice, energy efficiency efforts have been made by the four pilot plants, which are clustered into 4 major efforts:

- Good housekeeping: good housekeeping is the simple, no-cost, or low-cost practice. Good housekeeping refers to a number of practical measures based on common sense that pilot plant can undertake to improve their productivity, obtain cost saving, and reduce the environmental impact and resource use of their operation. Some efforts could be undertaken are avoiding air and water leaks, unnecessary running of equipment, lighting, heating, cooling.
- Better process control: an effort to control the process so that it runs properly and correctly. Activities carried out such as creating SOPs and controlling the application of these SOPs.; e.g., implement automatic control.
- Equipment modification is an effort to make modifications of equipment to improve the process, activities carried out include, e.g., improve insulation.
- Material and energy efficiency through utilization of useful by-products, and onsite reuse and recycling.

The efficiency efforts that have been made by the four pilot plants are summarized in table 41. So, what has been done by one company, it can be applicable for other companies.

Table 41. Implementation of Energy Efficiency

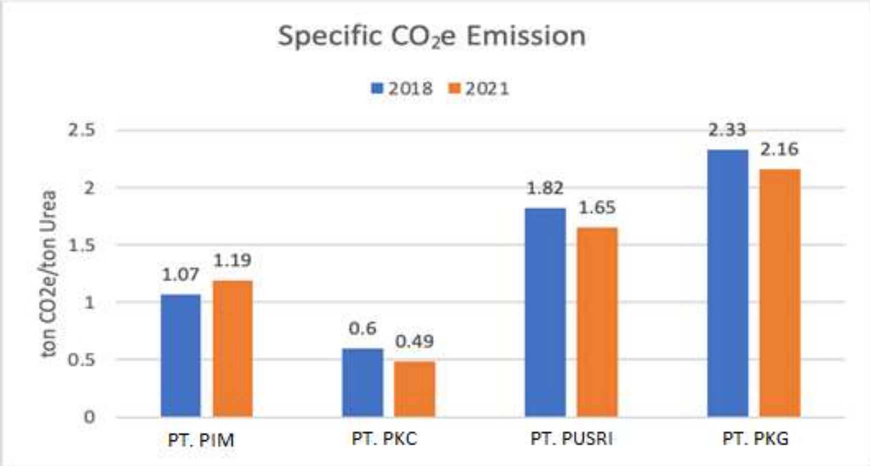
No	Scenario of Action	Investment	Stake Holder	Status
Good housekeeping				
1	Cleaning Arch Burner Reformer P-IV	-	Industry	Implemented
Better process control				
2	Save gas by speeding up the start-up process for entering the 101E absorber by changing the stages and start-up modes in the P-IB ammonia plant Purification unit	-	Industry	Implemented
3	Save wasted gas at start-up by modifying the method of the Compressor 101-J to minimize delays in the 101-J online	-	Industry	Implemented
Equipment modification				
4	Heater Installation in PB 3007-U P-III	-	Industry	Implemented
5	Utilization of Loop Process Exhaust Gas to be Additional Fuel in Auxiliary Boiler	-	Industry	Implemented
Material and energy efficiency				
6	PGRU (Purge Gas Recovery Unit) Serves to recover gas vents containing ammonia and hydrogen to be returned to the factory process	-	Industry	Implemented

4.2 Carbon (CO_2)

Specific CO_2e Emission

Specific data is total emissions divided by total urea production. the specific CO_2e emission at PT. PIM has increased from 2018 to 2021. Different from PT. PKC, PT. PUSRI, and PT. PKG, specific CO_2e emissions have decreased from 2018 to 2021. The specific details regarding Scope 3 emissions for PT. PKC, PUSRI, are unspecified. The calculation result of greenhouse emission could be different from the greenhouse emission reported because the energy consumption sourced not only from natural gas but also CO_2 gas as a by-product from production process.

Figure *29*. CO_2e emission data of PT. PKG, PT. PUSRI, and PT. PKC



Source: RECP Profile 2021: Pilot Plant

The specific greenhouse gas emission did not seem to reduce significantly. The highest CO_2 emission reduction is seen from PT. PUSRI AND PT. PKG, compared to the 2018 baseline. Although the total CO_2 emission was reduced, at the same time, there was a decrease in urea production compared to 2018.

Specific CO_2e emission is total emissions divided by total urea production.

Table 42.Technology Changing Implementation

No	Scenario of Action	Investment	Stake Holder	Status
1	Build a green surfactant plant with a capacity of 600 kilolitres (kL) that utilizes SO3 gas from a sulfuric acid plant as raw material through EOR (Enhanced Oil Recovery) technology in 2021	-	Petrokimia Gresik and surfactant and bioenergy research Center (SBRC) Institute of Agriculture, Bogor (IPB)	On-progressed
2	Build a soda ash factory with a capacity of 300,000-tons which is used as a raw material for products that are needed by the community, which are still imported. The raw material for soda ash is to utilize excess CO_2 produced from the ammonia manufacturing process. The by-product of soda ash in the form of ammonium chloride (NH4Cl) can be used as raw material for NPK so as to reduce the need for ZA imports as raw material for NPK.	IDR 4,5 trillion	Petrokkimia Gresik and Kementrian Investasi (Ministry of Investment	Planned
3	PT. Petrokimia Gresik switched to using PLN 11.4 MW of electricity through a progressive captive power acquisition program in August 2021, which previously relied on its own power plant and managed to reduce costs by 12%	-	Petrokimia Gresik and PLN Gresik	Implemented

No	Scenario of Action	Investment	Stake Holder	Status
4	Establishment of a catalyst factory (Red and white Catalyst) with a production capacity of 800 tons/year with an estimated construction period of 13 months to support the development of green fuel, and be able to reduce dependence on imported catalysts	IDR 286 billion	PT. Katalis Sinergi Indonesia yang terdiri dari PT. Pertamina Lubricant (38%), PT. Pupuk Kujang Cikampek 37%), dan PT. RekaciPT.a Innovasi ITB (25%)	On progress (groundbreaking 16 March 2022)
5	The construction of the PT. Pupuk Sriwijaya 3B factory will be implemented in the near future. The construction of the PUSRI 3B factory is a replacement for the PUSRI 3 and 4 factories which are in an old and inefficient condition	IDR 10 trillion	PT. Pupuk Indonesia (Persero)	Planned 2023 (Discussion on Feasibility Study including funding)
6	Construction of a liquid CO_2 factory with the aim of utilizing excess CO_2 gas from the production process of the Kujang 1A and 1B factories to produce liquid CO_2 products that have a selling value	IDR 106 billion	PT. Pupuk Kujang Cikampek dan PT. Rekayasa Industri (contractor)	Implemented (early 2019 – Oct 2020)
7	PT. Pupuk Iskandar Muda and PT. Perusahaan Gas Negara (PGN) signed an MoU for mutually beneficial business development between PIM and PGN with the scope of down streaming natural gas such as blue ammonia, methanol and oPT.imizing the use of PIM gas	-	Pupuk Indonesia through its subsidiaries PT. Pupuk Iskandar Muda and PT. Perusahaan Gas Negara (PGN)	On progress (MoU 26 Feb 2022)

Suggestion to reduce CO_2 emission

Based on the results of the study, emission reduction can be achieved through technology changing efforts, including:

1. Technology Changing at Cradle to Gate

- Cradle
    - ✓ Build a 600 kilolitter (kL) capacity **green surfactant plant** that utilizes SO_3 gas from a sulfuric acid plant as raw material through EOR (Enhanced Oil Recovery) technology in 2021
    - ✓ Build a **soda ash plant**
    - ✓ Build a **catalyst plant** (Red and white Catalyst)
- Gate
    - ✓ Technology Revitalization
    - ✓ Petrokimia Gresik switch by using PLN electricity of 11.4 MW
    - ✓ Construction of Pupuk Sriwijaya Plant 3B
    - ✓ Construction of liquid CO_2 Plant
    - ✓ Downstreaming of natural gas such as blue ammonia, methanol and optimizing the gas use of PIM

2. Blue and Green Ammonia

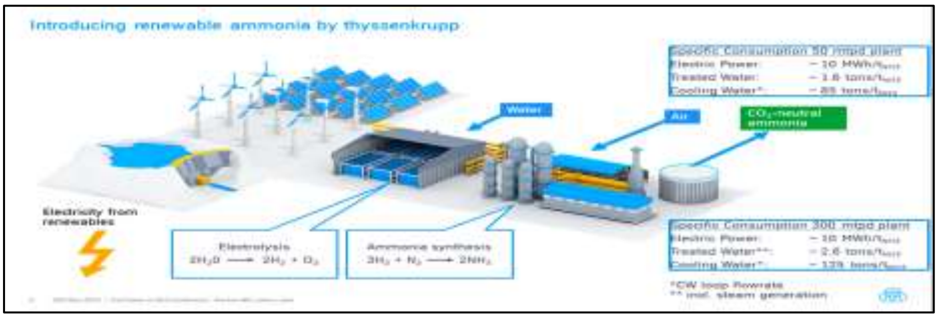
Blue ammonia is a low-carbon method of producing the chemical compound, using steam methane reformation. Hydrogen is first derived as a by-product of carbon dioxide, which has been captured and stored. It is then combined with nitrogen to produce ammonia.

Green ammonia can also be produced through electrolysis powered by renewable energy. The decarbonisation of ammonia production is integral to the global transition to net-zero emissions by 2050.

References

The use of renewable ammonia or green ammonia is an Option for implementing RECP that can reduce greenhouse emissions. However, further feasibility studies are needed on the implementation of this Option.

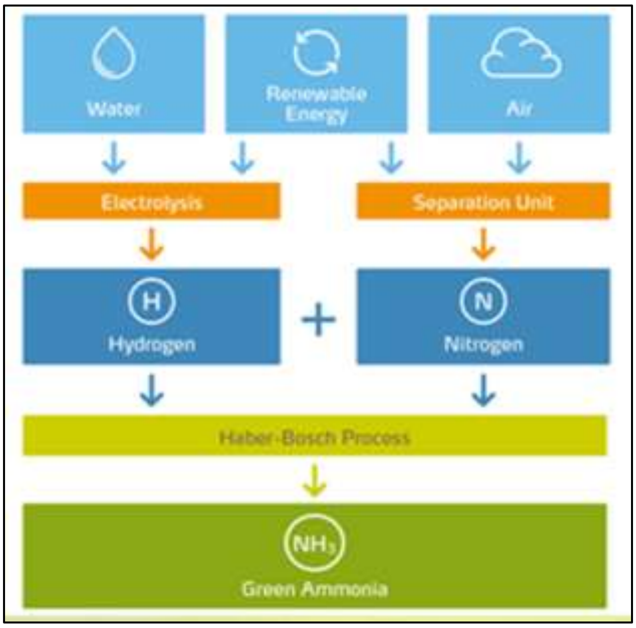
Figure 30. Renewable Ammonia



Source: renewable ammonia by ThyssenKrupp, 2021

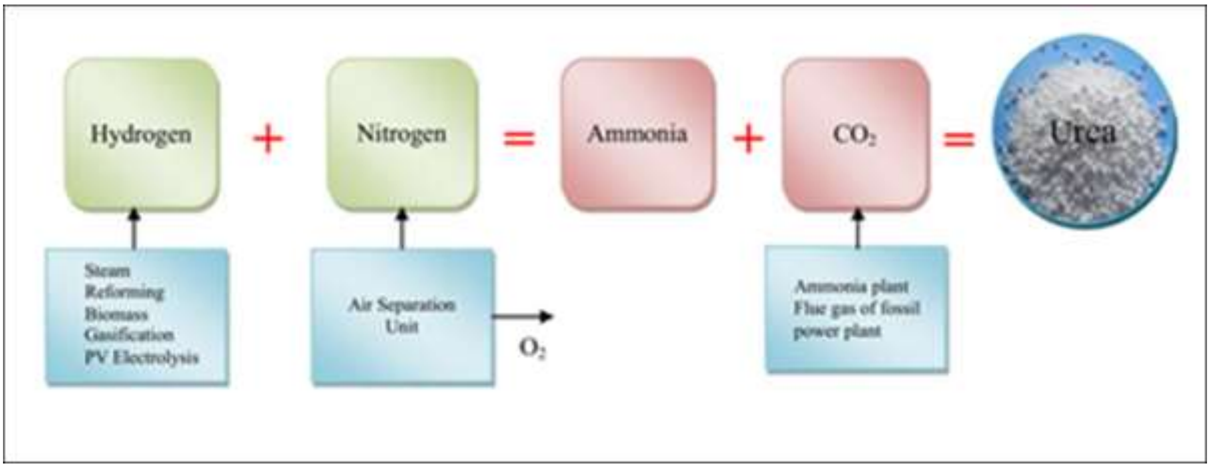
The use of renewable ammonia or green ammonia is an Option for implementing RECP that can reduce the effect of greenhouse emissions.

Figure 31. Renewable Ammonia for Reduce Greenhouse Emission



Source: www.yara.co.uk

Figure 32. The concept of applying renewable energy in the urea fertilizer industry



Source: Alfian & Purwanto, Energy Science & Engineering, 2019

4.3 Water

Specific Wate Consumption (SWC)

The calculation of SWC is formulated below:

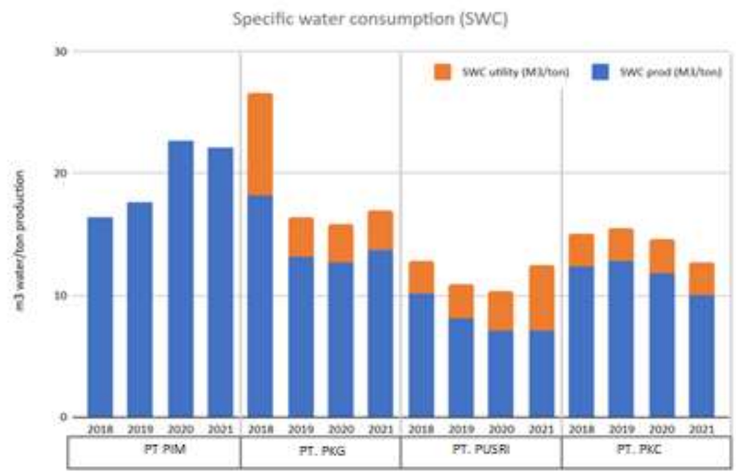
$$\text{SWC utility} = \frac{\textit{Demin Water consumption}}{\textit{product output}} \qquad \text{SWC } \textbf{Production} = \frac{\textit{Filtered Water consumption}}{\textit{product output}}$$

Consumption of demin water is used for steam/boiler and cooler/chiller (cooling tower) generators.

Calculation of Specific Water Consumption (SWC) is divided into 2 types, namely SWC utility which is a comparison between demin water consumption and product output, and SWC production, which is a comparison of filtered water consumption and product output. Demin water consumption is used for steam/boiler and chiller (cooling tower) generators.

Based on the calculation of Specific Water Consumption (SWC), at PT. Pupuk Iskandar Muda (PIM), the SWC production is increasing. The value of SWC utility at PT. Petrokimia Gresik (PKG) already meets the Green Industry Standard (SIH No. 27/1998), but the Specific Energy Consumption (SEC) is declining. Meanwhile, PT. Pupuk Sriwijaya Palembang (PUSRI) and PT. Pupuk Kujang Cikampek (PKC) are also increased in SWC utility.

Figure 33. The Calculation of Specific Water Consumption (SWC)

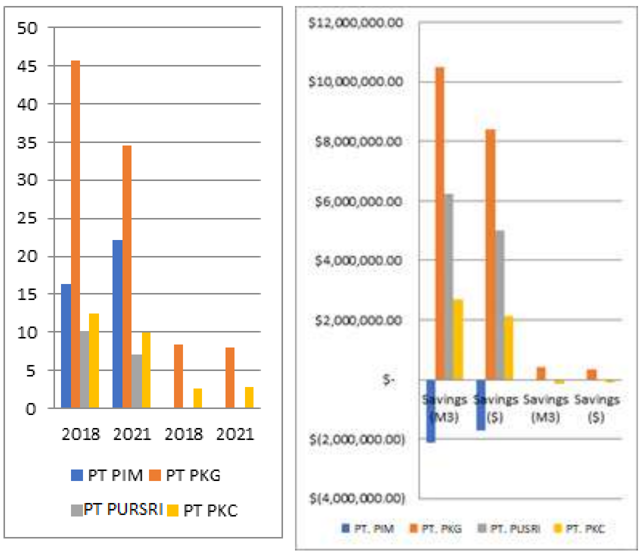


Source: RECP Profile 2021: Pilot Plant

Benchmarking: SIH No. 27 year 1998, SWC Prod: -; SWC Utility: max 5.5 M3/ton

Water Saving

Figure 34. Water savings 2018 vs 2021



- PT. PIM yearly output 2021 = 375,000 ton
- PT. PKG yearly output 2021 = 950,000 ton
- PT. PSP yearly output 2021 = 2,100,000 ton
- PT. PKC yearly output 2021 = 1,100,000 ton

Source: RECP Profile 2021: Pilot Plant

Water cost = $ 0.8/M3; yearly savings = (SWC2018 – SWC2021)*output

Implemented Water Management Activities

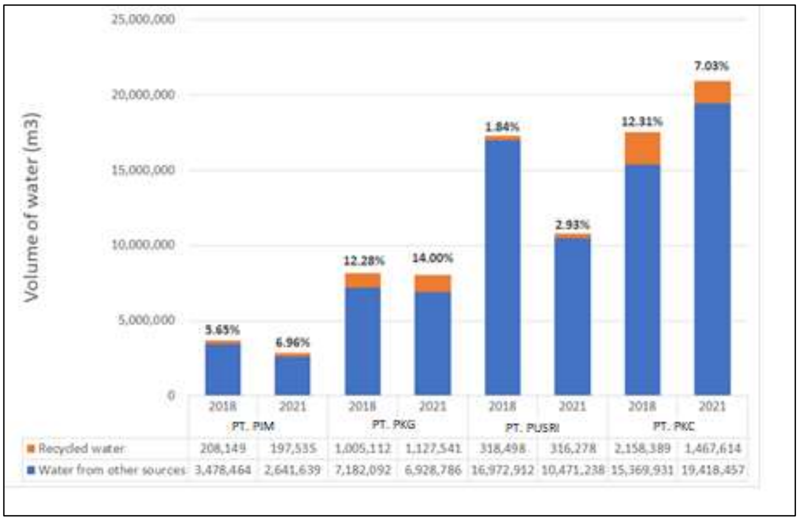
- ✓ Wastewater Treatment Plant functioned to separate ammonia levels in wastewater, the ammonia content drops to 98%
- ✓ PET (PUSRI Effluent Treatment) to recover wastewater from Urea factory process water by hydrolysis and then stripping

Utilization of Recycled Water

The recycled water used comes from:

- wastewater treatment
- reuse water (example: condensate water, cooling water, back wash)

Figure 35. Utilization of Recycled Water



Source: RECP Profile 2021: Pilot Plant

Benchmarking: SIH: National: 40% (textile industry); International: 90%

Best Practise: PT. PKG 's Recycled Water Utilization is around 14% of total water consumption.

V Findings and Recommendation

5.1 Findings

Table 43. Recapitulation of Pilot Plant's RECP Profile

Items	PIM	PKG	PSP	PKC	SIH	IBM
SEC (MMBTU/ton)	39.26	44.12*	30.77	-	37	
SWC utility (M3/ton)	-	8.22*	3.52	2.73	5.5	
SCO2eE (t-CO2e/ton)	1.17	0.27	0.40	0.62	1.6	0.43
Waste water recycle (%)	6.30	9.67	12.46	2.38	-	90%

- ❑ The energy efficiency program has not been implemented comprehensively, although some industries have achieved sub-standard specific energy. **There are industries that already meet the standards, so the benchmarks/good industry practice can be used.**

- ❑ The water efficiency program is not evenly distributed, although specific water consumption is below standard. **There are industries that already meet the standards, so the benchmarks/good industry practice can be used.**

- ❑ CO_2e reduction calculation is based on total utilization, not based on total reduction. So, **the SIH limits based on Total CO_2 reduction (energy efficiency, emissions and utilization) need to be reviewed.**

- ❑ The utilization of recycled water has not been included in the Green Industry Standard

- ❑ Pupuk Indonesia SR 2020: "For efficiency, Pupuk Indonesia is gradually increasing the use of coal and reducing the use of natural gas for heating and steam, considering that coal has a lower price, so that production costs can be reduced. " – **This approach will have an impact on GHG emissions, should be reconsidered.**

5.2 Recommendation

Technology Recommendation

The fertilizer industry in Indonesia can explore various technology change options to enhance resource efficiency and sustainability. The following options highlight potential areas for improvement:

- Factory revitalization: Upgrading and modernizing existing fertilizer factories can improve energy efficiency, process optimization, and overall productivity. This may involve the adopting advanced equipment, automation systems, and control mechanisms to maximize resource utilization and minimize waste generation.
- Utilization of exhaust gas CO_2: Capturing and utilizing carbon dioxide (CO_2) emissions from exhaust gases can contribute to reducing greenhouse gas emissions. Technologies such as carbon capture and utilization (CCU) or carbon capture and storage (CCS) can be explored to

harness the CO_2 emitted during the production process for beneficial purposes, such as in the production of other chemicals or for use in agricultural applications.

- Operational data digitization system: Implementing a comprehensive data digitization system enables real-time monitoring and analysis of operational parameters. This allows for better decision-making, identification of inefficiencies, and optimization of resource usage. Advanced data analytics and machine learning techniques can be utilized to extract valuable insights and support continuous improvement efforts.
- Innovation in industrial waste monitoring equipment: Investing in advanced monitoring equipment for gas and liquid waste emissions enables accurate and continuous monitoring of environmental performance. This ensures compliance with regulatory requirements and facilitates prompt corrective actions to mitigate negative impacts.
- Improved wastewater treatment plant (WWTP) performance and water recycling facilities: Enhancing the performance of WWTPs and implementing water recycling systems can significantly reduce water consumption and minimize the environmental impact of wastewater discharge. This includes adopting advanced treatment technologies, optimizing processes, and implementing water reuse strategies.
- Increasing the use of renewable energy: Integrating renewable energy sources, such as biomass for the production process and solar photovoltaic (PV) systems for office spaces, reduces reliance on fossil fuels and decreases carbon emissions. This transition to clean energy sources aligns with sustainability goals and contributes to a low-carbon future.
- Improved interconnection between factories: Establishing efficient interconnection systems between fertilizer factories allows for the exchange of resources, such as waste heat, steam, or by-products. This promotes resource sharing, reduces waste generation, and enhances overall energy efficiency.
- Knowledge sharing between industries: Collaboration and knowledge sharing among fertilizer industries can facilitate the equal implementation of best practices and technologies. Sharing experiences, lessons learned, and successful case studies support the industry-wide adoption of resource-efficient practices and foster a culture of continuous improvement.
- Standard implementation with consistent GHG calculation approach: Implementing standardized approaches for calculating greenhouse gas (GHG) emissions ensures consistency and comparability across the industry. This enables meaningful benchmarking, identification of emission hotspots, and formulating of targeted strategies to reduce carbon footprints.
- Factory revitalization, The four pilot plants were established between the 1950s - 1980s, the technology and infrastructure were obsolete, the effectiveness of the technology could not be improved, so revitalization was needed.

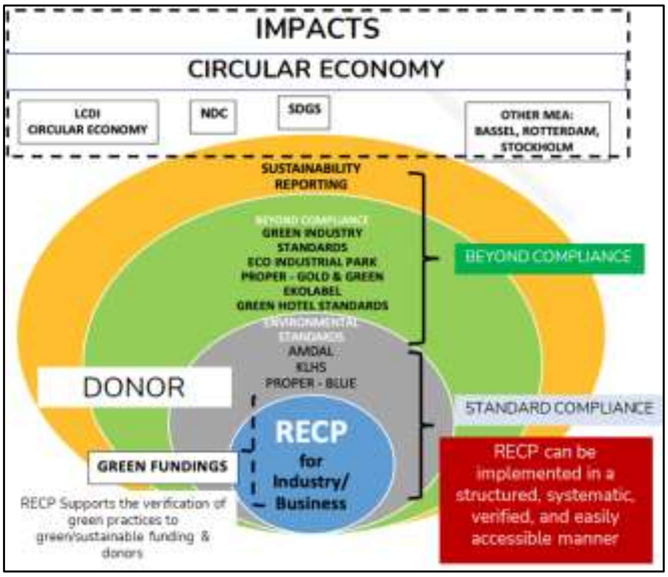
<u>Management Recommendations</u>

- Implementation of energy management and audit systems
- Employee training and development related to environmental management
- Implementation of environmental management system in all the fertilizer industries
- Implementation of heat/steam recovery systems in all the fertilizer industries
- Comprehensive and integrated data collection system

Financing Recommendation

It's important for fertilizer companies to conduct a comprehensive analysis of policy instruments, market conditions, and available financing mechanisms to determine the most suitable and advantageous financing options for their specific RECP projects. Engaging with financial institutions, industry associations, and relevant stakeholders can provide further insights and guidance on accessing financing for sustainable initiatives, described in the following figure:

Figure 36. RECP Circular Economy



Source: Report on Policy, Regulatory Framework, and Financing Mechanism to Promote RECP in Indonesia

RECP is a capacity-building tool to improve industry productivity and environmental performance to meet green industry standards. It can support the government in making mitigation efforts and adaptation to reduce GHG emissions. Climate change issues become the main criteria in the green funding scheme.

Based on the above policy and financing analysis of RECP, the following recommendations are drawn:

- Option of long-term technology replacement requires substantial funding, so **a long-term corporate strategy is needed**.
- **Synergy with financial institutions** is needed relating to sustainable funding mechanisms to accelerate the implementation of resource efficiency and cleaner production that can reduce significant greenhouse gas emissions in Indonesian fertilizers (stakeholders: BAPENAS, Ministry of Industry, Ministry of Energy and Mineral Resources, KLHK, Pupuk Indonesia (Persero).
- The funding mechanism can be synergized with the road map for sustainable finance phase II (2021 – 2025) issued by the Financial Services Authorization (OJK). Some examples of the application of sustainable finance include financing for new renewable energy projects (financing electricity sourced from hydropower, geothermal power, hydropower, solar power, biogas power, biomass, and other renewable energy sources, energy efficiency, and others). OJK has stipulated **Green Taxonomy** that supports the financial institution in distributing activities related to environment/sustainability.

- Green taxonomy for the fertilizer industry can be found by scanning the following barcode:

- Besides the green taxonomy developed by OJK, ISO/DIS 14030 - **Environmental Performance Evaluation - Green debt instruments- Taxonomy** also provides the potency of environmental benefit for the fertilizer industry:
  - Reducing emissions from the manufacturing activity in the manufacturing of ammonia and nitric acid as these manufacturing processes are highly carbon intensive
  - Alternative organic fertilizers from natural resources
- ISO**/DIS 14030 – Environmental Performance Evaluation - Green debt instruments-Taxonomy** provides information about Indicator environmental performance:
  - Metrics for the ammonia production process-
    - ✓ **<u>Direct emission</u>**: tCO_2/t ammonia
    - ✓ **<u>Combined CO_2 emissions</u>** (indirect emissions): tCO_2/t ammonia
    - ✓ Calculation of emissions from the ammonia process, namely the production of hydrogen intermediate products and the synthesis of ammonia
  - Areas to explore
    - ✓ Production of hydrogen from the electrolysis process
    - ✓ The manufacturing process for nitric acid— GHG produced is Nitrous Oxide
  -
    - How is the technology to reduce nitrous oxide? (Target 80% emission reduction)
    - What emission factor should be set for nitric acid, i.e., GHG emissions per unit of production?
    - What is the target for GHG emissions?

    - ✓ Emissions to air (nitrous oxide, N_2O), nitrogen oxides (NOx), and ammonia (NH_3) in the production process.
    - ✓ Use of water resources for production activities, usually in the cooling process, especially in water stressed areas.
    - ✓ Hazardous waste generated, especially those waste from the remaining of the catalyst (spent catalyst).

<u>LCA Recommendation</u>

RECP study in the fertilizer industry can be upgraded through Lifecycle Assessment (LCA) study. RECP study with system boundary from gate-to-gate can be wider become cradle to grave. The study was done for the following purposes:

- Developing alternative industrial-scale products to replace urea that is not based on fossils will one day run out and, at the same time, reduce the effects of greenhouse gases.
- Potential application of recycled packaging through a program to return unused packaging to producers as a form of implementation of expanded producer responsibility (EPR).
- The efficiency can be done through the application of the right fertilizer according to the soil nutrient needs studied by the development of research on nutrition and soil health for certain types of soil and plants. The right nutrient source is applied at the right rate, at the right time, and in the right place.

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