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Development of Biomass Co-firing Technology by *PT. Jawa Bali* (PJB) Power Plant in Supporting the Energy Transition Towards Net Zero Emission 2060 during the COVID-19 Pandemic

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Abstract:- Indonesia is committed to achieving Net Zero Emission (NZE) by 2060. As a form of support for this commitment, the State Electricity Company (STATE POWER GENERATION COMPANY) has taken several important steps to reduce greenhouse gas emissions, one of which is through the new renewable energy mix (Renewable Energy). As a subsidiary of STATE POWER GENERATION COMPANY, PT. Generation Java Bali (PJB) is a pioneer who continues to play an active role in the development of co-firing technology in Indonesia and even in Asia. This study aims to analyze the development of biomass co-firing technology by PT. PJB in order to support the energy transition to NZE before and during the COVID-19 pandemic. The method used in this research is a descriptive qualitative analysis method based on thinking systems. Where the data used in this study were obtained from the results of a literature study and based on information obtained from the Focus Group Discussion (FGD). The data obtained were then analyzed using the SWOT method to analyze the performance of PT. The Java-Bali generation in supporting Indonesia's energy transition along with the characteristics of each of these SWOT factors. The results of this study are known that the government has ratified Law No. 16 of 2016 concerning NDC, the step was then welcomed by PT. STATE POWER GENERATION COMPANY with the issuance of RUPTL in its commitment to reduce greenhouse gas emissions so that in the future Indonesia will be able to switch from fossil energy sources to new and renewable energy. The acceleration of the energy transition is carried out by PT. PJB through a co-firing program in several coal-fired power plants by mixing biomass in the boiler. In addition, the application of co-firing has a positive impact on the company's investment costs, increases the sense of belonging to the community around the power plant and is relatively environmentally friendly so that it has the potential to reach NZE in 2060.

Keywords:- *NZE, Co-firing, PT. PJB, SWOT.*

I. INTRODUCTION

In 2015, UN member countries through the Paris Agreement committed to lowering the earth's temperature by around 1.5-2°C. And Indonesia, through the Intended Nationally Determined Contribution (INDC) program, is committed to reducing greenhouse gas emissions by 29% and 41% with international assistance by 2030 to achieve Net Zero Emissions (NZE) by 2060 [1]. One of the contributors to greenhouse gas emissions in Indonesia comes from the industrial sector, namely the power generation industry. In response to these problems, the Indonesian State Electricity Company (STATE POWER GENERATION COMPANY) aspires to support the achievement of NZE 2060 through:

- There is no construction of new coal plants after 2022;
- The NRE mix in 2025 is 23%;
- Cessation of coal generation in 2056; and
- Carbon Neutral Commitment by 2060.

In order to achieve these aspirations, it is necessary to increase the potential of NRE, reduce fossil energy through the use of clean coal technology (clean coal technology) in power plants, the substitution of energy use from fuel to natural gas, and conservation of sustainable energy through the implementation of energy management, and efficient lifestyle. energy and equipment efficiency in various industrial sectors [2]. Besides that, Based on the RUPTL (2021) in supporting the energy transition, the concept of acceptability needs to be added in the development of power plants which initially only recognized the concepts of affordability and security of supply. An overview of the development of the concept can be seen in Figure 1.

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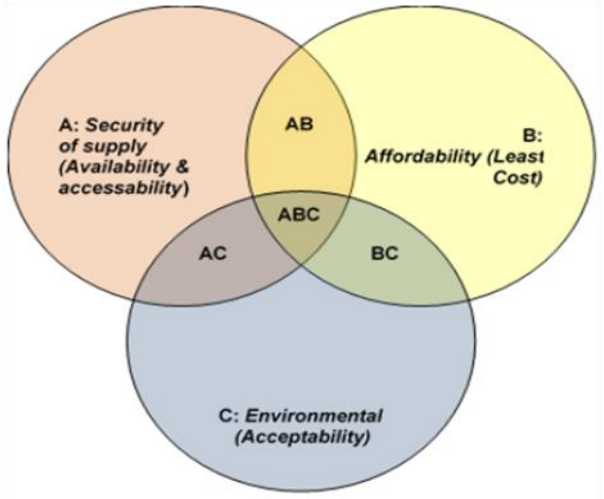

Fig. 1: Concept of Three Pillars of Electricity Infrastructure Development [15]

Based on the provisions above, one way to reduce greenhouse gas emissions can be done through fuel switching by replacing some of the coal fuel with biomass for co-firing with coal at the COAL POWER PLANT in Indonesia's future power generation sector. STATE POWER GENERATION COMPANY has long planned to use Co-firing in coal-fired power plants in an effort to increase the renewable energy mix. From the results of the study, the co-firing method has the potential to be applied to a number of steam power plants with a total capacity of 18,895 MW.

One of the STATE POWER GENERATION COMPANY subsidiaries that apply the co-firing method is PT. Generation of Java and Bali (PJB). The company is primarily engaged in providing electricity through 9 Generation Units (UP) with a total installed capacity of 8 generators of 7,054 MW. It has been applied for the use of co-firing such as COAL POWER PLANT Paiton 1 and 2, COAL POWER PLANT Indramayu and COAL POWER PLANT Rembang which use biomass in the form of pellets. wood pellets and COAL POWER PLANT Paiton 9 and COAL POWER PLANT Pacitan which use biomass in the form of sawdust [15].

Support PT. PJB as a Pioneer in the development of renewable energy and biomass Co-firing consists of three main principles, namely [21]:

A. Largest in terms of capacity

As the parent of PT. PJB Investasi (PJBI) together with Masdar formed the Java Bali Masdar Solar Energi (PT MSE) to build the largest floating PLTS, namely PLTS Cirata with a capacity of 145 MW, targeted for COD in 2022.

B. Greenest through Co-firing

Coal COAL POWER PLANT reforestation program in Java through co-firing of biomass at COAL POWER PLANT 1&2 as a pioneer of co-firing biomass in the STATE POWER GENERATION COMPANY Group.

C. Leading in research and innovation

PJB is committed to developing research and innovation through the development of PLTS since 2015 such as PLTS Cirata 1 MW and is currently preparing Hybrid PLTS with BESS Bawean (PLTS 400 KWp and BESS 1,300 KWh).

PT. PJB is one of the companies in Asia that plays a major role in the development of co-firing technology in Indonesia. And the co-firing technology development effort did not stop during the COVID-19 pandemic. PT. PJB continues to manage power plants based on regulations imposed by the government. However, until now there has been no written paper containing research related to the development of co-firing technology by PT. PJB. Therefore, this paper aims to analyze the development of biomass co-firing technology by PT. PJB in order to support the energy transition to NZE before and during the COVID-19 pandemic.

II. METHOD

A. Qualitative Descriptive Research Method

The research method used is a qualitative research based on Thinking system and SWOT supported by literature study. Qualitative thinking systems research is a holistic approach to analysis that focuses on how the components of a system are interrelated and how systems work over time. Thinking systems view a problem as a whole or comprehensively [2-3].

B. Study Literature Review

A literature review is a part of academic writing that demonstrates knowledge and understanding of the academic literature on a particular topic [4-5]. In particular, this research discusses the Biomass Co-firing Technology Development Study by PT PJB in dealing with Net Zero Emission conditions and the COVID-19 Pandemic. The literature review also includes a critical evaluation of the material. Usually a literature review is part of a dissertation, research project or long essay. However, it can also be organized and graded as a stand-alone work [6].

C. SWOT analysis

SWOT analysis is an abbreviation of Strengths, Weaknesses, Opportunities, and Threats, SWOT analysis is the best analysis carried out to design a company development strategy [7] especially PT PJB in response to international responses and the contribution of Indonesia's NDC. SWOT can also reveal the weaknesses of PT Java-Bali that hinder the achievement of energy transition conditions. SWOT analysis can assess internal and external factors that occur inside and outside PT. Java-Bali. The input data will be processed comprehensively and analysed as many possible factors as possible based on these 4 aspects [8-9]. The dominant aspect is selected based on the results of the SWOT weighting which is divided into 4 quadrants. The quadrant classification of each aspect is shown in Figure 2.

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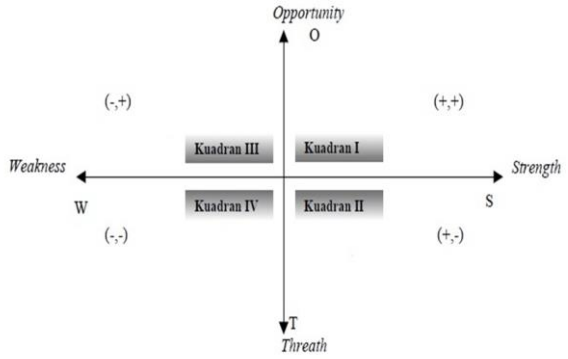

Fig. 2: Classification of Quadrants I-IV.

D. Data collection technique

Data collection techniques were carried out by conducting Focus Group Discussions (FGD) with informants from related companies and documentation sourced from international/national journals and proceedings, books, anecdotes, agency reports and other scientific references [10-11].

E. Data Processing Method

a) Data Checking Technique

Data checking techniques in qualitative research include credibility testing (extension of observations, increasing persistence, triangulation, negative case analysis, and using reference materials), transferability, dependability, and confirmability. In particular, this research checks between 3 dimensions, namely (1) implementation of (2) policies and (3) Local Government based on transcripts, documents, and minutes which are then interpreted [12-13].

b) Qualitative Data Analysis Techniques

Analysis of qualitative data based on the theory of Miles and Hubberman (2018) in qualitative data analysis must pass data reduction, data presentation and conclusion drawing and verification of field conditions. This can be seen in Figure 3.

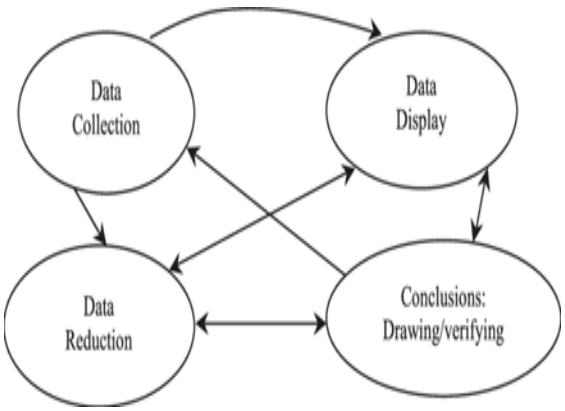

Fig. 3: Qualitative Data Analysis Schematic [14]

III. RESULT AND DISCUSSION

A. STATE POWER GENERATION COMPANY's Green RUPTL Strategy

In 2060 Indonesia has committed to supporting the realization of Net Zero Emissions, in which the ratio of CO_2 emission expenditures must be balanced or lower than emission expenditures generated from new and renewable energy sources. In supporting the energy transition from non-renewable energy (fossil-based) to new and renewable energy, PT. STATE POWER GENERATION COMPANY has prepared several strategies to achieve clean and green energy. As has been issued by Law No. 16 of 2016 concerning Ratification of the Paris Agreement to the United Nations Framework Convention on Climate Change. and the Nationally Determined Contribution (NDC) has been established [15].

Based on the Indonesia Energy Outlook 2019 and the National Energy Council (DEN), the potential for renewable energy in Indonesia is equivalent to 442 GW used for power generation. while BBN and Biogas of 200,000 Bph are used for fuel purposes in the transportation, household, commercial and industrial sectors [16].

In its development, NRE is faced with several challenges, including:

- Renewable energy Intermittent Character, energy storage is required for stabilization
- Low research and prototyping support
- Limited capacity, large enough land area.
- The difference between the location of the NRE source and the source of the electrical load.
- Mastery of technology, low manufacturing capability, weak domestic generating machines.
- System load stability, Security of electricity supply.

Currently PT. STATE POWER GENERATION COMPANY Persero issued a Business Plan for the Provision of Electricity (RUPTL) for 2021 – 2030, one of the aims of which is to assess the impact of the COVID-19 pandemic on electricity sales estimates, the phase of recovery of income for the customer sector affected by the pandemic, and plans for infrastructure development, both generators, transmissions and substations. parent. PT STATE POWER GENERATION COMPANY's RUPTL currently has a program to support the government in committing to reduce greenhouse gas emissions by 29% by 2030. The scheme for the pathway to net-zero emission conditions is shown in Figure 4.

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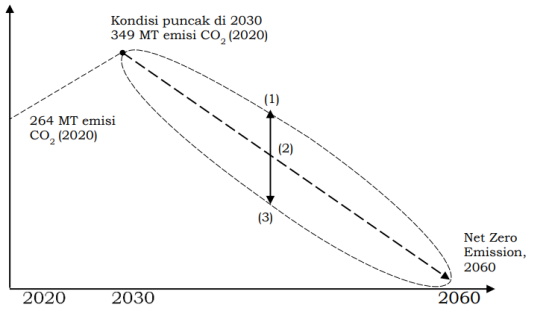

Fig. 4: The Path to Net Zero Emission [15]

The following are STATE POWER GENERATION COMPANY's policies in reducing greenhouse gas emissions:

- Prioritizing the development of new and renewable energy
- Fuel switching and exhaust gas utilization
- Utilization of biomass-based fuel as an energy source.
- Using low-carbon and more efficient technology.

In the RUPTL it is explained that the use of biomass-based energy in the projection of Indonesia's power generation fuel needs is prepared with 2 energy mix scenarios. The scenarios are the optimal scenario and the low carbon scenario. here is the table:

Co-firing	Unit	2022	2025	2030
Optimal Scenario	Kilo ton	1.508	13.947	8.047
Low carbon scenario	Kilo Ton	1.306	13.138	11.825

Table 1: Projection of Indonesia's power plant fuel demand

B. Domestic Biomass Co-firing Development

Co-firing technology is very important to support net-zero emission conditions, this has been formulated in the RUPTL strategy of PT. STATE POWER GENERATION COMPANY. In the process, Indonesia must be able to shift from a growth pattern that is driven by resources and depends on capital and labour, this must be changed to a growth pattern that is based on technology, innovation and high productivity. In implementing this change there are several keys that can be done, namely:

- A more even development in all corners of the country
- Connectivity and Infrastructure that supports growth
- Technology and Innovation that triggers the use of resources.
- Improving the quality of human resources that are able to compete globally
- Have energy, food, and water resistance.[17]

In its efforts, the Government to accelerate the mix of new and renewable energy, the Government has created a Co-firing program for coal-based power plants. Co-firing is the process of mixing coal with biomass with a certain dose which will later be burned together in the Boiler. This Co-firing innovation has been widely used abroad, some of the advantages of adopting this Co-firing are lower investment when compared to building your own biomass generator, as well as the abundant potential of biomass in Indonesia. The abundant potential of biomass itself in Indonesia has many types and its own characteristics, so adjustments are needed and the type of boiler used.[18]

By having these advantages, it cannot be separated from the shortcomings that occur due to Co-firing, in the use of biomass, one must also pay attention to the amount of ash content (%) and the elements in it which include elements that are alkaline, namely Fe2O3, CaO, MgO, Na2O, and K2O as well as elements that are acidic, namely SiO2, Al2O3, and TiO2. This content has an impact on the occurrence of slagging in the boiler room and fouling in boiler heat transfer equipment [19].

Strategic Plan for Accelerating Biomass Development as a Sustainable Energy Source	Improving governance and regulations regarding the purchase of electricity from renewable energy
	Encouraging capacity building for Biomass power plant
	Encouraging Captive Power
	Encouraging the use of Biomass Cofiring pellets in existing coal power plants
	Construction of small-scale wind power plants for the farthest, outermost and underdeveloped areas
	Increased cooperation with the Ministry of Environment and forestry for the development of energy plantations
	Encouraging the use of industrial agro-waste
	develop and produce biomass pellets as raw material.

Table 2: Description of the Strategic Plan for the Development of Accelerated Biomass as an Energy Source

Source: F.x. Sutijastoto (2020) [17]

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In the fourth point, it is stated that co-firing of biomass pellets on existing COAL POWER PLANT in the strategic plan table above is a sign that the development of co-firing in Indonesia is strongly supported by the government as a concrete step to reduce the use of fossil energy as the backbone of electricity generation in Indonesia.

Fig. 5: Coal-biomass Co Firing power plant [17]

Fig. 6: *feedstock* for Coal-biomass Co-firing power plant [17]

Figure 5 and Figure 6 are an illustration of the Co-firing development that has been carried out at coal-based power plants in Indonesia which is quite successful, but if we look closely, this Co-firing is still centered on Coal Power Plants located on the island of Java, in the future development COAL POWER PLANT with Co-firing technology must be evenly distributed to all COAL POWER PLANTs in Indonesia, not centralized on the island of Java alone.

C. Overseas Biomass Co-firing Development

The overseas development of Biomass Co-firing has increased rapidly as a result of research and development to find environmentally friendly energy sources at low cost. The solution to this problem is to mix coal-biomass material (Hybrid) in a power plant. Hybrid combustion in coal-biomass power plants requires less capital investment than dedicated biomass power plants. The energy conversion of the power plant takes place in 2 (two) stages:

- The first energy conversion efficiency is from the performance of the boiler during combustion. The basic normal assumption for a well-optimized power plant has an efficiency of 88% with a high calorific value.
- The second energy conversion occurs in the efficiency of the steam cycle. It is assumed that the coal-biomass co-firing power plant adopts the modern Rankine cycle which has efficiency varying from 35% to 44%. In the experimental results of Yoshino et al (2018), it is assumed that the efficiency value is 44% so that the overall conversion efficiency is 44% x 88% = 38.72%.

The recommended ratio of coal and biomass to produce a power output of 100 MW is shown in table 1.

	Coal	**Wood Pellet**
Ratio Co-Firing (%)	80%	20%
The efficiency of power plant (%)	38.72%	
Nilai Kalor (kJ/Kg)	32,000	20,680
Volatile Metter (%)	1.825% (Sulfur) 1,446% (Nitrogen)	0.1656% (Sulfur) 0.4078% (Nitrogen)
Output Power Capacity	100 MW	

Table 3: Assumption Ratio between Coal and Biomass (Wood Pellet) coalescing [1]

Source: Hamzah, N., Zandi, M., Tokimatsu, K., & Yoshikawa, K. (2018). Wood biomass pellet characterization for solid fuel production in power generation. International Journal of Renewable Energy Sources, 3

Based on Table 2, the calorific value of coal and wood pellet biomass yields 32 MJ/kg and 20.68 MJ/kg, respectively. Therefore, the amount of coal burned per second is 258,000,000 J/s divided by 32,000,000 J/kg giving a mass of 8.06 kg/s of coal that needs to be burned. Multiplying by 86400 seconds (the number of seconds in a 24-hour period) requires 696,600 kg of coal to be burned per day, or 696.6 tonnes per day. Therefore, 80% of coal is equal to 557,280 kg of coal burned per day or 557.28 tons per day.

In wood pellets, the biomass that is burned per second is 258,000,000 J/s divided by 20,680,000 J/kg resulting in the number of biomass wood pellets that need to be burned of 12.48 kg/s. Multiplying this number 86400 seconds = 24 hours will yield 1,007,911 kg of biomass wood pellets burned per day, or 1,077.9 tonnes/day. Thus, 20% biomass wood pellets are equal to 201,582 kg of coal burned per day or 215.58 tonnes per day. According to Cebrucean et al (2019) [26] revealed that Coal-Biomass power plants are not sufficient to reduce CO_2 emissions during the combustion process, therefore a carbon emission catcher is needed, namely Carbon Capture Storage (CCS), which is shown in Figures 7a and 7b.

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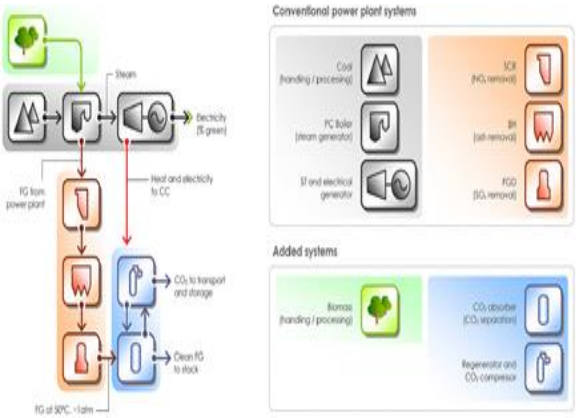
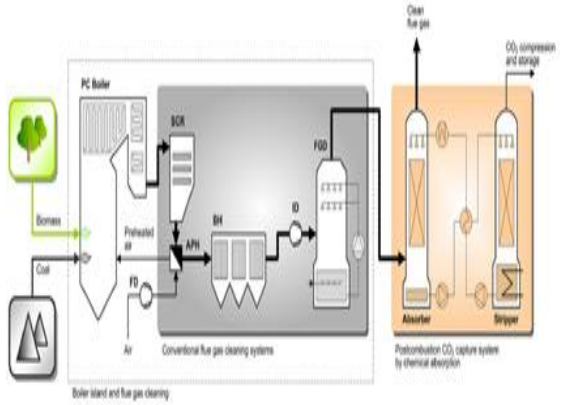


(7a)



(7b)

Fig. 7a and 7b: Coal-biomass power generation scheme and integrated with CO_2 capture chemical absorption technology after combustion [26]

Figures 7a and 7b show the advantages and disadvantages of using CCS, the drawback being that efficiency decreases as a result of extracting a large amount of steam required for solvent regeneration, leading to a decrease in the power output of the steam turbine and an increase in additional fuel consumption associated with capture and compression. In an effort to maintain a constant capacity, the fuel consumption of coal-biomass power plants with CO_2 capture increased by about 30% compared to the case without CCS. However, to date CCS is the only measure that reduces CO_2 emissions significantly. CO_2 emissions from CCS-integrated plants are reduced to values as low as 103–111 kg/MWh in the case of coal-burning alone and to 106-121 kg/MWh in the case of co-firing. When compared to the coal-fired case, the coal-biomass combustion system becomes carbon negative when considering the carbon neutrality of the biomass fuel. Net CO_2 emissions from biomass-coal power plants were found to be in the range of 14 to 277 kg/MWh depending on the share of biomass in the fuel mixture and type of generation.

Yonsei University Korea, Sung et al [27] built a 30 kW scale Circulating Fluidized Bed (CFB) boiler combined with flue gas recycling to study oxy-fuel combustion from sludge, and the characteristics of biomass and CO_2 are shown in Figure 8

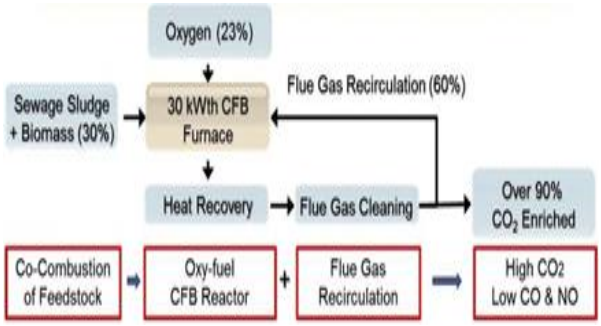


Fig. 8: Oxy-Fuel Combustion System of CFB reactor [27]

The fuel mixing ratio (wood pellet) is 0-70% and the oxygen concentration ratio is 21-30%. By increasing the mixing ratio of biomass and oxygen concentration ratio, combustion is accelerated, and ignition time is shortened. The results of this research produce very few pollutant emissions with CO is 0.91% and NO is 14 ppm but produces CO2 gas which is very much > 90% so that it requires CCS or further research to overcome the CO_2 gas.

D. Impact of Co-firing on the Environment as an Effort in Achieving Net Zero Emissions

The mandate of the Paris Agreement requires each country to contribute to protecting the earth from global warming and climate change due to excess CO_2 production. Therefore, a long-term plan was formed to achieve low emission development by 2050 and is expected to guide the implementation and development of further National Determination Contributions (NDCs). Indonesia proposes an innovative plan towards a common goal of imperatively taking ambitious action to address the challenge of climate change, not only through deeper GHG emission reductions towards the NZE but also through elements of the climate resilience pathway, along with NDC commitments.

The strategic approach of Indonesia's NDC based on the update of Indonesia's NDC by the Ministry of Environment of the Republic of Indonesia (2021) is based on the following basic principles:

- Using a landscape approach: Climate change adaptation and mitigation efforts are basically multi-sectoral, Indonesia takes an integrated landscape-scale approach that includes terrestrial, coastal and marine ecosystems.
- Practical work-oriented: Indonesia intends to increase the diversity of traditional wisdom (multi-stakeholder), innovative climate change mitigation and adaptation efforts by the government, the private sector, and the community.
- Prioritizing the climate agenda into development planning: recognizing the need to integrate climate change into development processes and spatial planning and budgeting, Indonesia incorporates key climate change indicators in formulating its development program targets.

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- Promote climate resilience in food, water and energy: recognizing the importance of meeting the needs of its growing young population for food, water and energy, Indonesia will improve its natural resource management to enhance climate resilience by protecting and restoring mainland, coastal and marine ecosystems.

Coal itself plays a dominant role in people's lives and the national economy, but it becomes a debate when coal is used as a source of energy to generate electricity. The global issue that is on the rise, namely GHG which accelerates climate change is directly related to COAL POWER PLANT. Electricity is generated through various processes that play a large role in GHG production, thus the use of Coal as a source of electrical energy is a big question to follow policies that have referred to NDC. But on the other hand, the use of coal cannot be stopped suddenly because it will cause vibrations in all sectors. Therefore, strategic steps are needed in the utilization of coal as well as reducing its impact on the environment.

The fourth point of the NDC strategic approach explains that energy is a necessity and should be met according to the concept of climate resilience. The State Electricity Company plans 2 scenarios in an effort to fulfil Indonesia's ambitions. First, innovation in storage technology that is more economical to replace COAL POWER PLANT with Renewable Energy-based generators and second, technology called Carbon Capture and Storage (CCS) and Carbon Capture, Utilization, and Storage (CCUS) so that COAL POWER PLANT utilization can still be carried out without contributing to increased gas. greenhouse with clean coal technology.

PT.PJB supports by increasing the Burning of coal - biomass through CCS which can actually achieve net zero emissions from coal-fired power plants, which can extract carbon dioxide from the atmosphere. Combustion technology Biomass-Coal hybrid system or CCS can only reduce carbon emissions without reducing harmful pollutants such as NOx, Sulfur, CO and others.

According to Wang. R et al (2020) to deal with the conditions of Net Zero Emission (NZE) offered 3 technical solutions for the transformation of low carbon coal-fired power plants + CCS (CP-CCS), biomass-coal + CCS (CBP-CCS), and Coal-Biomass + Co-firing. This can be seen in Figure 9.

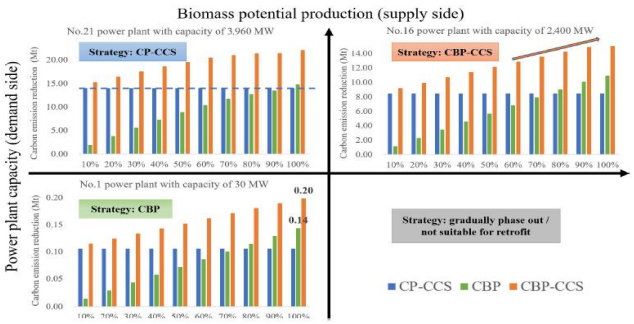

Fig. 9: Potential for Biomass Production in Supply side [20]

Figure 9 shows the power plant classification matrix for different strategies according to the capacity and resources of the surrounding area. the value on each histogram graph shows the difference in carbon emissions between coal-based power plants and hybrid power plants.

The carbon emission curve for each power plant at a different hybrid combustion ratio can help us figure out where the co-combustion ratio of a power plant can achieve net zero emissions. The answer to the right ratio can really help the government formulate targets for strengthening co-firing and controlling the process of achieving NZE in the electricity industry.

Efforts to focus on coal-biomass mixing as a form of business for NZE 2060, the challenges in meeting the supply of biomass must be faced by Indonesia. COAL POWER PLANT generates massive electricity. it requires a large amount of biomass. It must be considered how the fulfilment of biomass reserves can be done without releasing carbon. On the other hand, CCS technology innovation must be followed by various adaptations. technology for capturing carbon is still derating from the generator by 30-40% and reduces combustion efficiency so further research is needed to improve the technology [24]. Not all of the designed carbon storage is located around the power plant area, which causes more costs to manage it, especially transportation.

To achieve NZE 2060, we must not only focus on being an energy producer, but we need to consider supply chain sustainability. Big questions will arise if CCS is implemented to reduce environmental impacts, starting from the supply chain that still produces carbon, for example in the distribution process to storage areas, processing CO_2 storage waste, and adapting technology to power plants that are quite outdated. In addition, it must be remembered that the ash produced from combustion will be used as a raw material for the cement industry. So that the implementation of biomass co-firing will affect the quality of the ash produced [25]. And it is also necessary to pay attention to the distribution of biomass from the plantation to the power plant area.

E. Implementation of Biomass Co-firing PT. PJB to support Net Zero Emission Year 2060

COAL POWER PLANT Paiton is a Pioneer of Co-Firing Biomass in the STATE POWER GENERATION COMPANY Group, the First Test of Co-Firing using a Wood Pellet-based PC Boiler at the STATE POWER GENERATION COMPANY Group in September 2019. The first commercialization in the STATE POWER GENERATION COMPANY Group was carried out on June 10, 2020. This effort was made to inspire other coal-fired power plants. this has an impact in 6 months and then additions will be made in Pacitan, Suralaya, and Ketapang at the end of 2020. There are 3 types of COAL POWER PLANT Co-Firing namely PC, CFB, and Stoker. The sources of biomass used are Wood Pellets, Palm Shells, Tankos, Sawdust, Organic Pellets, Lamtoro Wood Woodchips, Sago Woodchips, Coconut Shells, Rabasan

Woodchips, Gamal Wood Chips, Rice Husk, and EFB Pellets.

In its implementation, PT PJB in this case COAL POWER PLANT Paiton East Java to support Net Zero Emission 2060 using the Co-firing method with Biomass fuel:

- Co-firing of biomass as a solution without CAPEX.
- Paiton Steam Power Plant Be the first to do Co-firing in the STATE POWER GENERATION COMPANY Group.
- Paiton Steam Power Plant Co-firing with 5% saw dust [21]

In general, there are five main stages in the implementation of biomass co-firing, namely: technology review of co-firing, fuel analysis, numerical modeling stages, burn test stages, and commercial operation stages. The implementation process at PT. PJB started in 2017, PT. PJB incorporates biomass co-firing into the company's strategic program and is stated in the RJPP and RK STEK. Then, PT. PJB together with the Japan Coal Energi Center and Mitsubishi Hitachi Power Systems, held intense discussions and sharing related to biomass co-firing technology in September 2018. After that, PT. PJB in collaboration with the Bogor Agricultural Institute, the Sepuluh November Institute of Technology, and the Agency for the Assessment and Application of Technology, conducted a numerical test up to the first burn test on three percentages of biomass mixture (1%, 3%, and 5%) and ended in December 2019. Until finally in March 2020, the President Director of STATE POWER GENERATION COMPANY ratified STATE POWER GENERATION COMPANY's President decree No. 1/2020 which oversees the co-firing program. And on June 10, 2020 COAL POWER PLANT Paiton 1 and 2 carried out the first commercial biomass co-firing operation at the STATE POWER GENERATION COMPANY Group. This makes Paiton a pioneer of biomass co-firing in Indonesia. Just six months after this commercial operation started, another unit started implementing biomass co-firing [21].

Overall, of the 52 STATE POWER GENERATION COMPANY power plants, 20 are under the auspices of PT. PJB. And of the 20 power plants, there are 19 that have carried out the burn test. And 12 of these plants have carried out commercial operations of biomass co-firing. With the increase in the number of power plants implementing co-firing technology, the GWh Green from biomass waste is increasing (Figure 10). From the 12 generators, 130.2 GWh Green were produced cumulatively from January to December 2021. With a monthly average of 18.9 GWh Green. To produce this electrical energy, a total of 18161 tons of biomass is needed per month [21].

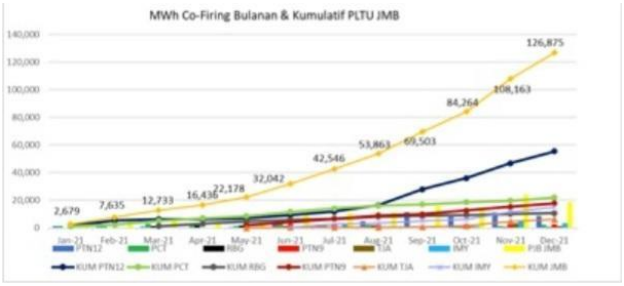

Fig. 10: MWh *Co-firing* COAL POWER PLANT [21]

F. SWOT Analysis

To measure the performance of PT.PJB in the field of co-firing, it is shown in the four aspects of Strengths, Weaknesses, Opportunities and Threats. In particular, internal factors consist of aspects of strengths and weaknesses, while external factors (not yet happened) consist of aspects of Opportunities and Threats. this can be seen in tables 11a and 11b.

Faktor Internal				
No.	Strengths	Bobot	Rating	Skor
1	Prioritas Pengembangan EBT (RUPTL PLN)	0.06	1	0.06
2	Ketersediaan Bahan Baku Biomassa yang melimpah	0.08	2	0.16
3	Mengurangi Penggunaan Batubara	0.11	4	0.44
4	Tidak Membutuhkan CAPEX (*Capital Expenditure*)	0.1	3	0.3
5	Mengurangi Emisi Carbon	0.15	5	0.75
	Jumlah Strengths	0.5		1.71
	Weaknesses			
1	Tingginya standar baku mutu briket biomassa	0.1	-4	-0.4
2	Dukungan Riset dan Prototyping EBT yang rendah	0.08	-3	-0.24
3	Menghasilkan Polutan NOx, CO, Sulfur, dll	0.13	-5	-0.65
4	Mempengaruhi kandungan *Ash* yang akan dimanfaatkan oleh pabrik semen	0.1	-4	-0.4
5	Belum Semua PLTU menerapkan co-firing	0.09	-3	-0.27
	Jumlah Weaknesses	0.5		-1.96
	Total IFAS	1		
	S - W			**-0.25**

(11a. Internal)

Faktor Ekternal				
No.	Opportunities	Bobot	Rating	Skor
1	Adaptasi Teknologi *Carbon Capture Storage (CCS)*	0.11	4	0.44
2	Peningkatan Kapasitas Pembangkit Listrik Biomassa	0.09	3	0.27
3	Teknologi Co-firing mendukung carbon netral	0.15	5	0.75
4	Peningkatan Perekonomian Masyarakat	0.07	1	0.07
5	Pemanfaatan kembali limbah sebagai bahan bakar	0.11	4	0.44
	Jumlah Opportunities	0.53		1.97
	Threats			
1	Harga Teknologi CCS Cukup Mahal	0.08	-2	-0.16
2	Target Net Zero Emission Tahun 2060	0.1	-3	-0.3
3	*Retirement* PLTU	0.13	-5	-0.65
4	Berpotensi Deforestasi Lingkungan	0.11	-4	-0.44
5	Efisiensi Pembangkit berkurang jika menerapkan CCS	0.08	-2	-0.16
	Jumlah Threats	0.5		-1.71
	Total EFAS	1.03		
	O - T			**0.26**

(11b. External)

Fig. 11a and11b: Overall SWOT Score Results

Figures 11a and 11b show the scoring results of each strategy formulated based on the results of the FGD and literature studies related to the development of Co-firing for PT. PJB. The results of internal factors can be seen by subtracting strengths from weaknesses resulting in -0.25, this means that the dominance of weaknesses is greater than strengths, so it is recommended to improve PT.PJB's co-firing weaknesses, especially the pollutants produced as a result of biomass burning have the potential to harm the worker. alone.

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External factors are measured based on the results of reducing opportunities against threats. the final score shows that opportunities dominate more than threats with a score of 0.26, therefore a strategy is needed to follow up on opportunities that will occur later, starting from the use of waste as biomass fuel, adaptation and acceleration of research on Carbon Capture Storage (CCS) technology so that co-firing technology will support NZE conditions and potentially achieve carbon neutrality. but it is necessary for PT.PJB to support replanting/reforestation of plants. Development of Biomass PLT with high technology to potentially overcome the energy base load gradually with a certain ratio so that steam power plants that produce high emissions on a regular basis can be reduced. The resulting meeting point is shown in Figure 12.

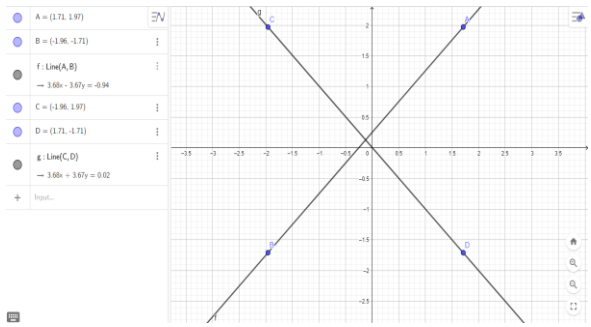

Fig. 12: Meeting point of the results of the SWOT Analysis

Based on Figure 12, it can be seen that the point of intersection is from the analysis of internal factors and external factors. point encounters occur in quadrant 3 (according to Figure 2). Therefore, the recommended strategy is to overcome weaknesses and follow up on opportunities. Therefore, the Recommendations for Overcoming Weaknesses Strategies to Pursue Opportunities (Opportunities of Progressive) are described as follows:

- There is a need for Research and Technology to follow up on potential pollutants such as NOx, CO, Sulfur, etc. that have the potential to harm workers.
- Acceleration of Technology Adaptation and Research related to Carbon Capture Storage (CCS) at PT. PJB and Equitable adaptation to all Co-firing Technologies in the majority of COAL POWER PLANTs on a regular basis.
- Development of research related to waste Biomass fuel, plenty of natural sources (high supply), and already meeting the SNI standard (5 Basic Measurement of Fuel)

Namely considering solutions from indicators of threats and weaknesses so that the stability of the SWOT analysis can be met at or meeting point (0.0). Quadrant IV shows the dominance of Weaknesses and Threats is the key to be overcome by PT. PJB in the future in contributing to Indonesia's NDC and facing Net Zero Emission Conditions in 2060.

IV. CONCLUSION

The development of Biomass-Coal Co-firing will play a major role in supporting Indonesia's National Determination Contribution (NDC) and Net Zero Emission Conditions, this is because coal fuel will be reduced by a certain ratio with biomass waste so as to get more points in reducing organic waste. For the use of co-firing domestically, PT PJB is a Pioneer or the first to conduct trials and commercial operations. However, it is necessary to consider adapting new technologies such as Carbon Capture Storage (CCS) so that the carbon from co-firing that is still produced (slightly) can be recovered. capture so that the system can generate Net Zero Carbon. Strengthening research related to high-quality biomass fuels by reducing the resulting pollutant so that the acceleration and distribution of power plants can be applied to COAL POWER PLANT in Indonesia which is cleaner. Harmful pollutants such as NOx, CO, Sulfur etc. can be reduced by research and high technology such as Circulating Fluidized Bed (CFB) boilers combined with CCS.

The role of PT PJB in the Covid-19 Pandemic Period also plays an important role in keeping the electricity supply safe so that health facilities can still operate normally, not only maintaining the electricity supply, PT PJB also keeps some of its employees able to work during the pandemic, by conducting mass vaccinations. to all its employees by providing some humanitarian assistance to the community around the PT PJB site during the Covid-19 pandemic. In its operation, the COAL POWER PLANT owned by PT PJB which is an Obvitnas or National Vital Object does not escape the strict guarding of the relevant agencies, the POLRI assisted by the TNI always maintain security for smooth operations at the COAL POWER PLANT owned by PT PJB.

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