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Indonesia's Biomass Cofiring Bet

Beware of the Implementation Risks

Executive Summary

Over the past year, Indonesia's energy policy teams have devoted new resources to a plan focused on efforts to extend the life of PT Perusahaan Listrik Negara's (PLN's) coal-fired power fleet by switching to biomass cofiring. The plan focuses on leveraging PLN's existing 18 gigawatts (GW) of coal-fired power plant capacity. The planners are betting that they can slowly increase biomass power generation by cofiring, a strategy that would potentially extend the life of older and under-utilized coal units while at the same time claiming credit for increasing the renewable energy mix.

PLN's cofiring roadmap proposes to migrate its 114 existing coal-fired power plants to cofiring by 2024. The plan includes 'feedstock increases' between 2021 and 2023. The cofiring plan, advanced by the Ministry of Energy and Mineral Resources (MEMR), will require nothing less than the creation of a large-scale biomass industry, to provide a stable cofiring fuel supplies anywhere between 4 to 9 million tonnes annually.

The cofiring plan will require nothing less than the creation of a large-scale biomass industry.

IEEFA's analysis shows that MEMR's analytical framework for biomass cofiring should be adjusted to reflect both the technical and economic variables associated with biomass cofiring. It is also crucial to acknowledge the many market barriers to developing sustainable biomass feedstock supply chain.

At the market level, the viability of this plan will rest on the following considerations:

- **Low ratio cofiring is a mature technology – yet its application globally remains small in comparison to other technology options. This raises the question of economic feasibility.** Cofiring has been utilized since the late 1990s in a number of countries. The primary barriers to acceptance have remained largely unchanged over the past twenty years. This includes the premium price of biomass, the ability to establish stable feedstock supply chains, and a range of technical challenges—all of which need to be addressed clearly by the developers, PLN and MEMR. It is not clear that this technology can scale efficiently in Indonesia's diverse geographies.

- **Policy interventions and incentives have been instrumental to the development of cofiring elsewhere. Does PLN have the resources to support this initiative?** Policy support such as Feed-in-Tariffs (FITs) and

Renewable Portfolio Standards (RPS) have been critical in the development of cofiring in other countries. Currently, no planned policy incentives have been introduced which raises the question of whether PLN will be able to deliver cofiring without encountering technical and financial barriers.

- **To understand the full costs of biomass cofiring, it is crucial to analyze the "total impact" of cofiring on PLN's operational and financial results**. Analysts know that cofiring cannot be evaluated just on the basis of fuel costs alone. Key stakeholders will need to evaluate the costs resulting from the way that cofiring will change the operational profile of coal-fired power plants, resulting in increased ash deposition, corrosion, and reduced fuel usage efficiency. Non-conventional wood biomass such as sawdust could offer a lower cost fuel, but feedstock options need to be anchored to a viable supply plan and a sound technical assessment. Proper examination of a waste-based refuse derived fuel (RDF) specification is even more critical given its potentially challenging properties for cofiring. Technical implications of using lower grade biomass should be fully considered to ensure that the performance of PLN's coal-fired power plants is not 'sacrificed' in the process.

- **Biomass cost should always be disclosed in an energy-adjusted way.** The unit cost of biomass—IDR/USD per kg—comparison versus coal should be normalized to permit energy equivalent comparisons. It is clear that most of the biomass candidates have lower energy values and that operating in cofiring mode could degrade the performance of the coal-fired power plant units. PLN's company policy has already incorporated this factor and public disclosure of cofiring plans should be delivered coherently with similar clarity.

- **The recent growth in Indonesia's wood-based biomass industry is a result of increased international demand for biomass based on premium pricing. Whether a market would develop to respond to the low-cost biomass demanded by PLN remains an open question.** Traditional wood-based biomass such as wood pellets and Palm Kernel Shells (PKS) are likely 'priced out' with the intent to acquire biomass at a price lower than coal**.** Non-conventional biomass such as sawdust could be an option, but its viability and transportability will need to be critically examined with wood-based biomass largely confined to Sumatra and Kalimantan, where only 18% of PLN's coal-fired power plants reside.

- **Flexible cofiring reduces operational risks but raises market risks due to the potential of feedstock supply problems.** The fuel flexibility offered by cofiring (the ability to switch back to coal) relieves PLN from biomass supply reliance—something that has dragged down many biomass power generation projects. Such flexibility, however, can discourage potential investors looking for a secure market opportunity. Long-term purchase contracts would likely be needed to help build a critical mass for the biomass industry. At the same time, if long-term contracts are required, it could result in the same type of "lock-in" risk that PLN already faces with coal and gas suppliers.

- **PLN's aggressive pursuit of cofiring should take into account the lessons learned from other countries.** Currently PLN has outlined an aggressive plan to meet its cofiring targets by 2024. China and the U.S. have taken measured and prudent steps in adopting cofiring, despite their enormous biomass potential, large coal-fired power plant fleets, and strong power plant technological base. Comparison to biomass applications in other countries -such as UK- should also be treated with care. In 2019, policy-based support toward UK's largest biomass power plant amounted to more than £700m. PLN and MEMR would benefit from studying lessons from other countries to ensure the viability of a cofiring program. The key problems have been financial risks due to poor fuel economics and operational constraints resulting from the challenging properties of biomass. The predominance of pulverized coal (PC) boilers in PLN's coal fleet should also be evaluated as PC boilers have a narrower range of tolerance for fuel properties.

- **Presenting a clear cofiring roadmap that addresses the market challenges will be crucial to gain trust from both public and private sector investors. Constructing a targeted priority plan would likely be more beneficial than casting a nation-wide net.** Putting forward pilot cases which are heavily funded by grants and CSR funding also does not build confidence about the ability of cofiring to attract major investments. Transparency of the viable supply cost (which can be scaled up) is necessary, along with clarity of the demand centre, and demand forecasts. Establishment of a biomass specification standard has been suggested and is essential for establishing a viable biomass feedstock market.

Given the inflexibility of Indonesia's generation mix, it is not surprising that cofiring could be viewed as one of the few technically feasible strategies for increasing bioenergy use. The challenge lies in its economic feasibility. The claim that biomass could be obtained at a price lower than coal is a commendable ambition, but it has generally not been possible in other countries which implement cofiring based on careful selection of biomass.

The challenge lies in its economic feasibility.

Optimal coal-fired power plant operation is dependent upon the utilization of higher-grade wood chips, pellets and (to a certain extent) palm kernel shells. IEEFA's evaluation of both existing wood biomass and RDF pilot projects suggest substantial hurdles remain and that a clear roadmap which identifies how these challenges will be addressed may be needed to address viability. Launching a large-scale national program without addressing regional feedstock supply problems does not provide clarity for the road ahead.

Would cofiring be possible? Perhaps, but stakeholders should remain critical about the realistic scale at which it can be achieved in comparison to the bold targets proposed by MEMR. Reaching the scale required by the plan warrants a large industrial-scale investment to ensure stable long term supply, as well as overcoming other outlined constraints. Furthermore, the projected rise of Independent Power Producers (IPP) and the decline of PLN power generation share in the coming decade would also need to be considered in evaluating the full impact.

IEEFA believes that a focused effort to prioritize particular regions could be more viable than chasing the dream of an ambitious nation-wide deployment plan. A targeted deployment plan focused on demonstrating commercial viability and PLN's willingness to support long-term purchase agreements would send a stronger positive signal to attract major investments for the biomass industry. Indonesia has the potential to become a powerhouse for the biomass industry, and the cofiring ambition could be a starting point to spark its development. Such ambition, however, could only be established with sound planning and the transparency needed to support a stable long-term market.

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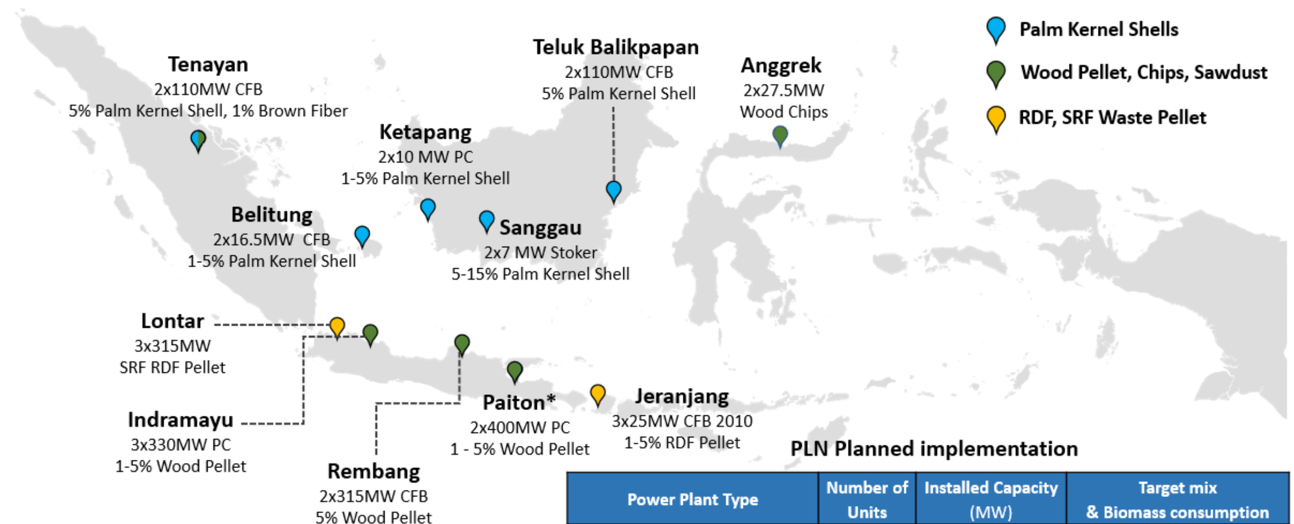
Background

In early 2020, the MEMR and PLN announced plans to implement cofiring in Indonesia’s coal-fired power plants (CFPP) by blending solid biomass as fuel along with coal. With the aim to increase the renewable energy mix, the ability to capitalize on PLN’s existing CFPP capacity was deemed an attractive opportunity for Indonesia with its 31GW of CFPP in operation, comprising 50.3% of the country’s installed power generation capacity.[1] The country’s total bioenergy generation capacity has stagnated below the 1.9GW mark, largely comprised by captive power generation with less than 11% connected to the grid.[2]

The pivot towards biomass does not come without viability risk, however. Power generation involving the biomass sector has had a long trail of challenges, both in economics and in securing feedstock supply, warranting a careful examination of how the cofiring initiative can be fully realized. PLN is spearheading the program with the grand ambition of using biomass cofiring across its 144 CFPPs, a goal which essentially requires the creation of a large-scale biomass industry across the country.

Figure 1: Cofiring Initial Trial Runs



PLN Planned implementation

Power Plant Type	Number of Units	Installed Capacity (MW)	Target mix & Biomass consumption
Pulverized Coal	45	15,490	5% biomass, 10,375 t/day
Circulating Fluidized Bed (CFB)	39	2,435	5% biomass, 2,175 t/day
Stoker	30	229	30% biomass, 1,684 t/day
	114	**18,154**	

Trial runs by August 2020 with further trials planned

*) Paiton 1 & 2 has performed continuous cofiring since June 2020 Consuming 3,800 tonne in 103 days (avg 37 t/day)

Source: MEMR, PLN. MEMR Presentation on biomass. Figures presented only include PLN CFPPs.

As a country with a sizeable agricultural and forestry industry, the utilization of residues in cofiring could help add economic value while municipal waste usage

[1] PLN. PLN Coal Forecast presented at APBI-ICMA event. 2020.
[2] Ministry of Energy and Mineral Resources. Renewable Energy and Biomass presentation. June 2020.

could alleviate the growing waste management challenge in urban areas. For clarity, the use of waste as an energy source in Indonesia is sometimes addressed as 'biomass resource' although the technical definition depends on the composition of the waste, which can vary from organic material to non-organics such as plastics.[3]

To create momentum for the program, PLN announced in September 2020 that it had successfully completed a number of cofiring runs in several of its subsidiary power plants under PT Pembangkitan Jawa Bali (PJB) and PT Indonesia Power (IP). Depending on local sources, palm kernel shell, RDF waste pellets, wood pellets, wood chips and sawdust of varying ratios had been utilized in the trials.

Indonesia's biomass plans were confirmed earlier in the year when the Indonesian National Energy Plan (RUEN) projected a prominent role for bioenergy in the power sector. RUEN outlined a target of 5.5GW by 2025 while the 2019-2028 Electricity Supply Business Plan (RUPTL) outlined a lower target of 2.6GW.[4] With a current bioenergy capacity of 1.9GW, cofiring presents a potential avenue to close the realization gap.[5] The plan rests on MEMR and PLN's target of 900MW of a bioenergy mix to be achieved through 5% cofiring across all of PLN's CFPPs. This plan acknowledges the fact that private IPPs would be excluded from any biomass cofiring plan. This reflects the fact that contractual PPA terms with existing take-or-pay fuel supply contracts would not support an ad hoc shift to new fuels or amended operating conditions.

Based on our analysis of the biomass cofiring plan and the experience of other countries that have pursued biomass energy, we believe that policymakers and market players should focus on the following program fundamentals to assess viability.

Low-Ratio Cofiring Is a Mature Technology – Its Application Has Largely Been a Question of Economics

What Is It?

Cofiring involves the combustion of solid biomass which could be obtained from forestry or wood industry residues, agricultural residues, municipal solid wastes, and dedicated energy crops. Cofiring offers the benefits of lower capital costs, improved economies of scale, and the higher efficiency of large CFPP compared to smaller pure-biomass power plants which lack scale.

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[3] Waste in Indonesian urban settings (Jakarta) have been estimated to be comprised of 17% plastic composition. Clinton Foundation study, cited in Solusi Bangun Indonesia RDF presentation. November 2019.
[4] Ministry of Energy and Mineral Resources. Renewable Energy and Biomass presentation. June 2020.
[5] Ministry of Energy and Mineral Resources. MEMR presentation on national renewable energy policy. December 2019.

For PLN, the capital investment cost will be reduced by using existing CFPP. However, new investment will be required if the units need to be retrofitted depending on the type of biomass and cofiring ratio planned. Given the vast variety of biomass feedstock properties which can differ widely compared to coal properties, proper evaluation of biomass fuel is essential. Stable feedstock supply, high cost of biomass, and technical challenges such as ash deposition and accelerated boiler corrosion are common problems that can degrade facilities and would need to be addressed upfront to ensure a successful and sustainable cofiring program.

Why Do It?

The key driver behind cofiring adoption in many countries has been the aim to reduce greenhouse gas (GHG) emissions by replacing coal use with biomass. Traditional pollutants such as SOx and NOx also decrease with the different properties and lower sulphur content of most biomass fuels.[6]

Not all biomass fuels are created equal, however, and the extent of the environmental benefit is highly sensitive to the biomass feedstock origin and the supply chain process involved. With the growth in global biomass consumption, increasing public attention has been drawn on biomass feedstock sustainability, especially with subsidies having to be provided to many biomass power projects.

The aggressive ambition to increase biomass contribution to meet RUEN and Indonesia's NDC of 29% GHG emission reduction by 2030 is commendable[7], but the viability of the plan warrants a careful examination. The current plan outlined by PLN and the government suggests that a sizeable portion of the biomass would be sourced from existing forestry/agriculture residues and municipal

The Question of Environmental and Social Impact

Not all sources of biomass are created equal. The challenges in maintaining a balance between environmental preservation and producing biomass feedstock is a consistent challenge globally, and attention should be paid to the specifics of the feedstock origin and the supply chain.

The use of residual wood materials and replanting products should -in theory- help minimize deforestation from clearing activities for new plantations. The establishment of new crops could -when unmanaged- pose environmental and social sustainability risks, particularly in the absence of clear product traceability and strict monitoring in remote regions.

Lessons of sustainability criteria could be taken from existing guidelines implemented by a number of countries, whether through mandatory or voluntary schemes, such as the Sustainable Biomass Program. Lessons could also be taken from local implementation challenges related to sustainability standards in key industries such as the oil palm sector. Each approach may be imperfect for the Indonesian context but could nonetheless provide a good starting point.

Furthermore, biomass importing countries such as Japan have also slowly started to expand their focus on more stringent standards, an initiative which could also pose long-term market risk to Indonesia's biomass exports.

Ultimately, development of the biomass sector comes with its inherent benefits and trade-offs. Each type of biomass warrants a close examination by the government, PLN and investors. Usage of questionable biomass feedstocks could raise the fundamental question about the 'green' credentials of cofiring. The country would be well-served by considering the sustainability subject head-on from the start to avoid irreversible damages if and when the biomass industry started to grow.

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[6] IEA Bioenergy. Global operational status on cofiring biomass. 2013.

[7] Government of Indonesia. Nationally Determined Contribution, Republic of Indonesia. November 2016.

solid waste (MSW) materials, which could arguably still be generated in the absence of a cofiring plan. This could mitigate associated environmental and land conversion risks. In addition, there could be questions to address regarding whether biomass cofiring could increase net emissions if it were to have the effect of extending the life of CFPP due for retirement.

A Mature Technology

Cofiring at a low ratio has long been considered a mature technology[8] and its adoption has primarily been a question of economics and feedstock availability, rather than a question of technology. It was adopted primarily in Europe in the late 1990s and early 2000s in accord with increased attention on low carbon energy.[9] Policy interventions and incentives have been required to support cofiring and not all countries decided to pursue the route given the challenging economics and certain technical complexities it can entail. Both the U.S. and China have not developed sizeable cofiring operations despite their enormous biomass potential, large CFPP fleets, and strong power plant technological bases.

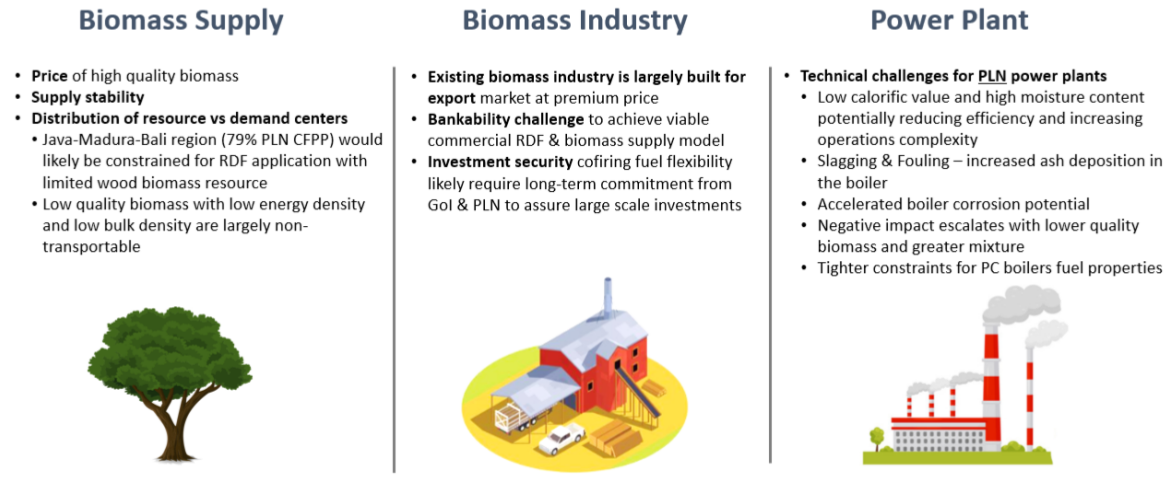
With the growth of other renewable energy options, cofiring has seen a decline in certain European countries with policy incentives being redirected toward other renewable energy technologies, which become increasingly more competitive. Cofiring has, however, gained traction in some Asian countries, such as Japan and South Korea, assisted by policy support to reach their respective energy mix targets, as we will examine in a later section.

Cofiring in the Indonesian Context

Indonesia's current plan suggests the use of direct cofiring which involves combustion of the biomass within the same boiler as the coal. It is the most common and least costly cofiring method and is likely a suitable option for the intended goals of low-cost and low ratio cofiring. Other methods, such as indirect cofiring, involve gasification of the biomass. This is more costly but can be the preferred option in situations where a greater control of the biomass is required.

[8] International Renewable Energy Agency. Biomass for Power Generation. June 2012.
[9] North American cases have largely been limited to demonstration tests.

Figure 2: Principal Cofiring Challenges



Source: IEEFA.

Investment Costs

While cofiring at a higher ratio of more than 50% (on an energy basis) is technically feasible, cofiring operations are more commonly performed below the 5% ratio on a continued basis.[10] Cofiring implementation entails potential costs that are inherently site-specific. The amount of capital investment required is dependent on the type and ratio of biomass, the planned cofiring method, and specific CFPP conditions. Modifications to fuel handling and storage systems are potentially required given the different properties of biomass, although larger modifications of a power plant may not be required when the cofiring ratio is limited to a low level. Different biomass properties such as particle sizing, storage requirements, chemical properties, and calorific content all need to be considered when evaluating cofiring implementation.

The International Renewable Energy Agency (IRENA) has suggested that the Operations & Maintenance (O&M) cost for cofiring is likely comparable to the CFPP operation, but actual costs will inevitably be influenced by the quality and the ratio of the biomass.[10]

PLN has reported that cofiring has occurred at its Paiton 2x400MW CFPP with the existing coal boiler, that is, without significant modification.[11] Nevertheless, a policy document related to PLN’s cofiring policy -Peraturan Direksi PT PLN No.001/P/DIR/2020- appears to suggest that an 0.85 ‘infrastructure addition/modification factor’ could be applied to the biomass purchase price.[12] This correction factor shows that PLN acknowledges the increased complexity of cofiring

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[10] International Renewable Energy Agency. Biomass Co-firing Technology Brief. January 2013. Implementation in Japan in 2020 still shows similar trend of low cofiring ratio at around 3% biomass. IEA Clean Coal Center. Bringing Cofiring Biomass With Coal to Japan. March 2020.
[11] Kontan. PT PJB accelerates renewable energy through biomass cofiring. June 11, 2020.
[12] Ministry of Energy and Mineral Resources. Policy and Strategy of Biomass Development. April 2020.

caused by (amongst others) the lower bulk density, higher moisture, and greater water-affinity properties of biomass. The PLN cofiring policy further emphasizes its aim to procure biomass at a price lower than coal, a commendable ambition which we will evaluate in further detail.

Figure 3: Biomass Price Calculations

Maximum Biomass Price = Avg Coal price x Fk x Fc

Maximum Biomass Reference Price (HPT) : The maximum price of biomass specific for each CFPP

Avg. coal price : 3 month average coal price, CIF term, inclusive of transportation cost

Fk : **A factor of 0.85**. Correction factor to accommodate additional/modification of infrastructure for biomass utilization

Fc : Calorific Value correction factor, to normalize the different calorific content between biomass and coal

Fc = CV Biomass (as received) / CV coal avg (as received)

Source: PLN, MEMR[12]

Biomass Selection and Pre-treatments

Biomass feedstock quality can vary greatly, and proper selection of biomass fuel is essential. In addition to influencing CFPP modification requirements, different pre-treatment processes may be required to ensure suitability for cofiring. Pre-treatment processes typically involve drying, densification, and pelletization of the raw biomass to improve the fuel properties.

The following considerations should be taken into account when incorporating biomass:

- **Lower energy density,** with higher moisture content and lower Calorific Value (CV, energy content per mass unit typically stated in kcal/kg) biomass cofiring could potentially affect power plant operations and efficiency to generate the same amount of electricity. The greater amount of fuel would increase the burden on CFPP fuel handling systems.

- **Lower transportability**. Biomass predominantly has lower bulk energy density, requiring greater volume to be transported and increasing transportation costs. This is further compounded by the water-affinity of biomass posing further challenges for long-haul transport.

- **Physical and chemical properties suitability for CFPP**. The impact of biomass on CFPP operations should be scrutinized in detail, including requirements for boiler operations such as physical and chemical properties, as well as specific handling and storage requirements. Different types of boilers would also influence the selection given the different fuel tolerances.

Table 1 below outlines the different types of typical biomass fuels with reference to the different Calorific Values and representative prices. Greater detail on the specific Indonesian cofiring plan is outlined in later sections.

Table 1: Comparison of Predominant Biomass Fuels

Fuel type		Typical Calorific Value kcal/kg NCV	Typical Price Range *Not Normalized for CV*	Remarks
Wood Pellet		3,940 - 4,400	**IDR 1,040 to 2,000/kg at NCV > 3,940 kcal/kg** Vietnam FOB price index (Jul 2017-Sep 2019) **IDR 1,300+ /kg at NCV > 4,100 kcal/kg** Domestic market prices estimates	• Existing production is largely destined for export market with premium price • High production cost, majority of potential supplies are located outside of Java-Madura-Bali region (Jamali) • Properties could vary depending on the feedstock
Palm Kernel Shell		3,500 – 4,200	**IDR 825 to 960/kg at NCV > 3,500 kcal/kg** Indonesia FOB price index (Jul 2017-Sep 2019) excluding export tax package	• Existing production is largely destined for export market with premium price. PKS is a key biomass export with 1.72 miTonne exported in 2019 • Pulverized coal boiler which constitutes 85% of PLN CFPP capacity is largely unsuitable for PKS
Refuse Derived Fuel (RDF)	 	2,600 – 3,400	No clear price reference, below based on *reported* price from PLN and producers **IDR 300–550/kg at est NCV < 3,200 kcal/kg** Community-scale development with CSR funded capital. Note NCV varies with composition and pre-treatment **IDR 300/kg at 3,000-3,200 kcal/kg NCV** Industrial scale development with support funding from external grants	• No viable *commercial* model has been developed, existing community scale development are producing at very low capacity < 1 tonne/day • With limited potential of other biomasses in Jamali, cofiring in the region (with 76% of PLN CFPP capacity) will likely be constrained more toward RDF • Greater technical challenges, varying composition with potential contamination, higher ash content
Sawdust		±2,450	No clear price reference, below based on *reported* price from PLN **IDR 350/kg at NCV ±2,450 kcal/kg**	• Lower cost but largely unsuitable for long haul transport due to low energy density and bulk density, and more prone to weather exposure • ±140 kg/m³ Bulk density compared to coal (900), Wood pellet (780), PKS (590) (PJB Cofiring Study 2020) • Availability will competed with other existing uses, including as raw material for wood pellet production • Homogeneity of source material also need to be examined to ensure consistency
Coal		3,500 – 4,900	**IDR 766-782 /kg Average** PLN Avg coal price 2016-19 2020 PLN RKAP budget forecast of IDR 815/kg. PLN coal consumption is dominated by 4,400-5,200 kcal/kg GAR (47%) and 3,800-4,400 kcal/kg GAR (36%)	

Source: IEEFA market evaluation, compiled from various sources. Index prices from Argus 2019. Avg coal price from PLN Statistics 2019. Reader should be cautioned when comparing biomasses as properties could vary significantly even within similar category. Coal is commonly specified in Gross As-Received Basis (GAR) basis while biomass may be specified in the lower Net Calorific Value (NCV) basis.

The goal of proper selection and correct pre-treatment is to ensure that the use of biomass does not compromise CFPP operations. Advanced pre-treatment methods such as torrefaction (which involves thermochemical process to improve biomass properties) are available, but are costly and likely unsuitable for the current Indonesian context.

Given the vast variety of biomass materials potentially involved in PLN cofiring across the country, a clear biomass specification standard is essential for both PLN and potential biomass industry investors. The physical and chemical properties of the biomass is strongly correlated with the success of cofiring, particularly those involving RDF derived from a variety of waste materials. Biomass standards such as ISO 17225-1 and EN15359 have helped provide a general corridor for fuel specifications which is essential to ensure optimum CFPP performance and supporting industry establishment. Such standards can also help evaluate the potential environmental impact of biomass use. It has been suggested that a plan for the establishment of a domestic biomass standard is in progress involving the Indonesian National Standard (SNI).[13]

A clear biomass specification standard is essential for both PLN and potential biomass industry investors.

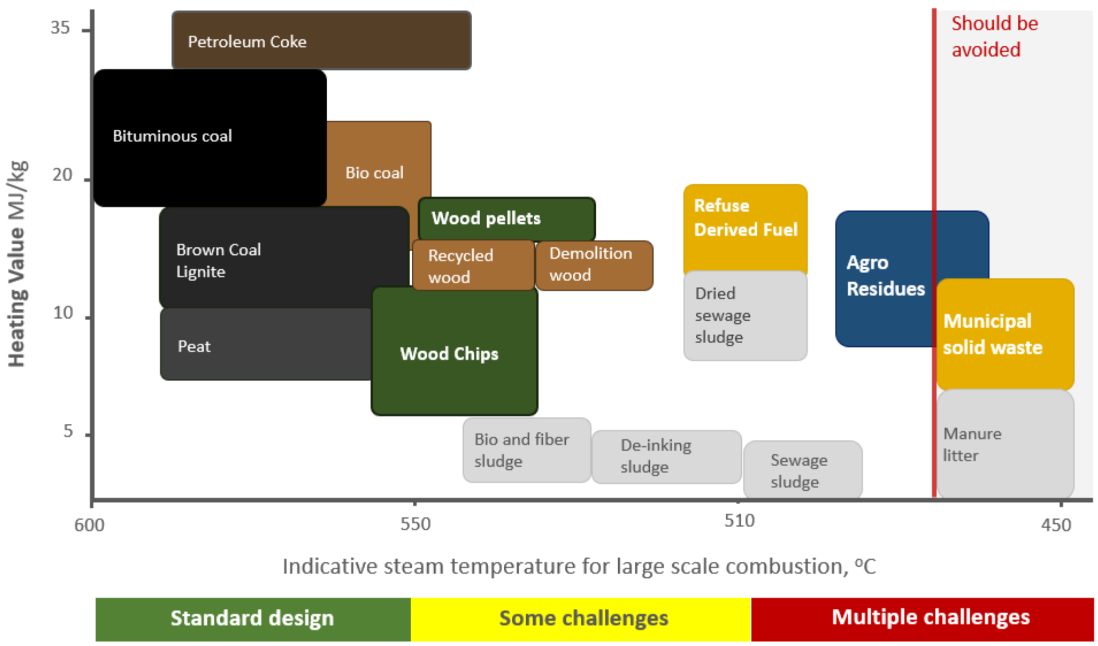
Technical Challenges

CFPPs are essentially designed to burn a specific type of fuel, i.e. coal, and expanding its use to accommodate a wider array of biomass fuel properties would require comprehensive evaluation. Among the challenges of cofiring is the higher potassium or chlorine contained in some biomass which can lead to accelerated corrosion in boiler components.[14] This effect is particularly notable in the use of straw-based agricultural residues. Furthermore, cofiring is likely to induce increased slagging and fouling (the deposition of ash within the CFPP boiler) which would reduce the boiler efficiency and can negatively impact CFPP performance.[15] The extent of these challenges is a function of the amount and the type of biomass utilized. Figure 4 outlines the different types of biomass and the different level of challenges they could pose to the CFPP operation. In addition to these challenges, technical support from the OEM (Original Equipment Manufacturer) of CFPP components is also a concern which should be sufficiently addressed.

[13] Ministry of Energy and Mineral Resources. Cofiring focused group discussion. October 2020.
[14] International Renewable Energy Agency. Biomass Co-firing Technology Brief. January 2013. IEA Bioenergy. Global Operational Status on Cofiring. 2013.
[15] IEA Clean Coal Centre. Slagging and Fouling in Coal-fired Boilers. July 2009.

We should note that 85% of PLN CFPP capacity is comprised of pulverized coal (PC) boilers that have a narrower tolerance for the fuel's physical properties which needs to be more readily pulverized, such as wood pellets.[16] With the tighter restriction in fuel properties, the predominance of PC boilers essentially limits the available fuel options. Palm kernel shell for example, despite being Indonesia's key biomass export, is likely unsuitable for PC boilers and is more suitable toward CFB boilers operation. This limitation is also evident in the ongoing cofiring trials, with PKS use largely limited to CFB boilers. Pre-treatment of the biomass to adapt to PC boiler specification could be possible, but with a considerable increase in cost.

Figure 4: Biomass Fuels Comparison



Source: van Niekerk, 2017, presented at joint IEA CCC/EPPEI workshop.

The use of RDF waste pellets poses further challenges as their composition relies on the waste input and can vary over time. RDF is produced from various wastes such as municipal solid waste (MSW). Raw waste is essentially unusable for combustion, separation, shredding, and drying, and the densification process is required to improve RDF properties. RDF typically has greater ash content compared to coal which increases the ash-handling challenge. Furthermore, the presence of substantial inorganic components could induce particle agglomeration within CFB boilers.[17] These technical challenges associated with different types of biomass fuel mean that stakeholders should focus on the 'total impact' costs of cofiring and not just the tonnage costs of biomass fuel.

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[16] Ministry of Energy and Mineral Resources. Cofiring focused group discussion. October 2020. Futuremetrics. Biomass Power Options for Power Generation. May 2017.
[17] Ministry of Energy and Mineral Resources. Cofiring focused group discussion. October 2020.

Policy Incentives Have Been Instrumental in Cofiring Development Elsewhere

Can PLN's Model Succeed Without Incentives?

The use of biomass for power generation across the world has traditionally required strong government support through policy interventions such as FIT or RPS requirements, and cofiring is no exception.

Table 2: FIT vs RPS

	Mechanism	Pricing and Challenges
Feed-in Tariffs (FiT)	A price-based scheme, providing a guaranteed price for eligible renewable energy producers.	Pricing determined by government. Insulate investors from revenue risks. Heavy burden on government and discourages continual cost reduction.
Renewable Portfolio Standard (RPS)	A quantity-based scheme that requires a specific proportion of electricity to be generated through RE sources. Such electricity could be generated by the utility companies, purchased from other parties, or met through the purchase of Renewable Energy Credits (REC).	Market pricing, based on Renewable Energy Credits, a tradeable instrument issued for RE power generation. Less burden on government, higher price volatility and monitoring efforts.

Historically, the development of biomass power generation in Indonesia has largely been focused on remote locations relying on diesel power generation or remote industries with rich biomass resources such as palm plantations and the pulp and paper industry. While biomass power could be viable when alternative fuels are more costly, it has been largely inconceivable to compare biomass against the economics of coal.

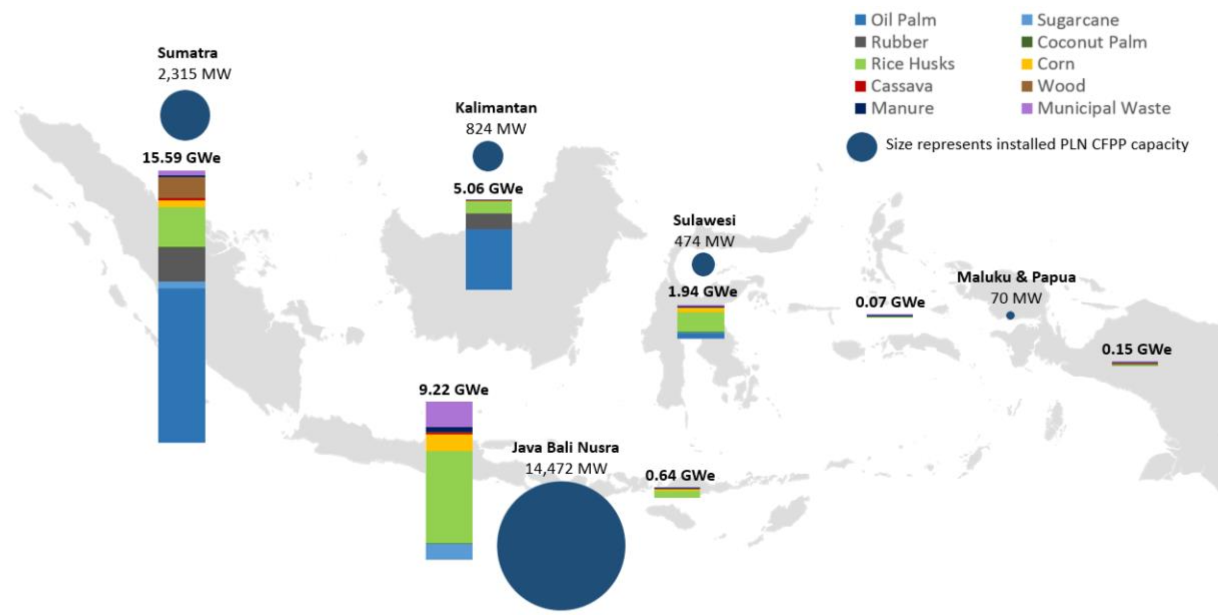
Traditional biomass fuel such as wood pellets (WP) and PKS regularly command premium prices of $70 to more than $120/tonne (Free On Board) in the Asian market. In contrast, the lower-rank coals, which are more predominant in the Indonesian domestic power market, have been hovering well below $70/tonne – a price that has been kept artificially low through government regulation. The price premium commanded by biomass is primarily associated with the cost of collecting, processing, and transporting the biomass, although the raw feedstock material may have relatively low economic value.

The lower energy density of biomass commonly translates to higher transportation costs and constrains biomass usage for power generation within the vicinity of the resources, typically within a 30-50 km boundary of the power plant.[18] Both the

[18] World Bank typically defines 50 km sourcing distance as a general limit.
The World Bank. Biomass Resource Mapping in Vietnam. December 2017. Page 31.
The World Bank. Biomass Reosurce Mapping in Pakistan. July 2016. Page 37.

energy density in terms of weight, and the bulk (volumetric) density matters for transport considerations. Buyers residing in countries with strong biomass policy incentives, nevertheless, would still be willing to pay premium prices to ship biomass fuel from overseas. **With this in mind, the biomass market should therefore be understood both as a local and a global commodity, depending on the context.** PLN's policies appear to suggest its aim is to acquire biomass at a lower price than coal, even after normalizing for the lower Calorific Value (CV) of biomass. Such an objective would likely be necessary for PLN as the government has not disclosed any plans for incentives to support cofiring initiatives while PLN is required to keep its electricity production costs (BPP) under control. This is in contrast to cofiring in other countries which are heavily reliant on policy incentives.

Figure 5: Biomass Potential (GWe) and PLN Installed CFPP Capacity (MW)



Source: MEMR[2] and PLN[1] ***Error! Bookmark not defined.***

One of those countries is Japan, where there was a remarkable increase in biomass consumption with the introduction of generous Feed-in-Tariffs in 2012. It is estimated that more than half of the existing CFPP was operating with cofiring in 2020, with additional plans underway.[19] While a sizeable portion of the biomass supply for power generation is sourced domestically, biomass imports have also risen significantly with a notable increase in palm kernel shell and wood pellets.[20] With a coal energy mix ratio of 31% in 2018, the development of cofiring in Japan is considered a short-to-medium term solution to meet its renewable energy share target of 22-24 % by 2030.[21] Most of the power plants that perform cofiring have been doing so at a low ratio below 3%, with only a few smaller units implementing

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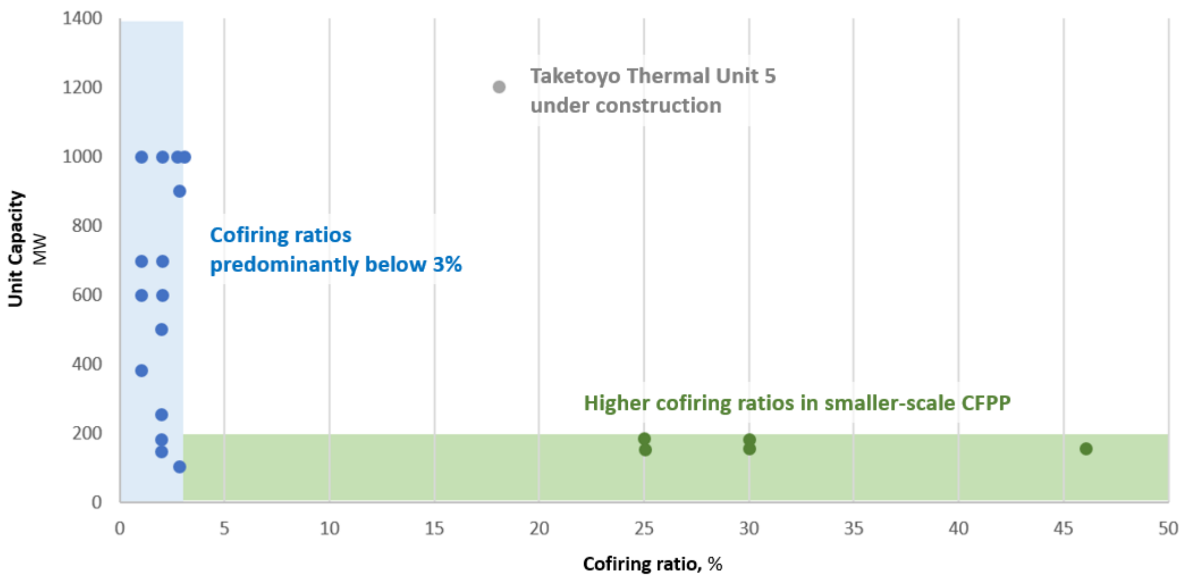
[19] FutureMetrics. Japan Biomass Outlook. June 2020.
[20] Japan Renewable Energy Institute. Solid Biomass Consumption. August 2020.
[21] Japan Ministry of Economy, Trade and Industry. Japan's Energy 2019. 2020. Page 9.

higher ratios.[22] It is important to point out that the economics of cofiring are different in countries like Japan which need to import coal. The premium coal price in Japan would also increase tolerance for a higher biomass price. Japan started with the RPS scheme to support biomass use and switched to FIT in 2012. **With a number of cofiring FITs expiring in 2019,[23] cofiring implementation in Japan has also been supported by the mandatory requirement of CFPP to meet 44.3% average thermal power generation efficiency level by 2030.**[24] Power plants which could not meet the higher efficiency requirement seek the benefit of cofiring to help meet the standard, as the government allows biomass input to be deducted from the fuel input, which consequently helps to increase the calculated efficiency.

Figure 6: Low Cofiring Ratio in Japan



Source: IEA Clean Coal Centre, Current technologies for cofiring biomass with coal [22]

China – A Biomass Powerhouse Treading Slowly in Cofiring

While China holds a sizeable pure-biomass power generation capacity, it has moved at a much slower pace in adopting cofiring. With a biomass installed capacity of 17.8 GW connected to the grid in 2018[25], China's biomass is primarily sourced from agriculture and forestry industries, followed by municipal waste. In 2018, a cofiring pilot project was initiated by the National Energy Administration (NEA). From the initial plans of 58 projects planned for agriculture/forestry residue cofiring only two

[22] IEA Clean Coal Centre. Current Technologies for Cofiring Biomass With Coal. March 2020.
[23] IEA Clean Coal Center. Bringing Cofiring Biomass With Coal to Japan. March 2020.
[24] Japan Ministry of Economy, Trade and Industry. Japan Strategic Energy Plan. July 2018
[25] Energy Reform Institute, China Renewable Energy Centre, Children's Investment Fund Foundation. China Renewable Energy Outlook. 2019.

are in operation with the remainder suspended, largely due to lack of policy support such as fixed feedstock price.[26] The preference to use indirect cofiring in China—comprising 55 out of the 58 projects—is likely due to the better mixture monitoring capability, allowing more transparent monitoring of biomass quantity by the government.[27] Indirect cofiring also allows greater control of the biomass mixture, a crucial point considering the use of agricultural residues such as straw with higher chlorine or alkali content known for their negative effects on the boiler.[28] There have been mixed results of cofiring both in terms of financial and operational performance. China Electric Power Planning and Engineering Institute reported multiple financial challenges faced by a number of cofiring projects.[29] In June 2018, China's Ministry of Finance and NEA published a list of renewable energy subsidies which excluded cofiring[27]. It is interesting to note that despite China's enormous agricultural base, large CFPP fleet, and strong power plant technological base, cofiring in China is largely still in the 'exploratory stage'.[30] As commonly encountered in other cofiring applications, poor fuel economy, unstable biomass supply, and potential adverse effects on the CFPP operations all suggest the limited viability of cofiring on a large scale and on a continuous basis.

The cases in these countries have clearly outlined that the viability of cofiring in many countries hinges on the incentives provided through government policies and the alternatives for achieving de-carbonization targets. In China's case, there is a large renewable fleet and the development of the new high voltage network will ensure that renewables will play a larger role in the generation mix in the future. This leaves little room for high-cost biomass strategies.

The viability of cofiring in many countries hinges on the incentives provided through government policies and the alternatives for achieving de-carbonization targets.

A comparison with these countries is also deemed more applicable given their sizeable and stable CFPP fleet compared to European countries, which are currently decreasing their coal energy mix. Comparison of biomass use to countries such as UK should also be treated with care, as in 2019, policy-based support toward UK's largest full-

[26] IEA Clean Coal Center. Bringing Cofiring Biomass With Coal to Japan. March 2020.
[27] IEA Clean Coal Centre. Support Mechanisms for Cofiring Biomass. January 2019. Transparent biomass quantity monitoring is important to ensure government incentives for cofiring utilization is not abused.
[28] IEA Clean Coal Centre. Current Technologies for Cofiring Biomass With Coal. March 2020.
[29] Canadian Biomass. WPAC report: Key takeaways from the IEACCC's biomass co-firing workshop. May 15, 2020.
[30] Yan Xu et.al. Coal-Biomass Co-firing Power Generation Technology: Current Status, Challenges and Policy Implications. May 2020.

biomass power plant amounted to more than £700m[31]. Cofiring in UK has declined substantially with policy support shifting toward full-biomass -albeit still at substantial costs- and with support which will likely wane in the coming years. Currently, Indonesia's cofiring plan does not include specific policy interventions. It remains to be seen whether PLN could conjure up a new cofiring and biomass feedstock model to implement cofiring at a low cost.

It is worth noting that large biomass potential does not necessarily translate into the economical use of biomass in power generation. Cofiring has not developed well in the United States, despite the country being the world's largest wood pellet exporter.[32] Even considering the low natural gas price in the U.S., coal still comprises 23.5% of the U.S. power generation mix[33] and serves as a further reminder of the policy-reliant nature of cofiring application. Successful development of the biomass feedstock industry in other countries relied on price premiums supported by regional and global market trends, largely in response to country-specific policy support. Attracting industrial biomass investments at the low selling price PLN is likely to require would certainly cast doubts which need to be clearly addressed upfront.

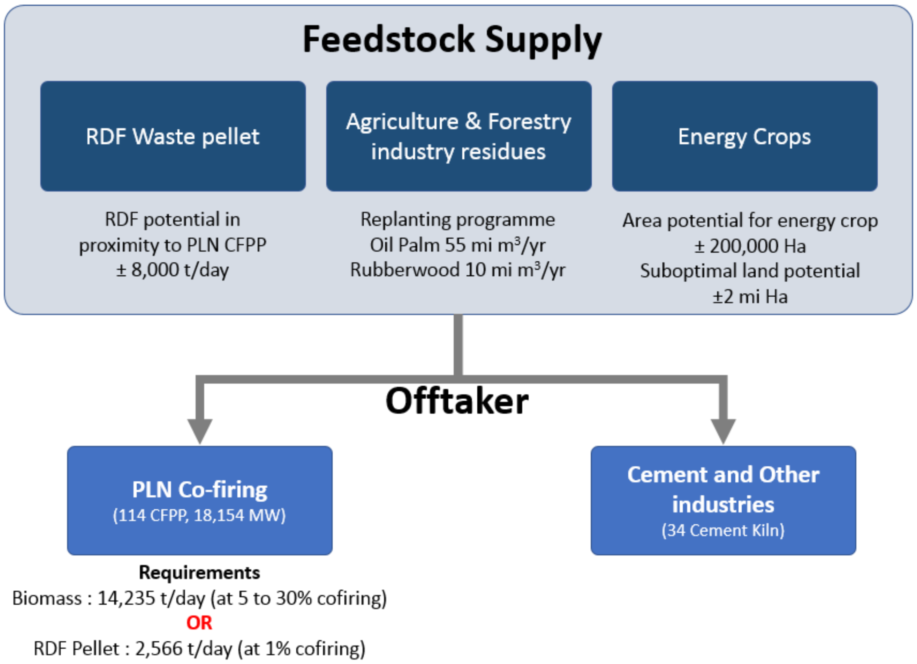
Comparison of biomass use to countries such as UK should also be treated with care, as in 2019, policy-based support toward UK largest full-biomass power plant amounted to more than £700m.

[31] Drax power generation of 13.4 TWh with 2.6 GW biomass capacity. Supports are received from earned Renewable Obligation Certicates and Contract-for-Difference income. Note that UK base electricity price (without policy support) is already substantially higher than Indonesia. Drax Annual Report (page 141, 157). 2019.
[32] IEA Bioenergy. Global Wood Pellet Industry and Trade Study 2017.
[33] U.S. Energy Information Administration. U.S Utility-scale Electricity Generation. 2019.

Securing Stable and Economic Feedstock

Scaling up From Pilot Tests Is Where the Real Test Begins

Figure 7: MEMR Feedstock and Offtake Plans



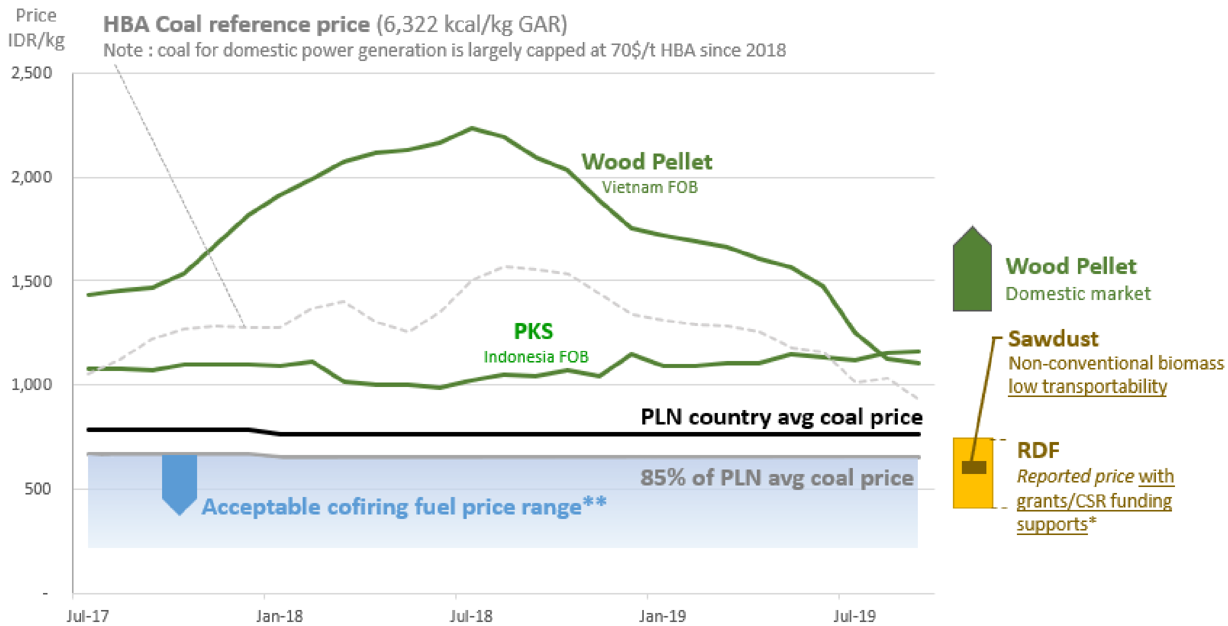
Source: MEMR[2]

MEMR has endorsed the use of three main biomass sources—municipal waste, forestry/agriculture industry residue, and energy crops—with the aim of supplying PLN and other industries, such as cement. Heavily populated Java island naturally provides a large municipal solid waste source, while other wood-based biomass supplies are concentrated primarily in Sumatra.[34] There has been little mention of the potential use of rice husks for cofiring, likely due to the technical complexity of straw-based biomass and market impacts due to competing uses. Within the forestry/agriculture sector, palm and rubber plantation replanting has been suggested as a potential biomass source to provide 65 million m3 of biomass annually.[35] Replanting activities are performed in existing plantations with low productivity mature crops.

Biomass products such as wood pellets and PKS have developed a substantial regional market in recent years, with Japan and South Korea as key importers. The premium price commanded by both commodities has fuelled the expansion of producers aiming for the growing export market.

[34] MEMR Press Release. Implementing Co-firing in CFPP, Here are the Biomass Potential for Coal Substitution. February 28, 2020.
[35] MEMR. Renewable Energy from Biomass presentation. June 2020.

Figure 8: Coal Price and Normalized Price for Selected Biomass



Source: PLN Coal unit price acquired from PLN Statistics book 2019 as approximation, values for each CFPP would be different. HBA[41] from MEMR. (*) See Table 1 & 3 for details of RDF. (**) Based on PLN cofiring fuel policy with 0.85 factor[12]. All biomass prices are normalized toward 4,200 kcal/kg NCV typical coal.[36]

Domestically, the wood pellet price has hovered upward of IDR 1,300 /kg in a number of producing regions,[37] whereas PLN's average coal purchasing price regularly fluctuates between IDR 700 to 800/kg[38]. When comparing across fuels the difference between the calorific values (CV) should always be considered given the generally lower CV of biomasses. With the PLN biomass purchasing price essentially locked in below 85% of the average coal price, biomass producers will face the fundamental question of investment feasibility to develop local biomass market.[39] **The relatively limited development of a large biomass industry in Indonesia even at a premium price level nevertheless raises questions about whether a large-scale biomass industry could be developed at a low biomass selling price demanded by PLN.**

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[36] NCV value for coal is based on *conservative* estimate from volume-weighed PLN coal consumption[39] and PT. IP typical coal in cofiring study[13]. NCV for biomass is based on Table 1 market evaluation. WP & PKS index price based on Argus baseline NCV. Vietnam wood pellet is presented as an approximation of regional market price with Free-on-Board (FOB) price given as a conservative estimate. PKS FOB price excludes export tax package to estimate the domestic market price. Currency conversion with Bank Indonesia middle exchange rates.

[37] Based on IEEFA market estimates.

[38] PLN. PLN Statistics 2019. June 2020.

[39] Biomass price of higher than 85% of coal price is possible where CV of biomass exceeds typical coal CV, such cases are unlikely to be the norm.

PLN CFPP coal consumption is largely dominated by 4,400-5,200 kcal/kg GAR

(47%) and 3,800-4,400 kcal/kg GAR (36%) coal ranks.[40] The domestic power market has largely been protected by the domestic market obligation policy, with a coal reference price (HBA)[41] cap of $70/t placed by the government in March 2018 and later extended in 2019.[42] PLN 2020 budgetary planning (RKAP) further forecasted an average coal purchase price of IDR 815/kg.[43] Against the backdrop of declining HBA in recent years, and under the existing domestic coal price regulation for CFPP, it is likely that domestic CFPP coal price, and therefore PLN's willingness to pay a premium biomass price will remain low for the foreseeable future.

The Paradox Between Cofiring Flexibility and the Need for Stable Biomass Industry Investments

Securing a stable biomass feedstock industry is a known challenge which has stood in the way of many biomass-based power projects in the past, frequently related to the complexity of the supply chain. Waste-based resources further possess specific challenges commonly related to underdeveloped waste collection system and low waste-disposal fee contribution to support waste processing.[44] There is an expectation, however, that co-firing will make it possible for PLN to manage feedstock market supply risks. With cofiring, PLN has the ability to adjust the scale of the cofiring ratio according to the availability of the biomass supply, switching back to coal as required. **Paradoxically, when unmanaged, this flexibility could compromise commitments from both PLN and potential investors to develop a large-scale biomass industry to support the outlined cofiring program**. We will further evaluate the viability of the existing biomass supply plan outlined by MEMR to have a better understanding of supply and economic viability.

With cofiring, PLN has the ability to adjust the scale of the cofiring ratio according to the availability of the biomass supply, switching back to coal as required.

[40] PLN. Coal Supply Strategy Presentation. September 2020.
[41] HBA coal reference price is based on 6,322 kcal/kg GAR coal.
[42] Kepmen ESDM No.1395 and No.1410 K/30/MEM/2018, further extended through Kepmen ESDM No.261K/30/MEM/2019.
[43] PLN, PLN 2019 Annual Report. 2020, p.218.
[44] International Energy Agency. Will energy from waste become the key for of bioenergy in Asia? January 2019.

Refuse-Derived Fuel (RDF) – Two Project Scales With a Common Thread

The promise of solving urban waste management challenges while generating economic product output has been a key attraction point in developing waste-based energy conversion. While the RDF production process is potentially less costly than traditional PLTSa waste-to-energy projects[45], the inherent challenges and complexity associated with waste-based fuel largely remain. The following table outlines the different models of RDF production often cited as the role model for RDF production. Details of these projects are further given in the appendix section.

Table 3: RDF Production Models

Production Mode	Current Pilot Examples	Remarks
Community-Scale RDF Production	Klungkung TOSS Jeranjang JOSS	• **Both established under CSR funding support of PLN subsidiaries** • Manual processing of municipal waste • JOSS has been reported to produce ±200kg/day of RDF, while Jeranjang PLTU (3x25MW) units targeted to be supported requires 600kg/hour of supplies each for 3% cofiring
Industrial Scale RDF Production	Cilacap Industrial RDF plant	• **Established with nearly 50% grant support from the total $6.1m capital investment, with further contributions from regional and central governments** • Production capacity of 50 tonne/day RDF • The product is presently targeted for Cement Kiln application located nearby, noting that the specification of RDF may not be directly suitable for CFPP application

Source: IEEFA, further details and sources are outlined in the appendix section.

Both RDF production models presented the different routes potentially taken to support cofiring operations. Positive externalities gained through RDF processing such as reduced land use for landfill will all need to be taken into consideration. Nevertheless, despite the vastly different scale between the two models, both hold a common thread of external financing support which would inherently distort the real costs associated with the projects. To gain the confidence of both potential investors and the public, the repeated narrative of 'lower than coal' RDF products presented to the public should take into account the financing nature of such projects, the lower CV, as well as the inherent supply and product challenges. The government could, of course, choose to fund such RDF projects from the state budget considering the benefits obtained from MSW handling. Such intention, however, warrants a thorough cost-benefit evaluation.

Wood-Based Biomass

Wood-based biomass fuels such as wood pellets, wood chips, and sawdust are commonly produced from wood and forestry industry residues as well as dedicated

[45] PLTSa: Pembangkit Listrik Tenaga Sampah. Waste-to-energy power generation.

energy crops. Among these, wood pellet has been the dominant solid biomass fuel traded globally, preferred for its high fuel specifications demand and suitability for long-haul transport. Global wood chip, on the other hand, is predominantly produced for the pulp and paper industry, which comprised 90% of its global trade.[46] With its lower energy density, the use of wood chips in energy has been more common in localized markets as transporting them can be expensive. International seaborne trade of wood chips has been possible, supported by a niche vessel market, but remains costly. Other cheaper wood-biomass materials such as sawdust are more commonly considered as raw input for wood pellet production with its low density, although interestingly this has been the biomass of choice in a number of PLN cofiring trials likely due to its low cost.

Compared to regional neighbours such as Vietnam, Indonesia's wood pellet production has been fairly limited. However, it is growing rapidly with a 20%+ compound annual growth rate (CAGR) in the last 5 years. Net export was 242,000 tonnes in 2019, compared to Vietnam's 2.8mi tonne.[47] In recent years there has been a growing interest in developing the production capacity targeting regional export destinations such as Japan and South Korea. Domestically, wood pellet has been utilized by smaller industries seeking to reduce their fuel cost by replacing liquified petroleum gas (LPG).

The mention of the potential of dedicated energy crops as biomass resource, in various forms of pellets or chips, should be viewed both positively and realistically. The development of dedicated energy crops in Indonesia has been fairly limited, although in recent years energy crops primarily aimed at export markets have attracted growing attention.[48] The energy forestry potential can be observed in Figure 9 below and presents a stark reminder of the need for sound economic planning given the spread and the distance of resources to the CFPP demand centres.

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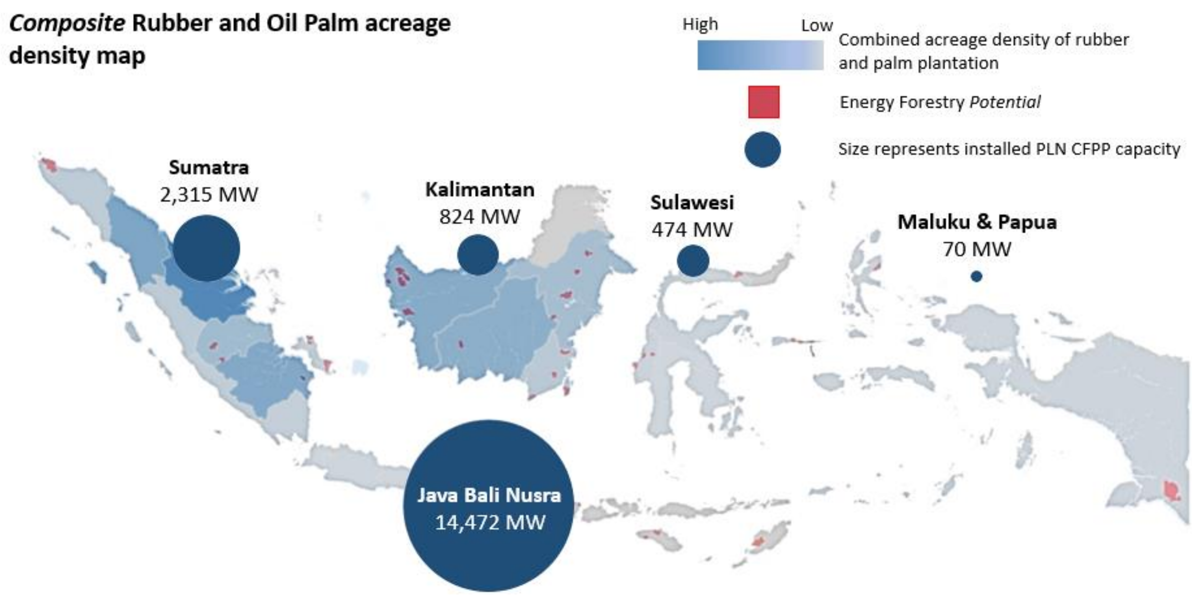
[46] Hawkins Wright. Wood Chips for Energy. 2019.
[47] FutureMetrics, Canadian Biomass, Wood Pellet Association of Canada. Global and Domestic Market Review. September 2020.
[48] Perhutani. Perhutani Transforms into Green Company. December 2019.
Perhutani (a forestry industry state-owned enterprise) is in progress of developing several energy crops projects for export markets.

Figure 9: Selected Biomass Resource Map



Source: Ministry of Agriculture, Ministry of Environment and Forestry cited by CIFOR.[49]

Considering that typical coal CV is anywhere between 6 to 50% higher than wood pellet, in the absence of policy incentives, wood pellet would be an unlikely option for cofiring. The domestic wood pellet price is estimated between IDR 1,300/kg to more than IDR 1,700/kg[50] compared to the coal price of IDR 700-800/kg.

The Promise of the Replanting Program

With 16.4 million hectares of oil palm plantations and 3.6 million ha of rubber plantations, biomass obtained from replanting on existing low-yield plantations has been suggested by MEMR as a potential biomass resource. Bearing in mind that these resources are principally located in Sumatra and Kalimantan (18% of PLN CFPP capacity), such a plan could be viable provided the following factors are considered in the evaluation:

- Replanting activity is a one-off program which could be performed every 25 to 30 years on both oil palm and rubber plantations. A comprehensive evaluation is required to determine whether a continual biomass supply from such an initiative would be conceivable.

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[49] Rubber and oil palm plantation acreage from Ministry of Agriculture. Oil Palm Statistics Book and Rubber Statistics Book. 2019.
Energy forestry acreage potential from Ministry of Environment and Forestry, cited by CIFOR. Opportunity and Challenges for Bioenergy Development in Indonesia. May 2016.
[50] IEEFA market estimates based on compiled sources in multiple locations. A study by International Tropical Timber Organization and ISWA on North Sumatra wood pellets suggested price estimate of IDR 1,700/kg. Prices could vary with quality, feedstock origins, and locations.

- Solid economic and technical evaluation of palm/rubber trunk as biomass fuel is essential. While trial pellet production from palm trunk has been reported[51] it is not yet a proven model. The high moisture content of the trunks may also require considerable processing and transportation costs. Furthermore, plantation-to-power plant distance assessment is essential with the supply costs of biomass being sensitive to transportation expenses. With resources largely constrained in Sumatra and Kalimantan, its use would likely be constrained.

- The viability of both government-sponsored and private companies' replanting programs will need to be evaluated with reference to past performances. A smallholder farmer replanting program for oil palm has long been initiated by the government with an aggressive target of 2.4 million ha with the support of the Crude Palm Oil Support Fund (CSF). Between 2016 and 2019 only 4.3% of the target was realized.[52] With Indonesia's growing biodiesel program requiring strong support from the CSF, it remains to be seen whether sufficient funding and commitment will still be in place to continue supporting the palm replanting program. The government-sponsored rubber plantation replanting program has also been progressing slowly, with a target of 180,000 ha annually which has yet to fully materialize due to a shortage in funding support.[53]

The viability of both government-sponsored and private companies' replanting programs will need to be evaluated with reference to past performances.

Other biomass feedstocks such as palm kernel shell, rice husks, coconut, and oil palm residues are all potential alternative biomass resources, but as we mentioned earlier, this does not necessarily mean they are viable biomass fuels. While the government has not specifically addressed PKS as a potential fuel for the cofiring program, PKS has been a major Indonesian biomass export far exceeding other biomass produce with 1.72mi tonne exported in 2019.[54] The high calorific value, low moisture content, and relatively lower cost compared to wood pellets had made it attractive for regional export destinations. While there have been a number of PKS cofiring trial runs conducted by PLN, the high cost of PKS linked to the international

[51] Trial pellet production reported to have been performed by PPKS Palm Research Centre. Antara News. DMSI: Pellet from oil palm trunk is potential to be developed. February 16, 2020.
[52] CNBC. Government provided 2.5 T IDR support for oil palm, what for? June 16, 2020.
[53] CNN. Government plans to combine Rubber replanting and wood processing. March 1, 2019.
[54] Portonews. Palm Kernel Shell, Indonesia's Future Energy. August 30, 2019.

market likely suggests that utilization of PKS for cofiring would be limited. Furthermore, PKS, as previously alluded, is also largely unsuitable for 85% PLN CFPP running PC boilers.

IEEFA's analysis on the current RDF and wood-based biomass further suggests the challenges in the commercial viability of the biomass supplies. The RDF price presented in several pilot projects is inherently distorted by external funding support while traditional biomass such as wood pellets and PKS are expensive. The promise of biomass resources from replanting and dedicated energy crops also needs to be scrutinized in detail, considering the geographical spreads and the technical and economic viability.

The promise of biomass resources from replanting and dedicated energy crops needs to be scrutinized in detail, considering the geographical spreads and the technical and economic viability.

Pursuit of Low-Cost Non-Conventional Biomass Fuel: The Need for a Clearer Roadmap and Long-Term Commitment for Biomass Industry Development

Our analysis of PLN's cofiring development efforts suggests that they are not focusing solely on wood pellets, but rather on a variety of biomass materials such as sawdust. In September 2020, PJB reported that it had successfully conducted cofiring operations at Paiton 1&2 with 3,800 tonnes of sawdust over 103 days, a consumption level which likely represents a cofiring ratio of 1%. With a significantly lower Net Calorific Value (NCV) of approximately 2,450 kcal/kg,[55] sawdust was reported to have been acquired at a price of IDR 350/kg.[56] Normalized to a typical 4,200kcal/kg NCV coal, such a price would translate to IDR 600/kg. This is still lower than wood pellets, and therefore presents an interesting example. **The effort to utilize non-conventional local biomass resources could be a differentiating factor for Indonesian cofiring, *provided* that it is technically viable.** Such initiatives could offer an alternative to traditional biomass fuel such as wood pellets and PKS would likely be 'priced out' from the cofiring market.

Traditionally, globally traded biomass feedstock commands a premium price to reflect demand for high-quality fuel for both power plant and long-haul transport considerations. If local sawdust resources could indeed be secured, it could present a good advantage *provided* that utilization of lower-grade biomass can meet energy-adjusted economic viability standards and does not negatively impact power plant performance. Competing use for sawdust in various industries and as raw feedstock

[55] PT. PJB Study. Cofiring focused group discussion. October 2020.
[56] Media Indonesia. PJB Utilizes Sawdusts in 11 CFPP, Media Indonesia. September 25, 2020.

for wood pellets will fundamentally determine the viable supply and price level, with PJB acknowledging the challenge of procuring the material.[57]

Through evaluation of the biomass fuel potential and the demand centres, the following key points should be noted:

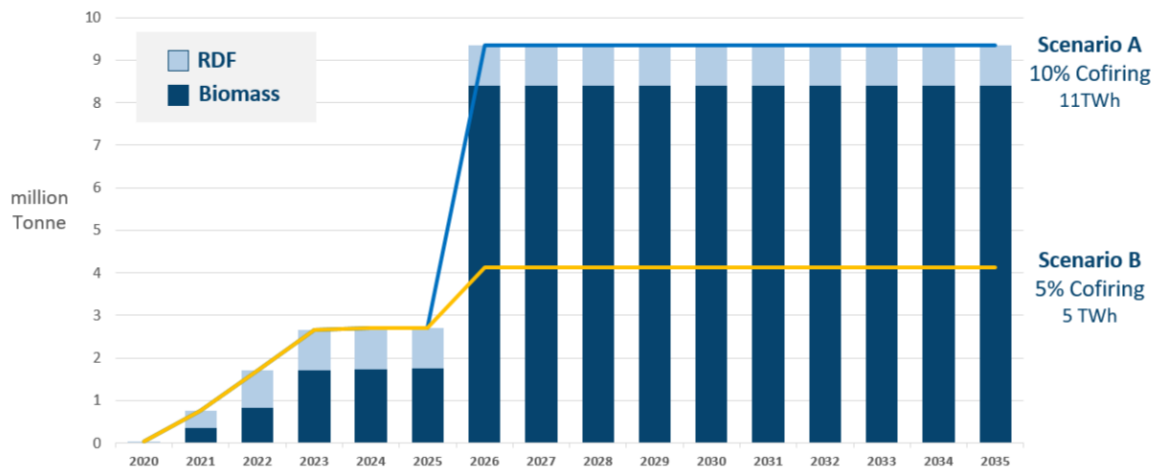
- 79% of PLN CFPP capacity is located in Java and Madura where wood-based biomass resources are very limited.
- Biomass energy density and bulk density is a key enabling factor for long-haul transport. Higher quality biomass fuel such as industrial wood pellets and PKS fare much better for long-haul transport, while transporting less dense biomass such as sawdust would likely be more complex and expensive. On the other hand, both wood pellets and PKS are generally more expensive than coal.
- There are reports of plans to increase wood-biomass supply in Java with energy crops, but they largely target the export wood pellet market which commands a premium price. Plans to increase supply could be feasible, but projections should remain grounded to historical track records of biomass industry development.

Taking these factors into consideration and working within the constraints of low-cost cofiring intended by PLN, we could generally conclude that Java, with its enormous generation capacity, would largely be locked-in for RDF cofiring derived from municipal solid waste. The plan to utilize wood-based biomass would be more likely to be applied in Sumatra and Kalimantan while the viability of the plan in Maluku and Papua would more likely rely on local resources in the proximity of the power plant rather than secluded industrial forestry locations.

Analyzing the resource plan outlined by MEMR alongside the actual biomass fuel utilized in PLN's cofiring trials and matching this to the actual distribution of biomass resources and power demand centers certainly raises questions on the entire coherence of the cofiring plan. **One could certainly question the rationale behind cofiring trial runs with expensive biomass products which are unlikely to be applied for long-run implementation**. Furthermore, aggregating wood-based biomass and RDF potential across the country should be treated with caution as wood-based biomass potential is very limited in Java, while a viable RDF supply model is still largely in question.

[57] Bisnis.com. PJB Extends Power Generation Trial with Sawdust. September 24, 2020.

Figure 10: PLN Potential Cofiring Fuel Demand Projection



Source: PLN potential cofiring plans, presented by PLN on 7 Dec 2020.

Current cofiring scenario (Figure 10) illustrates the level of cofiring fuel supplies demanded by the plan at two cofiring ratio scenarios, and with stable projection for the coming decade. **As supply of 4 to 8 million tonne of biomass and nearly a million tonne of RDF is required. The exclusion of existing biomass production capacity -which are currently largely destined for export at premium price- in the plan may suggest that a new market is expected to develop** to support the projected 5 to 11 TWh of cofiring power generation.

While it could be reasoned that the outlined cofiring plan is still in the early phases, these questions nevertheless emphasize the need for greater clarity on the roadmap ahead. With biomass price already a primary hurdle, clearly outlining a publicly accessible roadmap is essential for building confidence in investors seeking to enter the biomass industry. IEEFA recommends that at a minimum, the roadmap should include the following:

- **Clear outline of the demand centers, medium and long-term demand forecast, and the feasible price acceptable for PLN**, including potential procurement commitments PLN is willing to support.

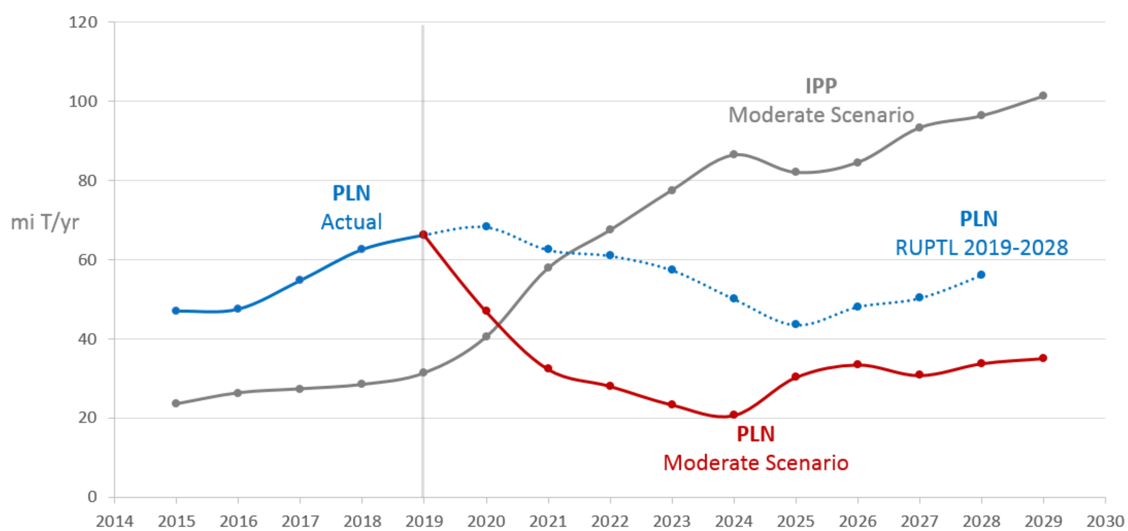
- **Biomass specifications required for cofiring.** Even when such a standard has not been formally established under SNI, this information would provide a useful framework for potential investors and a useful baseline resource map.

- **Outlining priority target regions.** Casting a wide net on deployment options does not necessarily translate to results, particularly when viable models are yet to be developed. By prioritizing regions that PLN considers having the greatest potential to achieve the intended cofiring target, PLN could set the benchmark for cofiring implementation and potentially present a replicable model to be adopted in other locations.

While building the biomass industry needed to support cofiring could be well outside the domain of PLN, providing clarity on the program roadmap is essential if the government and PLN are truly committed to the intended cofiring goals. Attracting investment to develop a truly scalable biomass industry requires more clarity on the medium-term opportunity. The 2019-2028 RUPTL has already projected that PLN will have lower levels of power generation and fuel consumption over the coming decade. With post COVID-19 power demand growth dropping and the rising dominance of private IPP producers working under take-or-pay contracts, power generation by PLN could potentially be reduced much earlier. Understanding these underlying dynamics is vital for investors seeking to enter the biomass industry supporting PLN, and PLN can assist by providing much-needed transparency.

With post COVID-19 power demand growth dropping and the rising dominance of private IPP producers working under take-or-pay contracts, power generation by PLN could potentially be reduced much earlier.

Figure 11: Power Generation Coal Consumption Projection



Source: PLN Coal consumption outlook, presented at APBI-ICMA, 2020.

Projecting the Right Signal: Credible Acknowledgement of Challenges

The claim that biomass could be obtained at a price lower than coal is a commendable ambition. It has largely been unachievable in other countries that have implemented cofiring with the careful selection of biomass. Utilization of higher-grade wood pellets, chips, and PKS are based upon sound technical reasoning to preserve optimal CFPP operation. The use of non-conventional biomass cofiring fuel such as sawdust could present an opportunity, but one which needs to be anchored to a viable supply plan and a sound technical assessment. A thorough evaluation of the technical implications of using lower grade biomass is a must to ensure that the performance of PLN CFPPs is not ‘sacrificed’ in the process.

Indonesia’s ability to create a stable low-cost market for biomass remains an open question. The domestic wood-biomass industry has only developed recently in response to increased international demand for premium priced biomass. With PLN aiming to procure biomass at a price lower than coal on an equivalent energy basis, it remains to be seen whether a market would develop to respond. An evaluation of both existing wood-biomass and RDF pilot projects has suggested that substantial hurdles remain. A clear roadmap that acknowledges these challenges would be welcomed. **Shrouding the challenges behind an aggregated nation-wide biomass potential does not provide clarity on the road ahead.**

Would cofiring be possible? Perhaps, but stakeholders need to critically examine the scale at which it could realistically be achieved with respect to the bold targets proposed by MEMR. Reaching the scale required by the plan warrants industrial-scale investment to ensure stable long term supply, as well as overcoming other outlined constraints. Furthermore, the projected rise of IPPs and the decline of PLN power generation share in the coming decade would also need to be considered in evaluating the full impact of the cofiring program.

IEEFA believes that a focused effort to prioritize particular target regions could be more viable than casting an ambitious nation-wide deployment plan. A scaled-down deployment plan with evidence of viable commercial projects and PLN’s willingness to offer long-term commitments will send a stronger positive signal to attract major investments for the biomass industry. At the same time, policymakers also need to calculate both the potential upside and risks that could result from locking-in long-term purchase commitments, particularly as other new technologies continue to be developed. Indonesia has the potential to become a powerhouse for the biomass industry, and the cofiring ambition could be a starting point to spark its development. Such development, however, could only be established with sound planning and the transparency necessary to support a stable long-term market.

Appendix: RDF Production Models – Dissecting the 'Cheaper Than Coal' Notion

Community-scale RDF Production

Jeranjang PLTU 3x 25MW located in Lombok, NTB province is one of the first CFPPs to perform a cofiring trial with RDF pellets. At maximum capacity each unit is estimated to require 600 kg/hour of RDF pellet at 3% cofiring ratio, or close to 45 tonnes per day for all three units.[58] The trial run which took place in 2019 was supported by RDF pellet produced by a small production plant based in Klungkung region, Bali. The Klungkung TOSS (Tempat Olah Sampah Setempat) RDF plant has been established as a cooperation between the local government, STT PLN (PLN established university) and Indonesia Power CSR program in 2018 to help address the local waste processing challenges. The RDF pellet produced has been reported to be sold for a price of IDR 300/kg to Indonesia Power, a price 'lower than coal' which is priced at IDR 700-800/kg.[59] Normalized to the typical coal 4,200 kcal/kg NCV, this RDF price approximately translates to IDR 406/kg. **An evaluation of these prices should fully consider that the TOSS facility has been built with CSR financing support.**

A similar model has been adopted in Jeranjang Olah Sampah Setempat (JOSS) plant, also established as part of Indonesia Power CSR initiative.[60] Similar commentaries on the low cost of RDF pellet have been reported with pellet priced at 'IDR 300 to 550 per kg' (IDR 406-745/kg NCV-normalized price)[58]. **With the target requirement of 600 kg/hour of steady supply for a small scale 25MW power plant, as of August 2020, it has been reported that only 100 to 200 kg of RDF pellet is produced daily at the JOSS facility**, with output fluctuating between 800 kg to 1.4 tonne per month.[61] The local plant operator did suggest that there are further plans to increase the production capacity to between 500 kg to 2 tonnes of RDF pellet daily.

This community-based model is currently in the process of being adopted in other locations such as Ciliwung river and Saguling dam waste management initiative. **The positive externalities obtained from the establishment of these small-scale networks of waste processing models are commendable and deserve further support.** Nevertheless, considering that Klungkung TOSS was established in 2018 and Jeranjang JOSS is producing well below the needed capacity, they also serve as a reminder that there is still much to be done to translate these pilot projects, established under CSR funding support, into an economically viable and scalable model.

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[58] Investor Daily. PLN Utilizes Waste Pellet for PLTU Jeranjang. February 11, 2020.
[59] Investor Daily. PLN Processing Waste as Coal Mix for PLTU. July 2, 2019.
[60] Indonesia Power. Indonesia Power press release. February 11, 2020.
[61] Mongabay. Producing Coal Replacement Energy, TPA Kebon Kongok Maximizes Lombok Waste Management. September 15, 2020.

Cilacap Industrial RDF Plant

Cilacap RDF plant was established with 50 tonne/day RDF production capacity aimed to be used as a coal-replacement fuel for a cement plant located nearby.[62] The RDF product is tailored for cement kiln operations with 3,000 – 3,200 kcal/kg CV and 22% moisture content.[63] The RDF was reportedly sold for IDR 300,000/tonne (~IDR 406/kg NCV-normalized price) to the cement plant with the remainder IDR 200,000/t production expense covered by the local government as a compensation for waste-handling.[63] **Evaluation of this RDF price should fully consider that nearly 50% of the estimated IDR 90 bn(US$ 6.1) capital investment cost has been supported by a foreign government grant**,[64] with further joint contributions from various elements of the central and regional government. With government officials hinting at the possibility of replicating the RDF project in other cities, it is worth noting that similar RDF project plans such as Lulut Nambo 500t/day RDF plant, have been in the pipeline for several years and have yet to fully materialize. Such cases are a testament to the complexities often encountered in MSW resource development. Along with economics and supply chain risk evaluation, proper assessment of the required fuel specifications for cofiring is essential to determine the viability of the plan.

[62] Detik. Waste-derived Fuel Cheaper than Coal for Power Generation. July 21, 2020.
[63] PT. Solusi Bangun Indonesia. Cilacap RDF Plant Inauguration event. July 2020.
[64] Ministry of Public Works and Public Housing (PUPR). PUPR Ministry constructed RDF processing plant in Cilacap. May 15, 2019.

About IEEFA

The Institute for Energy Economics and Financial Analysis (IEEFA) examines issues related to energy markets, trends and policies. The Institute’s mission is to accelerate the transition to a diverse, sustainable and profitable energy economy. www.ieefa.org

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