



Potential of Solid Waste from Palm Oil as Fuel for Steam Power Plants in Palm Oil Factories

Dino Erivianto¹, Ahmad Dani²

Universitas Pembangunan Panca Budi

¹derivianto@gmail.com, ²ahmad.kartasasmitta@gmail.com

Abstract:

This research aims to analyze the potential electric energy contained in the by-products and processed waste of palm oil. Biomass derived from palm oil by-products can serve as an alternative source of energy, with potential calorific value to generate electricity from boilers or as renewable energy. While solid waste from palm oil by-products is commonly utilized as boiler fuel and fertilizer, it holds promise as a renewable energy source in its entirety. The research process includes problem identification, formulation, determination of research objectives, literature review, field surveys, primary data collection through observation and interviews, data analysis, and presentation of research results. Field observations from several visited palm oil mills reveal that solid waste by-products typically consist of 5-7% shell, 11-14% fiber, and 20-22% Empty Fruit Bunches (EFB) per ton of processed Fresh Fruit Bunches (FFB). Considering the maximum electricity requirement for processing 30 tons/hour and the potential electrical energy contained in each waste type, utilizing fiber waste alone as boiler fuel is sufficient, offering a potential electrical energy of 542.1 kW. Any excess electrical power generated (580 kW) by the boiler can be sourced from shell waste, enabling surplus electricity to be sold to external parties. With the surplus electrical power estimated at 130 – 70 kW/hour, operating for 20 hours per day yields a surplus of 1.4 – 2.6 MW/day from processing. The calorific value of solid palm oil waste is notably affected by its moisture content. Proper management of fiber waste utilization can effectively fulfill the energy needs of palm oil mills. Additionally, there is potential to sell approximately 648 – 686 kW of electrical energy externally, derived from shell waste and EFB.

Keywords: solid waste, steam, fiber, efb, shell

Abstrak

Penelitian ini bertujuan untuk menganalisis potensi energi listrik yang terkandung dalam produk sampingan dan limbah olahan kelapa sawit. Biomassa yang berasal dari produk sampingan kelapa sawit dapat menjadi sumber energi alternatif, dengan nilai kalor yang potensial untuk menghasilkan listrik dari boiler atau sebagai energi terbarukan. Meskipun limbah padat dari produk sampingan kelapa sawit biasanya digunakan sebagai bahan bakar boiler dan pupuk, limbah padat ini memiliki potensi sebagai sumber energi terbarukan secara keseluruhan. Proses penelitian meliputi identifikasi masalah, perumusan masalah, penentuan tujuan penelitian, studi literatur, survei lapangan, pengumpulan data primer melalui observasi dan wawancara, analisis data, dan penyajian hasil penelitian. Pengamatan lapangan dari beberapa pabrik kelapa sawit yang dikunjungi menunjukkan bahwa produk sampingan limbah padat biasanya terdiri dari 5-7% cangkang, 11-14% serat, dan 20-22% Tandan Kosong Kelapa Sawit (TKKS) per ton Tandan Buah Segar (TBS) yang diproses. Mempertimbangkan kebutuhan listrik maksimum untuk pengolahan 30 ton/jam dan potensi energi listrik yang terkandung dalam setiap jenis limbah, pemanfaatan limbah serat saja sebagai bahan bakar boiler sudah mencukupi, dengan potensi energi listrik sebesar 542,1 kW. Kelebihan daya listrik yang dihasilkan (580 kW) oleh boiler dapat bersumber dari limbah cangkang, sehingga kelebihan daya listrik tersebut dapat dijual ke pihak luar. Dengan kelebihan daya listrik yang diperkirakan mencapai 130 - 70 kW/jam, maka dengan beroperasi selama 20 jam per hari, akan menghasilkan surplus 1,4 - 2,6 MW/hari dari pengolahan. Nilai kalor limbah padat kelapa sawit sangat dipengaruhi oleh kadar airnya. Pengelolaan pemanfaatan limbah serat yang tepat dapat secara efektif memenuhi kebutuhan energi pabrik kelapa sawit. Selain itu, terdapat potensi untuk menjual sekitar 648 - 686 kW energi listrik secara eksternal, yang berasal dari limbah cangkang dan TKKS.

Kata Kunci: limbah padat, steam, serat/fiber, tkks, cangkang

INTRODUCTION

The impact of the COVID-19 pandemic since 2020 has led to a decline in CPO production. In 2021, production decreased by 1.36 percent to 45.12 million tons compared to the previous year. However, in 2022, CPO production increased to 46.82 million tons. The largest CPO production in 2022 is predicted to come from Riau Province, reaching 8.74 million tons or about 18.67 percent of Indonesia's total production. Meanwhile, Central Kalimantan Province also contributed significantly to production, reaching 8.36 million tons or 17.86 percent of the total production.

Solid waste from Palm Oil Mills (POM) can be utilized by using it as a raw material for boilers in steam power plants. A boiler, or steam generator, is a vessel/container containing water or another fluid to be heated (Kaniapan et al., 2021). The heat energy from the fluid is then used for various purposes, such as for steam turbines, space heating, steam engines, and so forth. In terms of energy conversion processes, boilers function to convert the chemical energy stored in the fuel into heat energy transferred to the fluid (Labibah et al., 2024; Mohammad et al., 2021). It can be understood that the fuel requirements for boilers must have sufficient calorific value to convert water into steam, and the calorific value of a fuel also significantly affects the efficiency of the boiler itself (Agustiar et al., 2022)

In their research, G.M. Saragih, Hadrah, and Rahmad Fatulloh explore the utilization of palm kernel shell and fiber as fuel for boilers that generate steam to drive turbines, producing electrical energy. The palm kernel shell and fiber yield energy is calculated from the product of the factory's electricity demand and the duration of fuel usage amounts to 4,900 kWh. The total energy generated by the turbines is 8,253 kWh. This results in an energy surplus of 3,353 kWh over a 7-hour period (Saragih et al., 2020)

The biomass power plant utilizing solid waste at PT. Union Sampoerna Triputra Persada Group reveals that the highest energy content in fiber waste is 198,145,030 kJ/hour, while the lowest is 174,767,310 kJ/hour. For shell waste, the highest energy content is 118,927,500 kJ/hour, and the lowest is 104,797,310 kJ/hour. The amount of energy produced is influenced by the volume of fresh fruit bunches processed, the more fresh fruit bunches processed, the greater the energy yield. (Praevia & Widayat, 2022) In 2018, the potential bioelectricity generated was 5,812.37 kWh (5.81 MWh). The average annual surplus power of 5 MW could be utilized to supply electricity in Central Kalimantan, which has been facing electricity supply issues due to a shortage of power plants (Tambunan & Perangin, 2023)

The biomass from by-products of palm oil can be utilized as an alternative source of energy (renewable energy), which has the potential energy value in terms of calorific value to generate electricity from boilers or as a renewable energy source (Yanti, 2023). The aim of this research is to analyze the potential electric energy contained in the by-products and processed waste of palm oil.

METHODS

The framework of this research is based on the author's frequent visits and direct observations of several Palm Oil Mills (POM), both government and privately owned. The solid waste from palm oil by-products is utilized as boiler fuel and fertilizer. However, the entire solid waste can be utilized as an alternative energy source (renewable energy) (Yanti & Hutasuhut, 2020).

In almost all the POM visited, only a portion of the shell and the entirety of the fiber are used as boiler fuel, while the empty fruit bunches (EFB) are only used as mulch or processed into compost. This research aims to compare the potential energy generated from palm oil by-products used directly (fiber, shell, and EFB) with those processed into briquettes and the economic value derived from the utilization of this waste (Yanti & Hutasuhut, 2020).

The steps undertaken in this research include the initial stage, problem identification and formulation, determination of research objectives, literature review, field surveys, primary data collection (observation and interviews), data collection, and finally, the research results (Arifandy et al., 2021).

The data obtained through field observations from several visited POM reveal that the solid waste by-products generated consist of 5-7% shell, 11-14% fiber, and 20-22% EFB from each ton of processed FFB. Only fiber and shell are used as boiler fuel, while EFB is used as mulch or burned in incinerators and then processed into fertilizer after undergoing pressing. Almost all POM operate in this manner (Simanjuntak et al., 2021).

The author directly observed the processing at various POM where the solid waste by-product in the form of fiber (13%) is entirely used as fuel, and the fuel deficit is supplemented with shell (4%), which is directly mixed with the fuel conveyor for the next hour of processing. In utilizing this waste as fuel, the factory never measures the amount of waste used as fuel but maintains the steam pressure

generated by the boiler at 18 bar G. The boiler fuel door opening and closing system is automatically regulated by its electrical system. The boiler data installed in the POM factory are as follows:

Boiler specifications:

- a. Steam capacity (Q) = 20,000 kg/hour
- b. Steam temperature (Tu) = 280°C
- c. Steam pressure (P) = 20 kg/cm²
- d. Feedwater temperature = 90°C
- e. Boiler efficiency (η) = 73%
- f. Fuel ratio = 75% : 25%
- g. Fuel amount = 5,200 kg
- h. Steam produced = 18,000 kg/hour
- i. Piping efficiency = 92.5%
- j. Enthalpy value for steam pressure at 20 kg/cm² at 280°C is 710.9 Kcal/kg (2,976 kJ/kg) and enthalpy at 90°C is 90.03 Kcal/kg (377 kJ/kg).

For the availability of by-products generated by POM in 1 hour of processing capacity under normal processing conditions (POM 30 tons/hour) are as follows:

1. Fiber approximately 3,900 kg/hour from processing.
2. Shell approximately 1,800 kg/hour from processing.
3. EFB approximately 6,600 kg/hour (30% moisture content) from processing.

The research object involves the utilization of solid palm oil waste in the form of Fiber, Shell, Empty Fruit Bunches (EFB). By conducting a drying experiment manually or under direct sunlight for 8 hours, from the sample quantities of:

- a. 5 kg of wet fiber (collected from POM processing).
- b. 5 kg of wet shell (collected from POM processing).
- c. 5 kg of wet EFB (collected from POM processing).

After drying the waste for 8 hours, the results are:

- a. 3.25 kg of dry fiber (35% shrinkage, 65% yield).
- b. 3.25 kg of dry shell (35% shrinkage, 65% yield).
- c. 1.75 kg of dry EFB (65% shrinkage, 35% yield).

The Raw Material Preparation Stage aims to prepare the materials to be used in the experiment so that they have the same form and can be easily used in the next stage. This process involves separating the research objects from any adhering impurities and drying them manually under sunlight for 8 hours, allowing the calorific value of each material to be measured through laboratory processes. The purpose of this stage is to facilitate and accelerate the charring process.



Figure 1. Palm Oil Waste Raw Materials

Source: research documentation (2024)

The Charring Stage aims to convert the palm oil fiber, shell, and empty fruit bunches into charcoal powder for use in the next stage. The charring process is done traditionally using old cans heated on a stove, where heating continues until no more white smoke comes out of the cans for 4 hours. The materials are charred alternately in this process. After the charring process is complete, the

materials are ground to a fine powder using a grinder or blender and then sifted. The sifting process uses a standard sieve to obtain a truly fine material.



Figure 2. The Charring Stage and Refining Materials

Source: research documentation (2024)



Figure 3. Stages of Briquette Molding and Drying

Source: research documentation (2024)

In the Molding and Drying Stage, the finely ground charcoal powder is mixed with fox glue adhesive. The adhesive mixture is about 20% of the material to be made into briquettes (1:5) and then enough water is added. This mixture is stirred evenly until it is well combined. The next process involves placing the mixture into a mold with a diameter of 5 cm and a height of 5 cm and pressing it with a press tool that has a pressing force of 5 tons (6,250 KN/m²). The molded briquettes are then dried again manually under sunlight for 8 hours. After the drying process, the briquettes are ready to be used and tested for their calorific value.



Figure 4. The Calorific Analysis Stage in PTKI-Medan laboratory
Source: research documentation (2024)

The Calorific Analysis Stage aims to determine the calorific value of the waste that has been dried and processed into briquettes through laboratory tests at PTKI – Medan show in figure 4. After conducting the calorific analysis of the waste in the PTKI-Medan laboratory, the laboratory test results show the calorific values of each type of palm oil waste material as follows:

Table 1. Average Calorific Value of Palm Oil Processed Waste

Material	Calorific Value	
	kcal/kg	kJ/kg
Fiber/Strands	3.963,44	16.646,45
Shell	4.337,17	18.216,11
EFB	2.694,72	11.317,82
Fiber Briquette	5.818,68	24.438,46
Shell Briquette	6.338,34	26.621,03
EFB Briquette	5.257,85	22.082,97

Source: Data Processed by Researchers

RESULTS AND DISCUSSION

Energy Potential from Caloric Analysis

Based on the research objects taken from various types of palm oil waste and processed into briquettes in this study, followed by calorific analysis from laboratory tests at PTKI-Medan, each type of palm oil waste has the following calorific values:

- Fiber/Strands: 3,963.44 kcal/kg (16,646.45 kJ/kg)
- Shell: 4,337.17 kcal/kg (18,216.11 kJ/kg)
- EFB: 2,694.72 kcal/kg (11,317.82 kJ/kg)
- Fiber Briquette: 5,818.68 kcal/kg (24,438.46 kJ/kg)
- Shell Briquette: 6,338.34 kcal/kg (26,621.03 kJ/kg)
- EFB Briquette: 5,257.85 kcal/kg (22,082.97 kJ/kg)

From the laboratory analysis, it is found that palm oil waste, after undergoing drying and subsequent development into briquettes, has an increased calorific value. The drying and charring processes reduce the moisture content in the waste, leading to an increase in its calorific value. Referring to the calorific values obtained from laboratory analysis, the electrical energy potential of each type of waste can be seen in Table 2 below:

Table 2. Potential of Electrical Energy from Each Waste

No	Type of Waste	Caloric Value		Energy Potential
		kcal/kg	kJ/kg	kWe
			4,20	3.600,00
1	Fiber/Strands	3.963,44	16.646,45	4,62
2	Shell	4.337,17	18.216,11	5,06
3	EFB	2.694,72	11.317,82	3,14
4	Fiber Briquette	5.818,68	24.438,46	6,79
5	Shell Briquette	6.338,34	26.621,03	7,39
6	EFB Briquette	5.257,85	22.082,97	6,13

Source: Data Processed by Researchers

Biomass Fuel Analysis

Using the calorific data from the above research subject, the calorific consumption required by a boiler with the following specifications can be calculated:

Boiler with specifications:

- Steam capacity (Q) = 20,000 kg/hour
- Steam temperature (Tu) = 280° C
- Steam pressure (P) = 20 kg/cm²
- Feedwater temperature = 90° C
- Boiler efficiency (η) = 73%
- Fuel ratio = 75%:25%
- Fuel = 5,200 kg
- Steam produced = 18,000 kg/hour
- Pipe channel efficiency = 92.5%
- Power generated = 580 kW
- The Enthalpy value for steam pressure of 20 kg/cm² at 280° C is 710.9 Kcal/kg (2,976 kJ/kg) and the Enthalpy at 90° C is 90.03 Kcal/kg (377 kJ/kg).

Where the steam boiler output capacity = 18,000 kg/hour : 92.5% = 19,459.5 kg/hour = 5.41 kg/second.

$$\text{The consumption } Q = \frac{Q \times (hg - hf)}{\eta} = \frac{19.459,5 \times (710,9 - 90,5)}{0.73} = 16.537.909 \text{ kcal/hour}$$

From the availability of palm oil waste by-products and the calorific value of the waste, the potential calorific value of the waste is:

- Fiber/Strands

$$\frac{16.537.909 \text{ kcal/hour}}{3.963,44 \text{ kcal/kg}} = 4.172,6 \text{ kg/hour}$$
- Shell

$$\frac{16.537.909 \text{ kcal/hour}}{4.337,17 \text{ kcal/kg}} = 3.813,1 \text{ kg/hour}$$
- EFB

$$\frac{16.537.909 \text{ kcal/hour}}{2.694,72 \text{ kcal/kg}} = 6.137,2 \text{ kg/hour}$$

4. Fiber Briquette

$$\frac{16.537.909 \text{ kcal/hour}}{5.818,68 \text{ kcal/kg}} = 2.842,2 \text{ kg/hour}$$

5. Shell Briquette

$$\frac{16.537.909 \text{ kcal/hour}}{6.338,34 \text{ kcal/kg}} = 2.609,2 \text{ kg/hour}$$

6. EFB Briquette

$$\frac{16.537.909 \text{ kcal/hour}}{5.257,85 \text{ kcal/kg}} = 3.145,4 \text{ kg/hour}$$

The amount of fuel required, as well as the calorific value of the fuel and the fuel cost based on the calorific requirements of the boiler, can be seen in Table 3.

Table 3. Fuel Requirements for a Palm Oil Mill with a Capacity of 30 Tons/Hour

Fiber/Strands	Shell	EFB	Fiber Briquette	Shell Briquette	EFB Briquette
Types of Inner Fuel					
Kcal/kg Fuel					
3.963,44	4.337,17	2.694,72	5.818,68	6.338,34	5.257,85
Type of Fuel In					
Kcal/h Calorie Requirements of Boiler					
16.537.909					
Type of Fuel in					
Kg/hour Fuel Required					
4.172,6	3.813,1	6.137,2	2.842,2	2.609,2	3.145,4
Fuel Type In					
Kg/h Fuel Available					
3.900	1.800	3.960	2.535	1.170	2.310
Fuel Type In					
Kcal/kg Fuel Available					
15.457.416	7.806.906	10.671.091	14.750.354	7.415.858	12.145.634
Type of Fuel In					
Kg/h Lack of Fuel					
-272,6	-2.013,1	-2.177,2	-307,2	-1.439,2	-835,4
Type of fuel in					
Kcal/kg Lack of fuel					
-1.080.493	-8.731.003	-5.866.818	-1.787.555	-9.122.051	-4.392.275

Source: Data Processed by Researchers

By referring to Table 3 above, it can be seen that there is a significant difference in comparison between EFB waste and EFB briquettes compared to other types of waste. The EFB waste developed into EFB briquettes has the highest calorific value compared to the development of other types of waste into briquettes (Prayitno Susanto et al., 2017)

Analysis of Potential Electrical Power Based on Available Waste

Based on the boiler data above, where the generated power is 580 kW at a pressure of 18 bar with a temperature of 280°C, the potential electrical power from each type of waste is as follows:

1) Fiber/Strands

$$P_g \text{ potensial} = \frac{15.457.416}{16.537.909} \times 580 \text{ kW} = 542,1 \text{ kW}$$

2) Shell

$$P_g \text{ potensial} = \frac{7.806.906}{16.537.909} \times 580 \text{ kW} = 273,8 \text{ kW}$$

3) EFB

$$P_g \text{ potensial} = \frac{10.671.091}{16.537.909} \times 580 \text{ kW} = 374,3 \text{ kW}$$

4) Fiber Briquette

$$P_g \text{ potensial} = \frac{14.750.354}{16.537.909} \times 580 \text{ kW} = 517,3 \text{ kW}$$

5) Shell Briquette

$$P_g \text{ potensial} = \frac{7.415.858}{16.537.909} \times 580 \text{ kW} = 260,1 \text{ kW}$$

6) EFB Briquette

$$P_g \text{ potensial} = \frac{12.145.634}{16.537.909} \times 580 \text{ kW} = 426 \text{ kW}$$

Analysis of Electricity Availability for External Parties

The power requirement for a palm oil mill in processing 1 ton of fresh fruit bunches (FFB) is approximately 15 – 17 kW/ton. Therefore, for a palm oil mill with a capacity of 30 tons/hour, the electricity requirement is:

$$\begin{aligned} \text{Electricity requirement for the mill} &= 30 \times (15 - 17) \text{ kW} \\ &= 450 - 510 \text{ kW/hour} \end{aligned}$$

By knowing the maximum electricity requirement for processing 30 tons/hour and based on the potential electrical energy contained in each type of waste, it is sufficient to use fiber waste as boiler fuel, which has a potential electrical energy of 542.1 kW.

If the available electrical power generated by the boiler is 580 kW, the additional fuel can be sourced from shell waste, so the excess electrical power generated by the boiler can be sold to external parties. Based on the available boiler capacity and the electrical power required by the palm oil mill, the surplus electrical power is $580 - (450 - 510) \text{ kW} = 130 - 70 \text{ kW/hour}$. If the mill operates for 20 hours per day, the surplus electrical power from processing is 1.4 – 2.6 MW/day

CONCLUSION

Essentially, all palm oil by-products can be utilized as renewable energy in accordance with the desired application (Zero Emissions) using the conventional linear model. The calorific value of solid palm oil waste is influenced by its moisture content. The utilization of fiber waste can meet the energy needs of palm oil mills if managed properly. The potential electrical energy that can be sold externally is approximately 648 – 686 kW from shell waste and EFB. Processing solid palm oil waste into briquettes significantly enhances their calorific value, especially for EFB briquettes. If all palm oil mills can distribute their surplus electrical power to other parties, the electricity crisis can be promptly addressed.

BIBLIOGRAPHY

- Agustiar, Bantacut, T., Romli, M., & Pramudya, B. (2022). Palm Oil Solid Waste an Alternatif an Energy Source of Electrivity Generation in The Southwest of Aceh. *Jurnal Keteknikaan Pertanian*, 10(1): 1-10.
- Arifandy, M. I., Cynthia, E. P., Sarbaini, & Muttakin, F. N. (2021). Potensi Limbah Padat Kelapa Sawit Sebagai Sumber Energi Terbarukan dalam Implementasi Indonesian Sustainability Palm Oil PKS Sungai Galuh. *Jurnal Sains, Teknologi dan Industri*, 19(1): 116-122.

- Kaniapan, S., Hassan, S., Ya, H., Nesan, K. P., & Azeem, M. (2021). The utilisation of palm oil and oil palm residues and the related challenges as a sustainable alternative in biofuel, bioenergy, and transportation sector: A review. *In Sustainability (Switzerland)*, 13(6): 1-25. MDPI AG. <https://doi.org/10.3390/su13063110>
- Labibah, A. N. C., Yuliono, G. K. Q., Chairunniza, D. N., Nurrohman, T. P. N., & Radianto, D. O. (2024). Upaya Pemanfaatan Limbah Kelapa Sawit. *Jurnal Sains Student Research*, 2(2): 148–153. <https://doi.org/10.61722/jssr.v2i2.1187>
- Mohammad, S., Baidurah, S., Kobayashi, T., Ismail, N., & Leh, C. P. (2021). Palm oil mill effluent treatment processes—A review. *In Processes*, 9(5): 1-22. MDPI AG. <https://doi.org/10.3390/pr9050739>
- Yanti, Rina Novia., & Hutasuhut, I. L. (2020). Potensi Limbah Padat Perkebunan Kelapa Sawit Di Provinsi Riau. *Wahana Forestra: Jurnal Kehutanan*, 15(2): 1–11. <https://doi.org/10.31849/forestra.v15i2.4696>
- Praevia, M. F., & Widayat, W. (2022). Analisis Pemanfaatan Limbah Tandan Kosong Kelapa Sawit Sebagai Cofiring pada PLTU Batubara. *Jurnal Energi Baru Dan Terbarukan*, 3(1): 28–37. <https://doi.org/10.14710/jebt.2022.13367>
- Prayitno Susanto, J., Dwi Santoso, A., Nawa Suwedi, D., Pusat Teknologi Lingkungan, P., Gedung, B., Puspipetek Serpong, K., & Selatan, T. (2017). Perhitungan Potensi Limbah Padat Kelapa Sawit untuk Sumber Energi Terbaharukan dengan Metode LCA *Palm Solid Wastes Potential Calculation for Renewable Energy with LCA Method. Jurnal Teknologi Lingkungan*, 18(2): 165-172. <https://doi.org/10.29122/jtl.v18i2.2046>
- Saragih, G. M., Hadrah, H., & Fatulloh, R. (2020). Analisis Pemanfaatan Limbah Padat Pabrik Kelapa Sawit menjadi Bahan Bakar PLTU (Studi Kasus: PT. Agro Mitra Madani Kabupaten Tanjung Jabung Barat). *Jurnal Daur Lingkungan*, 3(2): 47-50. <https://doi.org/10.33087/daurling.v3i2.53>
- Simanjuntak, A. L. S., Rangkuti, I. U. P., & Ginting, M. H. (2021). Potential Of Palm Oil Solid Waste: Palm Oil Boards And Palm Oil Empty Fruits As Bioethanol Raw Material. *AGRO FABRICA Jurnal Teknik Pengolahan Hasil Perkebunan Kelapa Sawit Dan Karet*, 3(2): 52–63.
- Tambunan, J. M., & Perangin, I. P. (2023). Studi Potensi Limbah Padat Kelapa Sawit Di PT.Union Sampoerna Triputra Persada sebagai Bahan Bakar Pembangkit Listrik Biomassa. *Technology of Renewable Energy and Development*, 3(1): 181–189.
- Yanti, R. N. (2023). Pemanfaatan Limbah Perkebunan Kelapa Sawit Sebagai Sumber Energi Terbarukan. *Dinamika Lingkungan Indonesia*, 10(1): 7-11. <https://doi.org/10.31258/dli.10.1>