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# Utilization of fly ash and bottom ash waste: a study at PLTU tanjung jati B, Jepara, Indonesia

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**Abstract**
The high energy needs force the massive use of coal. PLTU as one of the largest energy-producing industries currently has a significant impact on the environment and social economy. One of the wastes from PLTU activities is fly ash and bottom ash (FABA). By taking a research study at the Tanjung Jati B PLTU one of the largest PLTUs in Indonesia, the authors try to see the impact of FABA waste on the environment and analyze the potential that can be utilized. The research approach used is quantitative by collecting data through literature studies. The results showed that FABA had a negative impact on the environment, especially when it was only left buried in landfills. On the other hand, FABA has the potential to improve the economy, especially for the people around the PLTU industry, including in the agricultural aspect. One of the benefits of FABA is for building construction purposes with a mixture of 20% to 35%. For agriculture, FABA is proven for soil enrichment on a small scale with a mixture of 35% to 50% and can increase the nutrients in the soil.
**Keywords:** B3 waste management; bottom ash; energy; FABA waste; fly ash; power plant

## 1. Introduction

Energy needs in Indonesia are increasing along with the growing population. The ratio of electricity consumption in 2014 was 84.35% of the total area throughout Indonesia, increasing to 98.89% in 2019 (Lidwina, 2020) Then, in 2020, it is projected that the need for electrical energy in Indonesia will reach 99.9%, or all regions in Indonesia this year must be electrified. Of the total national power plant capacity in June 2020 of 72 Giga Watt (GW), the largest capacity came from Coal PLTU of 35,220 MW, while the rest came from PLT Gas, Diesel, Water, Geothermal, and other EBT (Pribadi, 2020).

Based on the 2019 – 2038 National Electricity General Plan issued by the Ministry of Energy and Mineral Resources in 2019, it states that the provision of electricity is under the responsibility of the state whose implementation is regulated by the government and regional governments daerah (Ministry of Energy and Mineral Resources, 2019). This is intended to ensure that all Indonesian people must have access to electricity wherever they are by providing services at a reasonable price.

The government has also issued policies related to energy resources which are used as a reference in their utilization, where coal is one of the main primary energy for power plants as stipulated in the Minister of Energy and Mineral Resources Number 19 of 2017 concerning Utilization of Coal for Power Generation and Purchase of Excess Electricity (Excess Power) (Regulation of the Minister of Energy and Mineral Resources Number 19 of 2017). In addition, Presidential Decree No. 71 of 2006 was also issued concerning the

Assignment of PT Perusahaan Listrik Negara (Persero) to Accelerate the Development of Power Plants Using Coal as an effort to optimize the construction of coal-fired power plants in 2009 (Presidential Decree Number 71 of 2006). Thus, from 2006 to 2020 there have been 171 coal-fired power plants operating in Indonesia (Syahni, 2020).

The government's dependence on using coal as primary energy for electricity generation will certainly result in various environmental and health problems. One of them is due to the presence of coal ash waste or better known as fly ash and bottom ash (FABA) resulting from burning coal at PLTU, where this waste is categorized as B3 waste (Damayanti, 2018). As has been stated in Government Regulation Number 101 of 2014 it contains a B3 component from the waste products of a business that requires special handling in its processing and management. However, many studies state that the B3 content in FABA is still classified as below the quality standard of Government Regulation Number 101 of 2004. Even though it contains B3 elements, FABA contains many elements that can nourish the soil in plant growth, such as Cu, Zn, Mn, Mo, and Se (Kinasti & Notodisuryo, 2017). Another use of FABA is for building construction materials such as a mixture of paving blocks, concrete, and others because FABA is rich in Si, Al, Fe, and Ca which are good for construction materials (Qomaruddin et al., 2018).

The Tanjung Jati B PLTU, which is located in Tubanan Village, Kembang District, Jepara Regency, is one of the largest PLTUs in Indonesia. Fly ash waste production from the PLTU reaches 16 thousand tons/month and bottom ash reaches 2,000 tons/month (Fitri et al., 2015). This relatively high amount of FABA production allows for further management and utilization as renewable energy for the agricultural sector and construction materials.

The use of coal as the main energy as a fuel for power plants is inevitable. Tanjung Jati B PLTU has not yet managed FABA waste resulting from coal combustion based on the 2016 Environmental Activity Plan (RKL). Until now, the process being carried out is collecting it in a holding tank which is only 16 Ha (Fitri et al., 2015). However, FABA production will increase day by day, if it cannot be utilized, there will be accumulation of FABA waste, and it will simply be wasted regardless of the great potential that can be obtained from its utilization. In addition, the accumulated FABA waste can endanger the surrounding environment because it still contains hazardous and toxic materials (B3).

The Tanjung Jati B PLTU has obtained a utilization permit issued directly by the Ministry of Environment and Forestry for utilization products, such as paving blocks, bricks, and precast concrete (PT. PLN (Persero), 2019). Based on other studies, it also stated that FABA waste can be used for plant fertilizer engineering (Kinasti & Notodisuryo, 2017). And it is undeniable that other uses of FABA can continue to be explored to apply renewable energy and reduce fly ash and bottom ash waste. Based on the formulation of the problem described earlier, this study aims to analyze the impact of fly ash and bottom ash waste from PLTU Tanjung Jati B on the environment and analyze the potential utilization of fly ash and bottom ash waste from PLTU Tanjung Jati B.

This research is expected to provide input for the Tanjung Jati B PLTU in utilizing FABA waste based on the potential it has in its FABA content. In addition, it can also be taken into consideration in managing environmental impacts due to the presence of FABA waste around PLTU Tanjung Jati B. This research is also expected to add information to the education sector regarding what uses can be managed for FABA waste resulting from coal combustion. It is also expected to be able to increase community participation to contribute to the management of FABA waste utilization.

## 2. Methods

The approach used in this study is a quantitative approach, with a combined method (mixed method) between quantitative methods and qualitative methods. The purpose of combined methods is to broaden and strengthen study conclusions (Schoonenboom & Johnson, 2017). So this study, qualitative methods are used to explain and compare secondary data, and quantitative methods to describe secondary data. Overall, this research's qualitative and

quantitative data collection techniques were all carried out in the literature or literature study.

This research will be carried out for one month, namely in November 2020, starting with a literature study up to data processing. Meanwhile, the area being studied in the research is PLTU Tanjung Jati B, Tubanan Village, Kembang District, Jepara Regency. Tanjung Jati B PLTU is one of the largest PLTUs in Indonesia but has not maximized the utilization of B3 waste, especially fly ash and bottom ash (FABA) waste. Furthermore, the research location will be explained in Figure 1.

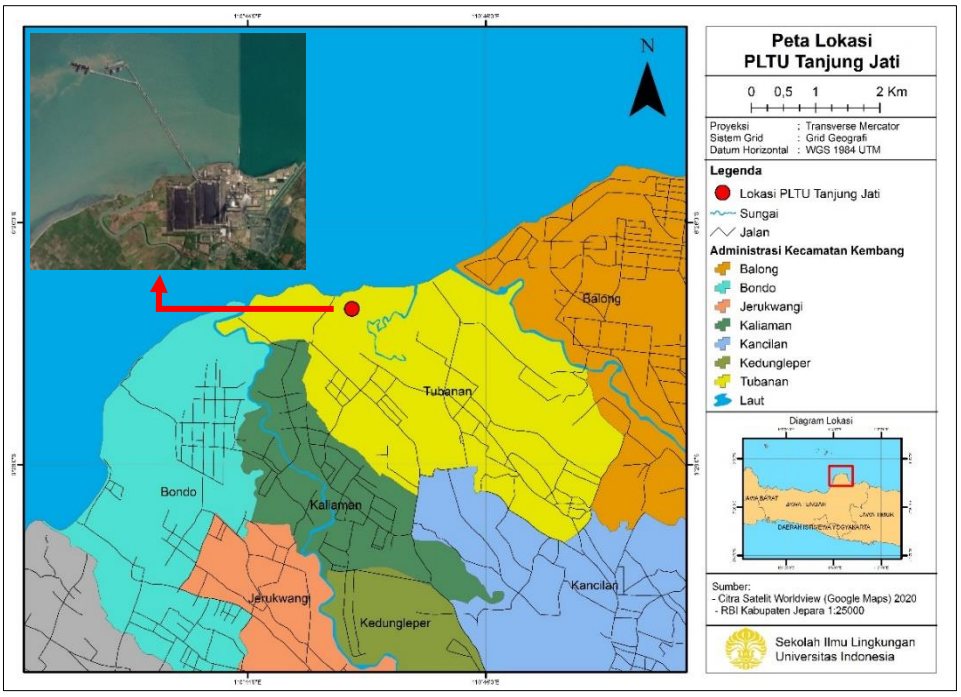


Figure 1. Research Location

*2.1. Data Collection And Analysis*

The data used in this research is secondary data, this data is to measure the variables and sub-variables that have been described previously. The data collection time was carried out in a cross-section, with a research process consisting of collection, processing, presentation, analysis, and interpretation. Secondary data collection is the collection of data from the literature, for the use of FABA waste, the chemical contents in it will be seen so that the contents can be analyzed for use in the construction and agriculture sectors. These data will be processed in the literature, then presented in a descriptive form and supporting images. The process of analyzing the data was carried out using descriptive statistics, so the conclusion will be devoted to the use of FABA at PLTU Jati B.

The analytical method used in this research is descriptive statistics. This type of analysis is used to analyze data that has been collected, then the data is described or described specifically so that it is easy to understand Sugiyono (2017). Furthermore, in this research, the data on FABA collected through literature studies will be concluded specifically on PLTU Jati B Jepara.

## 3. Results and Discussion

*3.1. Utilization of FABA Waste for Construction Materials*

Fly ash and bottom ash (FABA) are waste in solid form which is one of the outputs in the operation of a power plant using coal as raw material. (Turuallo *et al.*, 2016) divided the types of coal combustion in the power generation industry into 3 (three). The first type of

combustion is the type of dry bottom boiler. In this process, the fly ash produced is about 80% of the total ash that enters the gas funnel during the combustion process. The second is the wet-bottom boiler type, which produces 50% ash, while the remaining 50% will enter the gas funnel. The third type of combustion is the cyclone furnace. In this process only about 20-30% dry ash is produced, the rest will be retained as boiler slag. So far, the dry bottom boiler combustion type is the most widely used type of combustion in the power generation industry. The illustration of the burning is shown in Figure 2.

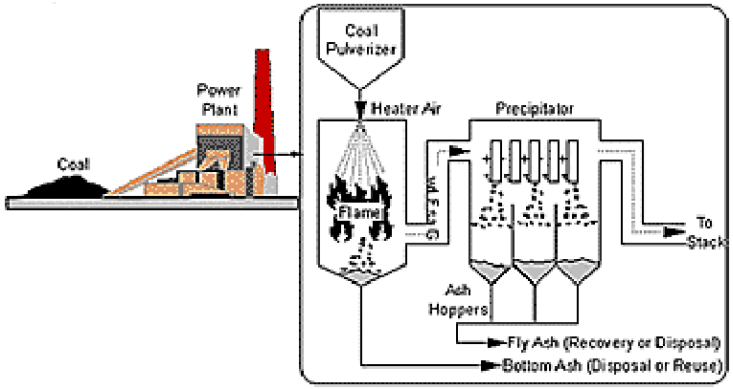


Figure 2. Illustration of FABA Production Scheme as a Result of PLTU Operations
Source: (Turuallo *et al.*, 2016)

FABA production cannot be avoided from PLTU operations. FABA hurts the environment. Based on PP No. 101 of 2014, FABA is categorized as one of the Hazardous and Toxic Wastes (B3). Furthermore, according to these regulations FABA is classified as a List of Hazardous Waste from Special Specific Sources with codes B 409 Fly Ash and B 410 Bottom Ash at the Hazard category level 2. Several countries have viewed FABA as a waste that has value benefits through proper processing. One of the potential uses of FABA is its use as a construction material. Pataras, et al. (2023) explained that in developed countries of the European Union and America, FABA is commonly used as an admixture for construction materials such as cement and concrete. Through processing as a mixture, FABA can be used as a material for construction purposes such as roads, buildings, paving blocks, etc. Another example, is SEFA Group,conscioustis ruction technology service company in the US, which utilizes FABA waste as a concrete hardener for roads, to use it as other building materials such as sidewalks, buildings, and bridges. An illustration of the use of FABA for construction purposes, such as that carried out by the SEFA Group in the United States (US), is shown in Figure 3.


Figure 3. Illustration of FABA Utilization for Construction Purposes in the US
Source: (SEFA, 2020)

The development of the use of FABA in Indonesia itself continues to experience development. A study conducted by the Center for the Study of Unconventional Earth Resources, Faculty of Engineering, (UGM, 2019), for example, was carried out on FABA waste from the operation of the PLTU PT. Bukit Asam (PTBA). Figure 4 shows a comprehensive picture of the potential utilization of FABA at PTBA through ongoing research activities. Gitari et al. (2008) explained that FABA is a fine material with main constituent elements such as Si, Al, Fe, Ca, K, and Na. These findings are also reinforced by research results from Adelizar *et al.* (2020) who revealed similar elements contained in FABA waste from PLTU Tanjung Jati B Jepara, the findings are presented in Table 1.

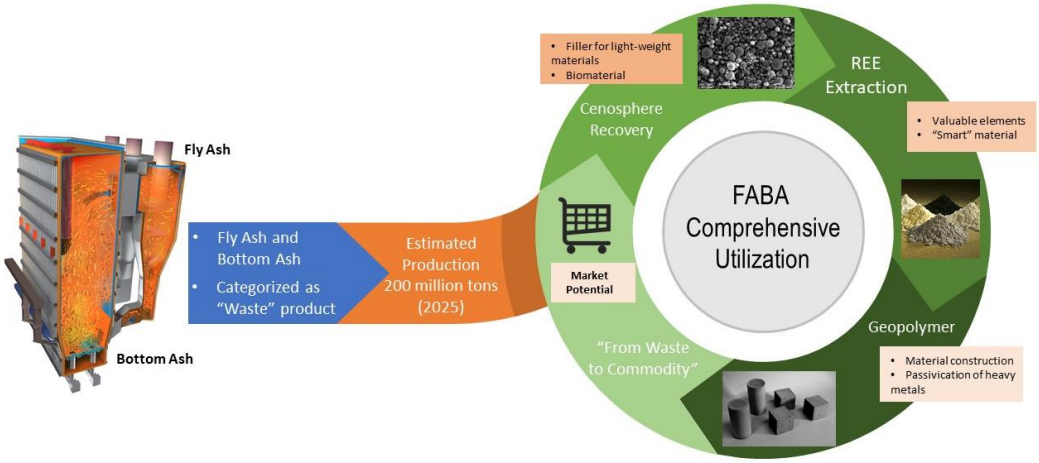


Figure 4. FABA Utilization Scheme at PTBA
Source: (UGM, 2019)

Table 1 Composition of Elements Contained in FABA Waste from PLTU Tanjung Jati B Jepara

| Composition | SiO2 | Al2O3 | P2O5 | SO3 | K2O | CaO | Fe2O3 | LOI | Lainnya |
|---|---|---|---|---|---|---|---|---|---|
| Fly ash | 37.5 | 12.5 | 1.89 | 2.07 | 1.97 | 19.7 | 19.9 | 1.87 | 2.5 |
| Bottom ash | 46.7 | 14.7 | 1.97 | 0.45 | 2.64 | 2.37 | 15.8 | 12.9 | 2.42 |

Source: (Adelizar et al., 2020)

In his research, Adelizar et al. (2020) also revealed that fly ash waste from PLTU Tanjung Jati B Jepara can form geopolymers with a maximum compressive strength of 58 MPa. The compressive value was obtained from the ratio of fly ash: bottom ash in a composition of 100 : 0 which was processed at 90°C with a processing duration of 28 days. Furthermore, the results of the study also revealed that the addition of bottom ash in geopolymers will reduce the value of its compressive strength. This is due to the carbon content of unburned bottom ash. Other research regarding the use of FABA as a mixture of construction materials was also carried out by Witarso *et al.* (2013). The results of this study revealed that at certain compositions FABA waste can be used as a mixture of block and paving block materials.

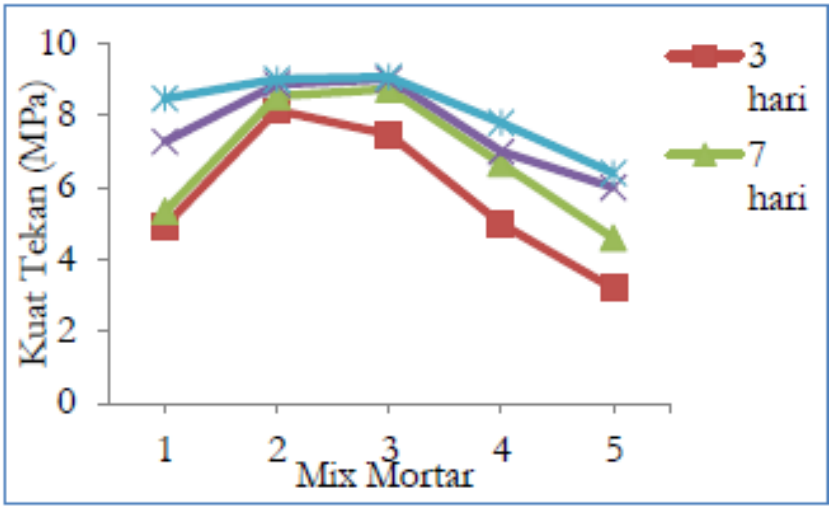


Figure 5. Graph of Comparison of Compressive Strength Value to the Percentage of Fly Ash Mixture Source: (Qomaruddin et al., 2018)

Another study regarding the FABA waste test of PLTU Tanjung Jati B Jepara for mixed concrete construction materials was also carried out by Qomaruddin et al. (2018). This study tested the compressive strength of concrete mortar from a mixture of FABA PLTU TJB Jepara using sand from Sungai Tempur, Kab. Japan as a mix. The results showed that the addition of fly ash mixture will produce a maximum value of mortar compressive strength at the percentage addition of 20% to 30% (Table 1). On average, the compressive strength of mortar with a mixture of 80% cement and 20% fly ash is 8.63 MPa. Whereas in a mixture of 70% cement and 30% fly ash, a compressive strength value of 8.57 MPa was obtained. The study also indicated that the presentation of the addition of more than 30% fly ash would result in lower compressive strength. As an illustration, Figure 5 shows a graph of the comparison of compressive strength to the percentage of mortar and fly ash mixtures carried out in the study.

Apart from being used as a mixture of cement and concrete, FABA waste can also be used as a construction material to prevent the formation of acid water due to coal mining activities. Coal mining can generate acid mine drainage from oxidized sulfide minerals. As a preventive measure, the prevention of acid mine drainage can be pursued by covering materials using materials that do not have the potential to form acid mine drainage, better known as Non-Acid Forming (NAF). NAF aims to reduce the contact that occurs in iron sulfide minerals with air/water so that the formation of acid water can be suppressed. In practice, materials for NAF were limited and difficult to obtain. Syaefudin et al. (2020) researched the potential for using FABA as an alternative material for mixing NAF. The results of research conducted on PT. FABA waste. Jorong Barutama Greston (PT. JBG) in South Kalimantan Province obtained the ideal composition of a mixture of FABA and NAF at a ratio of 35% fly ash: 35% bottom ash: 30% NAF. In this composition, the pH value tends to be controlled so that it does not exceed the quality standard value (6 - 9). Figure 4.5 presents the results of the comparison of FABA mixtures on these compositions.

Table 2 Comparison of Compressive Strength Values with 70% Cement Composition and 30% Fly Ash

| Age (days) | Weight (gram) | Fill weight (gram/cm$^3$) | Compressive strength (KN) | Compressive strength (Mpa) |
|---|---|---|---|---|
| 3 | 246 | 1.968 | 13 | 5.2 |
| 3 | 247.5 | 1.98 | 22 | 8.8 |
| 3 | 243 | 1.944 | 21 | 8.4 |
| 7 | 241.5 | 1.932 | 16 | 6.4 |

| Age (days) | Weight (gram) | Fill weight (gram/cm$^3$) | Compressive strength (KN) | Compressive strength (Mpa) |
|---|---|---|---|---|
| 7 | 257 | 2.056 | 25 | 10 |
| 7 | 268 | 2.144 | 24.5 | 9.8 |
| 14 | 271 | 2.168 | 22.5 | 9 |
| 14 | 259 | 2.072 | 23 | 9.2 |
| 14 | 253.5 | 2.028 | 22 | 8.8 |
| 28 | 261.5 | 2.092 | 19 | 7.6 |
| 28 | 250 | 2 | 18 | 7.2 |
| 28 | 263 | 2.104 | 31 | 12.4 |

Source: (Qomaruddin et al., 2018)

Referring to several previous studies as described above, the potential for FABA waste to be used as a mixed material for construction purposes is quite promising. Several studies conducted directly on samples of FABA waste at PLTU Tanjung Jati B Jepara have succeeded in presenting the results of a quantitative analysis of the compressive strength values for construction purposes. The results of some of these studies can be used as a scientific basis for planning the management and utilization of FABA waste for construction purposes.

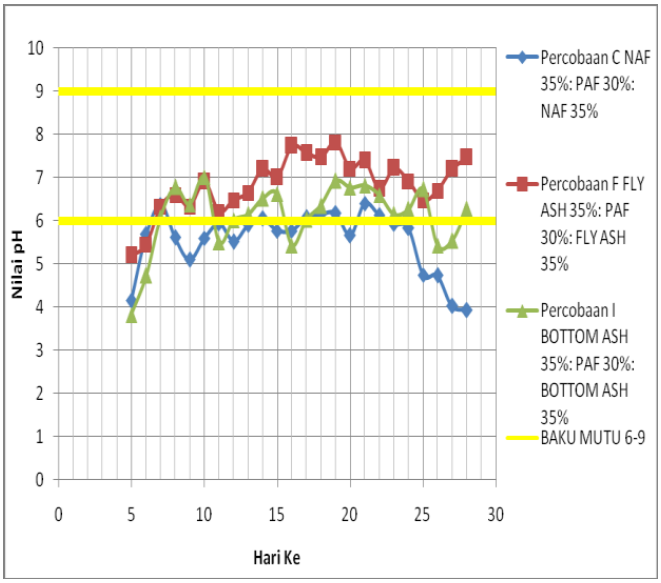


Figure 6. Results of Changes in pH Value on 35% FABA Composition
Source: (Syaefudin et al., 2020)

*3.2. Development of FABA Waste Utilization of PLTU Tanjung Jati B*

FABA waste produced by PLTU Tanjung Jati B Jepara was in the spotlight. Wahana Lingkungan Hidup (WALHI) (2015) explained that the coal waste storage area at PLTU Tanjung Jati B was initially only 16 hectares and then increased to 30 hectares in 2015, even though the shelter must accommodate B3 wastes such as FABA. Witarso *et al.* (2013) also explained that in 2013 the management of FABA at PLTU Tanjung Jati B was still not optimal. At least it is estimated that there are around 15,000 tons of waste per month stored in a holding pond of about 16 hectares.

This situation is now starting to be addressed by PLTU Tanjung Jati B. In 2018, for example, the management through the Environmental Management Plan and Environmental Monitoring Plan (RKL-RPL) is committed to starting to pay attention to the management and utilization of FABA waste. Several points regarding the FABA management and utilization plan in the document are as follows:

a. Utilizing B3 waste in the form of Fly Ash (FA) and Bottom Ash (BA) originating from PLTU TJB Unit 1-4 owned by PT PLN (Persero) Pembangkitan Tanjung Jati B as fill material, road pavement, and other suitable materials to support development PLTU TJB 56.
b. Utilizing B3 FA-BA waste generated from the operation of the TJB 56 PLTU during its operational period as a material for the production of paving blocks, bricks, tetrapods, fish apartments, and other suitable materials.

Based on the PT. PLN (Persero) (2019), the amount of FABA waste generated by coal-fired power generation activities from all PLTUs in Indonesia is 2,934,182.44 tons. This figure has increased from 2018 which was worth 2,576,110.88 tons. This value is relatively large, moreover, it only describes the value of FABA waste. However, in recent years, not all FABA waste in all PLTUs in Indonesia has been utilized. In Table 3, PLN releases a comparison of total FABA waste and how much can be utilized.

Table 3 Number and Efforts to Manage FABA

| **Jenis Limbah B3** | **Upaya Pengelolaan Limbah FABA** | **Jumlah Limbah B3 (ton)** | |
|---|---|---|---|
| | | **2019** | **2018** |
| Fly Ash dan Bottom Ash | Dihasilkan | 2934182.44 | 2576110.88 |
| | Disimpan di TPS Limbah B3 | 119683.35 | 385090.69 |
| | Dimanfaatkan Sendiri | 6334.9 | 5741.02 |
| | Dikelola Pihak Ketiga | 1831032.77 | 1402269.88 |
| | Di-landfill-kan | 977131.41 | 783009.29 |

Source: (PT. PLN (Persero), 2019)

The increase in the amount of waste that can be utilized, whether used directly or through third parties, is inseparable from obtaining a permit from the Ministry of Environment and Forestry regarding FABA waste management. In general, as shown in Table 4.4, the majority of PLTUs in Indonesia have obtained FABA waste management permits for mixed construction materials. PLTU Tanjung Jati B is a PLTU that has obtained a FABA waste management permit to mix paving block, brick, and concrete materials through a letter with number S.543/Menlhk/Setjen/PLB.3/8/2019.

Table 4. FABA Utilization Permits and Products

| **No.** | **Unit** | **Utilization Permit** | **Product Utilization** |
|---|---|---|---|
| 1 | PLTU Sebalang | SK661/Menlhk/Setjen/PLB3/11/2017 | Paving block, bricks |
| 2 | PLTU Asam-asam | SK942/Menlhk/Setjen/PLB3/12/2016 | Substitution of raw materials for soil materials in sub-pavement layers and sub-base layers |
| 3 | PLTU Tanjung Jati B | S.543/Menlhk/Setjen/PLB.3/8/2019 | Paving block, bricks, beton precast |
| 4 | PLTU Barru | S.51/Menlhk/Setjen/PLB.3/2/2019 | Paving block, bricks |
| 5 | PLTU Nii Tanasa | S.53/Menlhk/Setjen/PLB.3/2/2019 | Substitution of raw materials for making paving blocks and bricks |

| No. | Unit | Utilization Permit | Product Utilization |
|---|---|---|---|
| 6 | PLTU Indramayu | S.181/Menlhk/Setjen/PLB.3/4/2019 | Paving block |
| 7 | PLTU Rembang | S.583/Menlhk/Setjen/PLB.3/8/2019 | Paving block |
| 8 | PLTU Paiton 9 | S.608/Menlhk/Setjen/PLB.3/8/2019 | Paving block |
| 9 | PLTU Paiton 1&2 | SK883/Menlhk/Setjen/PLB.3/10.2019 | Produk Samping |
| 10 | PLTU Labuan | SK116/Menlhk/Setjen/PLB.3/2/2018 | Paving blocks, bricks, readymix, structural and non-structural concrete elements |
| 11 | PLTU Suralaya | SK577/Menlhk/Setjen/PLB.3/10/2017 | |

Source: (PT. PLN (Persero), 2019)

With the utilization permit obtained in August 2019, the utilization of FABA PLTU Tanjung Jati B waste can now be continuously increased. One example of the utilization that has been carried out is the renovation of residents' houses using brick materials produced from FABA waste of the Tanjung Jati B PLTU. According to several mass media sources, at least in 2019, the Tanjung Jati B Jepara PLTU has succeeded in renovating 3 (three) houses. residents in Kaliaman Village, one of the villages in Kembang District, Jepara Regency, which is an area affected by FABA waste.

So far, the permits that have been obtained from PLTU Tanjung Jati B for the utilization of FABA waste have begun to be applied for construction materials for residents' houses. Referring to several studies which revealed several findings related to the use of FABA waste, the FABA waste resulting from the Tanjung Jati B PLTU operational activities may be utilized in other products to be utilized more broadly.

## 4. Conclusions

FABA waste can hurt the environment, because according to Government Regulation Number 101 of 2014 Management of Hazardous and Toxic Waste, FABA contains B3 content in the form of Mn, Pb, Cu, Zn, Cd, Cr, Co, Hg, Se, V, and As. If left buried in landfills and blown away by the wind, it will pollute the surrounding environment, both air and water pollution. FABA waste that is properly managed has the potential to be used as a mixed material for civil engineering construction and soil fertilizer in supporting agricultural needs. The success of utilizing FABA waste in several countries for construction and agricultural purposes can be a reference for the use of FABA in Indonesia, especially in PLTU Tanjung Jati B.

The percentage of FABA mixing required for civil engineering construction purposes based on several studies is in the range of 20% to 35% with the addition of residue in the form of other raw materials, such as cement, concrete, and others. Meanwhile, for soil fertilizer, to increase agricultural productivity, the percentage of FABA mixture needed is in the range of 35% to 50%. Other mixtures are adapted to the needs of the commodity crops to be developed, which can be in the form of sandy soil or clay soil. In addition, several trials of FABA mixtures for soil enrichment activities in small-scale experiments show that FABA can increase nutrient elements in the soil, such as the content of Boron, Phosphorus Sulfur, and so on, which are useful for increasing the soil's ability to bind water content. By only using secondary data, it is hoped that further research will be able to quantitatively measure the benefits of FABA at PLTU Tanjut Jati B, including positive impacts that might be used as good practices for the community around the PLTU area.

**Acknowledgment**
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**Conflicts of Interest:**
The authors declare no conflict of interest.

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