Biomass co-firing in Indonesia: Prolonging, not solving coal problem

Katherine Hasan
Abdul Baits Swastika
05/2025

CREA
Centre for Research on Energy and Clean Air

CREA is an independent research organisation focused on revealing the trends, causes, and health impacts, as well as the solutions to air pollution.

Biomass co-firing in Indonesia: Prolonging, not solving coal problem

30 May 2025

Authors

Katherine Hasan, Analyst, CREA

Abdul Baits Swastika, Researcher, CREA

Editor

Jonathan Seidman, Editor, CREA

Designer

Wendi Wu

Cover photo

Empty road surrounded by trees by Rahmadiyono Widodo (Unsplash, 2019)

Acknowledgements

CREA gratefully acknowledges the support, feedback, and insight received from Putra Adhiguna of the Energy Shift Institute and Fiorentina Refani of the Center of Economic and Law Studies (CELIOS). The views expressed in this report are those of the authors and should not be attributed to any of the aforementioned.

About CREA

The Centre for Research on Energy and Clean Air (CREA) is an independent research organisation focused on revealing the trends, causes, and health impacts, as well as the solutions to air pollution. CREA uses scientific data, research, and evidence to support the efforts of governments, companies, and campaigning organisations worldwide in their efforts to move towards clean energy and clean air, believing that effective research and communication are the keys to successful policies, investment decisions, and advocacy efforts. CREA was founded in Helsinki and has staff in several Asian and European countries.

Disclaimer

CREA is politically independent. The designations employed and the presentation of the material on maps contained in this report do not imply the expression of any opinion whatsoever concerning the legal status of any country, territory, city, or area or of its authorities, or concerning the delimitation of its frontiers or boundaries.

The views and opinions expressed in this publication are those of the authors and do not necessarily reflect the official policy or position, or represent the views or opinions, of the Centre for Research on Energy and Clean Air (CREA), or its members and/or funders. CREA assumes no responsibility or liability for any errors or omissions in the content of this publication.

Biomass co-firing in Indonesia: Prolonging, not solving coal problem

Key findings

- Despite PLN's promotion of biomass co-firing as a means to create a green economy and mitigate emissions, the practice is a false strategy that will only leave room for prolonged use of coal, deviating from just transition principles and derailing Indonesia's goals to wean off fossil fuel power generation.
- Raising the share of co-firing at all grid-connected CFPPs poses a great challenge due to persistent barriers in supply and operations – all while having virtually no impact on air pollutant emissions. The 10% share scenario target is projected to merely deliver a 9% reduction in PM release, 7% in NO_x, and 10% in SO_2 at the plants where co-firing is applied. At the national level, biomass co-firing is only expected to reduce around 1.5 - 2.4% of the aggregated coal power emissions.
- Furthermore, emission threshold limits set for coal and biomass power generation differ, where biomass power plants are allowed to release higher levels. Applicable thresholds of emission limits from plants operating with coal-biomass blends is not clearly outlined in the current standards, meaning other pollutants linked to the combustion of specific feedstock may be released without any monitoring.
- Besides, claims on emission mitigation from biomass co-firing in PLN's coal power plants are made without comprehensive quantification — which not only includes the avoided coal use, but also life cycle emissions of the biomass supply chain that enables origin tracing, covering harvesting, processing, and transportation. The "true" environmental impacts remain unquantified and undisclosed.
- To justify bioenergy as a sustainable initiative, PLN should require independent verification of emissions released throughout the value chain and create a framework that enables proper plant-level assessment for all bioenergy use.
- Meanwhile, the Indonesian government must recognize the urgency to map the national coal retirement pathway that considers health benefits and wider economic gains by setting stringent air pollution emissions standards that would mandate the installation of effective air pollution control technologies.

Executive summary

Bioenergy utilisation in the power sector has been outlined as one of Indonesia's key strategies in reaching NZE (net zero emissions) by 2060 in climate-aligned planning documents, namely the 2021 LTS-LCCR (Long-Term Strategy for Low Carbon and Climate Resilience) and the JETP CIPP (Just Energy Transition Partnership Comprehensive Investment and Policy Plan). However, the recent national electricity plan, RUKN 2024-2060, has significantly scaled back future targets for bioenergy power generation and outlined rapid expansion of abated coal power through biomass co-firing in coal-fired power plants accompanied with the use of CCS (carbon capture and storage).

PLN, Indonesia's sole state-owned electricity provider, has consistently conveyed biomass co-firing as the corporate strategy to support a people-centred green economy and mitigate emissions. These claims, while not backed by transparent and thorough assessment, need to be questioned, given the current knowledge of various barriers to implementation. The "true" costs and emissions from feedstock supply and co-firing operations are left undisclosed and unaccounted. Furthermore, there is a lack of accountability and market coordination required to establish a transparent and traceable supply chain that is economically viable.

One common claim on air pollution mitigation linked to biomass co-firing should become an entry point for a more rounded national discussion on air quality. Biomass co-firing has little or virtually no impact on air pollution attributed to coal power generation – such that reduction in health-harming pollutants would be negligible at the current aims.

In order to effectively address air pollution, Indonesia must recognize the urgency to map a retirement pathway assigned to all coal power plants in Indonesia – those connected to the grid, as well as those solely integrated to industrial facilities as captive units – that considers health benefits and wider economic gains.

Furthermore, emissions mitigation in thermal power plants through the transition decades can only be addressed by stringent emissions standards, which would entail the installation of air pollution control technologies. Indonesia's emission standards for thermal power plants have room for further improvement, where widespread gains will be achieved if common threshold limits are set at the currently most stringent levels set for coal power plants operating after 2019.

Contents

CREA

Biomass in policy instruments

Climate commitment

Indonesia's climate commitment, outlined in the Enhanced Nationally Determined Contribution (ENDC),[1] is set at 31.89% as the unconditional target with its own efforts, and at 42.30% as the conditional target with international support against the 2030 business-as-usual scenario with 2010 as the base year (Republic of Indonesia, 2022).

Biomass utilisation – or energy sources derived from organic materials such as agricultural waste, food waste, wood, and animal waste – is notably listed in Indonesia's ENDC as part of its energy sector's national mitigation actions to increase renewables use. Under unconditional actions, at least 9 million tonnes of biomass is set to be used in on-grid co-firing, while direct use of biomass and biogas in off-grid power generation is set at 333,776 barrels of oil equivalent (BOE). Conditional actions would expand these efforts.

The 2021 Long-Term Low Carbon and Climate Resilience Strategy (LTS-LCCR) 2050 stipulates half of Indonesia's power generation in 2050 to rely on renewables. Power generation shares of renewables and Biomass Energy Carbon Capture and Storage (BECCS) or biomass-coal co-firing power plants connected to CCS in 2050 are set at 43% and 8%, respectively. Installed capacity for renewables and BECCS is projected to reach 217 GW — 13 GW from biomass, 14 GW from biofuel, and 23 GW from BECCS. The document highlights the central role of reliable biomass supply through integrated land use planning (Republic of Indonesia, 2021).

The Second NDC is due for submission in February 2025; however, at the time this analysis is published, the document has not yet been submitted, pending approval by the President (Kompas, 2025). Responding to the public consultation of the Second NDC draft in February 2024, **Indonesia's civil society expressed major concerns over bioenergy plans in power generation** - highlighting deforestation risks and conflict with the forest and other land uses (FOLU) target to reach Net Sink in 2030 (Madani, 2024).

If the draft is approved, Indonesia's NDC ambition will be slightly raised, where the LTS-LCCR 2050's scenarios are referenced, with the "current policy" scenario set as the unconditional target and the "low carbon" scenario as the conditional target. In addition,

[1] Indonesia's current national climate action plans submitted to the Paris Agreement in 2022. The Second NDC has not been submitted yet, in spite of the submission due date in February 2025, due to 8% economic target revision. Recent coverage mentions anticipated submission by July 2025.

greenhouse gas (GHG) reduction is to be evaluated against the 2019 emissions as a reference year, within a national inventory management[2] overseen by the Ministry of Environment (CAT, 2024; MOE, n.d.).

The methodology to quantify GHG mitigation from biomass power plants with capacities ≤ 15 MW, connected to the grid and captive power, was issued in November 2020, outlining detailed verification requirements, initiating documentation and record-keeping for transparency (MOE, 2020).

Energy and electricity plans

In November 2024, Indonesia released an update to the national electricity plan, namely *Rencana Umum Ketenagalistrikan Nasional* (RUKN) 2024-2060 - the first national regulation that integrates the NZE by 2060 target in the country's long-term power generation planning. **For 2060, the plan outlines the share of renewables in the primary energy mix to reach 50% — one decade later than the target outlined in LTS-SCCR 2050.** The rest of the power supply would come from nuclear power and abated fossil fuels, namely coal and biomass co-fired power plants equipped with CCS and gas-fired power plants with CCS (MEMR, 2025).

Fuel switching is listed as the preferred strategy to manage coal power transition instead of decommissioning, with biomass as one of the energy source options along with ammonia and nuclear. With this, there are two distinct streams of biomass use in RUKN's power generation planning, one for the biomass power plants, falling under the umbrella of bioenergy utilisation[3], and one for co-firing in coal power plants, making up a 10 to 30% share, or even up to 100% with retrofitting.

Provided in Figure 1 is the illustration of how much bioenergy power capacity is planned over the years against coal power plants, which will gradually transition to fully running on coal and co-fired with biomass, equipped with CCS. **Coal will remain a dominant fuel for decades to come, despite the deliberate biomass co-firing strategy to reduce coal use, with a rapid shift to biomass co-firing from 100% coal use in CFPPs from 2040 onwards.**

[2] *Sistem Registri Nasional Pengendalian Perubahan Iklim* (SRN)
[3] Bioenergy power generation includes biomass and biogas power plants and waste-to-energy technologies (incineration and landfill gas power plants)

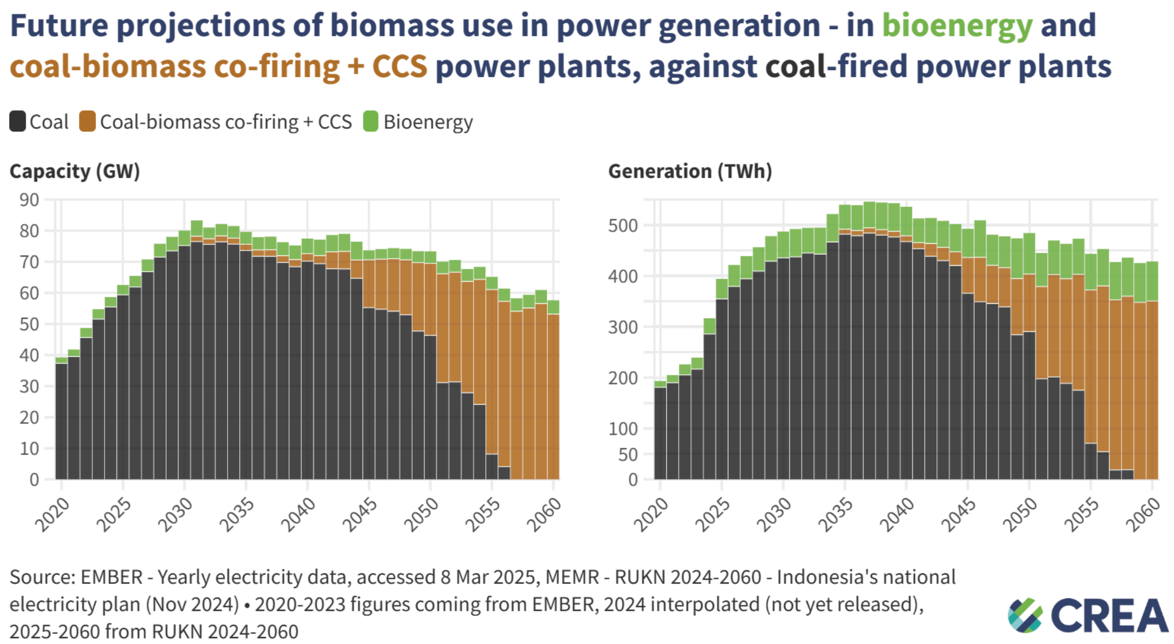


Figure 1. Projection of biomass use in Indonesia's power generation, including both utility grid and captive power plants for industrial use

In 2060, the capacity of coal fired power plants with biomass co-firing and CCS is set to reach 54 GW, producing 350 TWh. While the RUKN outlines plans to integrate bioenergy power plants in the power mix, it remains a minor contributor with minimal expansion compared to other renewables. Bioenergy power is set to only reach 4.5 GW in capacity (1%) and produce 78 TWh (4%) in 2060, while the reported capacity in 2023 is 3.2 GW, producing 22.5 TWh (EMBER, 2024). Meanwhile, the RUKN shows provincial-level potentials from biomass, biogas, and palm oil mill effluent (POME) that amounts to 57 GW in total primary energy (MEMR, 2025).

On the other hand, the Just Energy Transition Partnership's (JETP) Comprehensive Investment and Policy Plan (CIPP), released in November 2023, outlines **bioenergy as one of the major renewable sources that can contribute to on-grid power generation.** The CIPP projects generation from bioenergy to grow by 15-fold, from 17 TWh in 2025 to nearly 260 TWh in 2050, requiring an addition of 33.4 GW capacity from stand-alone biomass, biogas, and municipal solid waste plants over the same period (JETP Indonesia, 2023).

Biomass co-firing in coal power plants is accounted towards bioenergy generation in CIPP, where 5% co-firing is assumed for the shortlisted 52 CFPPs would account for 912 MW of bioenergy-based power. **Contribution from biomass co-firing is projected to reach 3% of the total bioenergy contribution in 2030, and decrease over time as CFPPs**

gradually retire early from 2040 onwards, repurposed to run fully on biomass (JETP Indonesia, 2023).

In the background, national stakeholders have long been anticipating harmonisation for the relevant national energy plans, especially during the cabinet transition from the previous President Joko Widodo to the current President Prabowo Subianto. Two notable documents are the national energy policy - *Kebijakan Energi Nasional* (KEN), and the national electricity supply plan - *Rencana Usaha Penyediaan Tenaga Listrik* (RUPTL).

The revision to the current KEN released in 2014, is still under review. The draft, referred to as *Rancangan Peraturan Pemerintah Kebijakan Energi Nasional* (RPP KEN), was recently approved by Indonesia's House of Representatives in February 2025 (Kompas, 2025a). Future targets are revised to reflect the 8% economic growth target from 2029 onwards set by the new cabinet and to set new and renewable energy NRE use targets at 60 to 70% in 2025-2040 (MEMR, 2025a). A notable revision is the lower target of NRE share in the 2025 final energy consumption — proposed to be revised from 23% to between 17 to 19% (IESR, 2024; Jakarta Post, 2024).

To date, fossil fuel dominates Indonesia's national energy consumption — as reported in MEMR's Handbook of Energy and Economic Statistics of Indonesia (HEESI) for 2023, listing 86.71% of fossil fuel use and NRE at 13.29%, and the sharing of MEMR's 2024 performance achievements, noting 15 GW of NRE share in the installed national power capacity, accounting for 15% of NRE share while fossil power stands at 85% (MEMR, 2024; MEMR, 2025b; Bloomberg Technoz, 2025).

A notable regulation, Ministerial Regulation of Energy and Mineral Resources (EMR) No. 10 Year 2025 on the Roadmap of Energy Transition in the Electricity Sector which was issued in April 2025, outlines biomass co-firing as one of the nine energy transition strategies (MEMR, 2025c).[4]

On May 27, 2025, **the summary of the highly anticipated RUPTL 2025-2034 was released. It outlines the addition of 42.1 GW of renewable energy capacity by 2034 – 0.9 GW from bioenergy. It also includes plans for 6.3 GW of new coal power but does not specify details on biomass co-firing** (MEMR, 2025d). The policy document has not yet

[4] Nine energy transition strategy includes, (1) implementation of biomass cofiring in PLTU, (2) acceleration of reduction in fuel oil usage in electricity generation, (3) retrofitting of fossil fuel power plants, (4) limitation of additional PLTU, (5) acceleration of development of variable renewable energy and addition of electricity generation only from new energy and renewable energy generation, (6) production of green hydrogen (H2) or green ammonia (NH3), (7) development of nuclear power plants, (8) development and/or increase in capacity of electricity system network and smart grid infrastructure; and/or (9) acceleration of termination of operational period of coal-fired power plants.

been released at the time of this publication, but it is anticipated that the revision will provide a detailed breakdown of the annual goals for the strategies outlined in the RUKN 2024-2060 for grid power generation. This includes the biomass co-firing strategies that were outlined in the current RUPTL 2021-2030 (PLN, 2021).

Implementation by PLN

RUPTL 2021-2030, which was enforced in 2021, still serves as the power development plan for PT Perusahaan Listrik Negara (PLN), Indonesia's sole state-owned electricity provider and the key implementer of decarbonisation efforts in the power sector. Even prior to its release, the government and PLN have been actively promoting biomass co-firing as the corporation's effort to foster a people-based economy for “green” electricity production (MEMR, 2020; PLN, 2022).

In March 2020, PLN first set the first general guidelines for biomass use in PLN and IPP coal power plants, namely types, general characteristics, and reference pricing (PLN, 2020). In September 2020, detailed guidelines for co-firing assessment in the existing CFPPs outlined the step-by-step process for feasibility, evaluation, and reporting (PLN, 2020a). In the same year, co-firing trials were successfully carried out in 28 coal-fired power plants, setting the stage for commercial-scale implementation in the following years (PLN, 2022a).

Despite the anticipated changes in the forthcoming revision, RUPTL 2021-2030 still holds relevance for biomass co-firing targets, outlining shares at 2 to 3% for pulverized coal-fired boilers (PC), 3 to 5% for circulating fluidized bed boilers (CFB), and 7.5% for stoker boilers (Stoker). **From 2025 onwards, PLN defines lower and upper aims – the 5% and 10% scenario, with shares set at 5 to 6% for PC, 5 to 40% for CFB, and 25 to 70% for Stoker.** Backed by the Indonesian House of Representatives (DPR), which supports co-firing as a strategy to reduce emissions and manage waste, the government recently urged the Paiton Powerplant to lead implementation by adopting 100% sawdust co-firing alongside CCS installation (Infosawit, 2025; Kompas, 2025b).

RUPTL 2021-2023 specifies that up to 2.7 GW capacity in 2025 can be claimed to be renewable-based under the 10% scenario, utilising 14 million tonnes of biomass annually in 52 CFPP locations. Nationwide biomass co-firing program implementation would cover 19 GW of coal power capacity — 15 GW in Java, Madura, Bali, and Nusa Tenggara, 2.3 GW in Sumatra, 1 GW in Kalimantan, and the rest in Eastern Indonesia. Distribution is illustrated in Figure 2. The plant-level list, supplemented with generation capacity, boiler type, and biomass usage in 2024, is summarised in Table A1 in the Appendix.

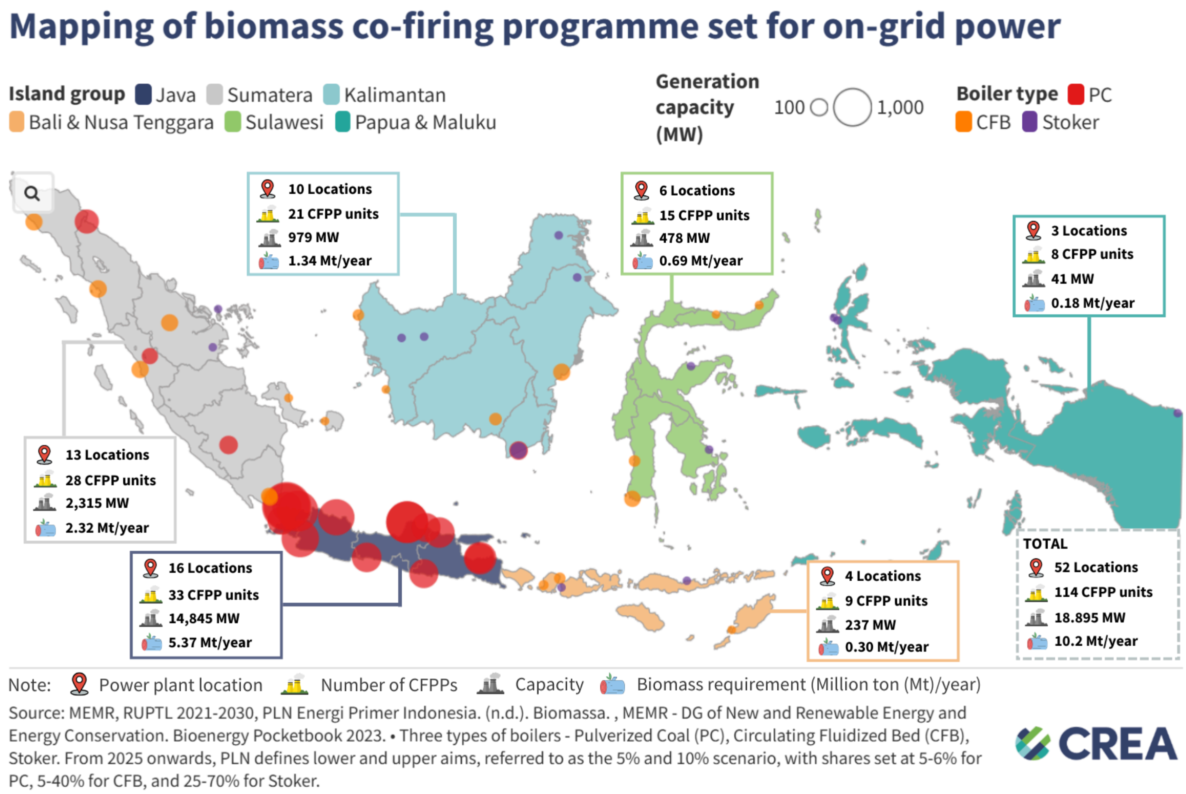


Figure 2. Map of biomass co-firing locations

Reality check and barriers to implementation

While biomass co-firing is positioned as a solution to increase renewable energy use in Indonesia's coal-dependent power sector, concerns remain over its economic feasibility, technical constraints, and supply chain reliability (IEEFA, 2021). This section summarises the available data to provide a current overview, enabling closer evaluation against existing plans and projections.

Missed targets, lack of accountability

Ministerial Regulation of EMR No. 12 Year 2023 outlines biomass utilisation as a fuel mixture, and sets 2023-2030 annual targets. The first notable change in this policy is the lower 2023 target, reduced to one-third of the original target in RUPTL 2021-2030. The second is the adjustment for the highest reference pricing applicable to PLN and IPP coal power plants from 0.85 to 1.20, to improve cost attractiveness (MEMR, 2023).

Clearly, these changes were made to solve difficulties in achieving a sufficient supply of biomass; however, they also uncover deeper issues, **indicating the lack of proper planning and governance prior to setting national targets in implementing the use of biomass in power generation**. The two relevant regulations, serving as implementation guidelines for biomass as fuel mixture in coal power operations as the country develops its regulatory framework for biomass co-firing, are summarised in the Appendix, Table A2.

Over the years, PLN steadily expanded the biomass co-firing program, covering 26 CFPPs in 2021, 36 in 2022, 43 in 2023, and 47 in 2024 as outlined in RUPTL 2021-2030 (PLN, 2022b; PLN, 2023; PLN, 2024; PLN, 2025). **Realisation is lagging behind the expected targets for 2024, in spite of the significant jump required to enter the developed stage set for 2025 onwards.**

Figure 3 illustrates the biomass co-firing targets set in the relevant national plans, against PLN's official reports and plant-level compilation collated for this analysis.

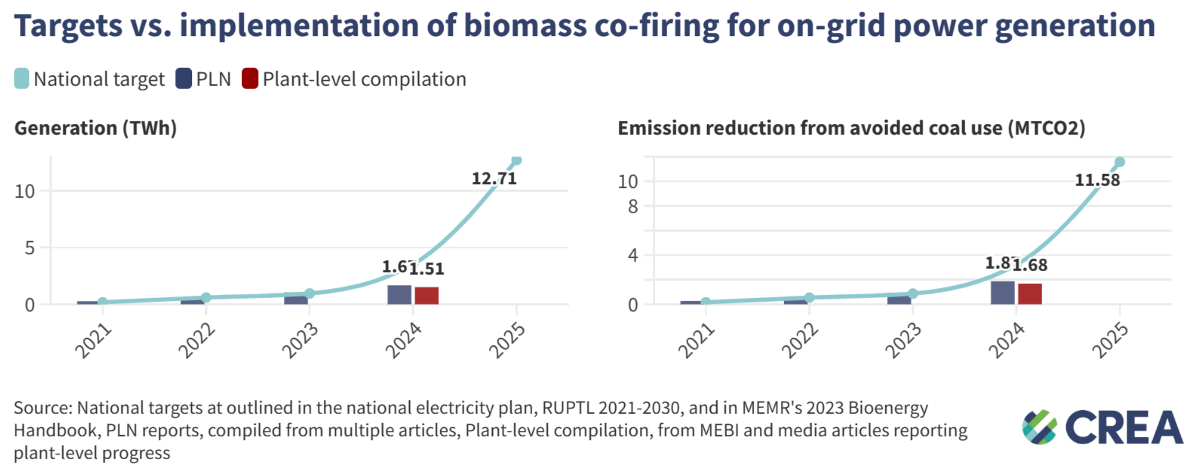


Figure 3. Biomass co-firing targets and realisation in 2020-2024, with significant rise expected in 2025, the year when the biomass co-firing program reaches developed stage

PLN's presentation of the latest status of the biomass co-firing implementation in August 2024 includes a stipulated revision to the projection of biomass use, referencing the draft of the yet-released RUPTL 2024-2033 as the source. Yet again, this indicates a very likely forthcoming revision to the national target. **The "new" target marks 10.2 million tonnes of biomass for co-firing by 2031 – six years later than the original 2025 target outlined in the Ministerial Regulation of EMR No. 12 Year 2023** (PLN, 2024a).

Figure 4 provides a summary of the targets of biomass use for co-firing that are currently set as well as stipulated for revision, to be compared with the realised implementation.

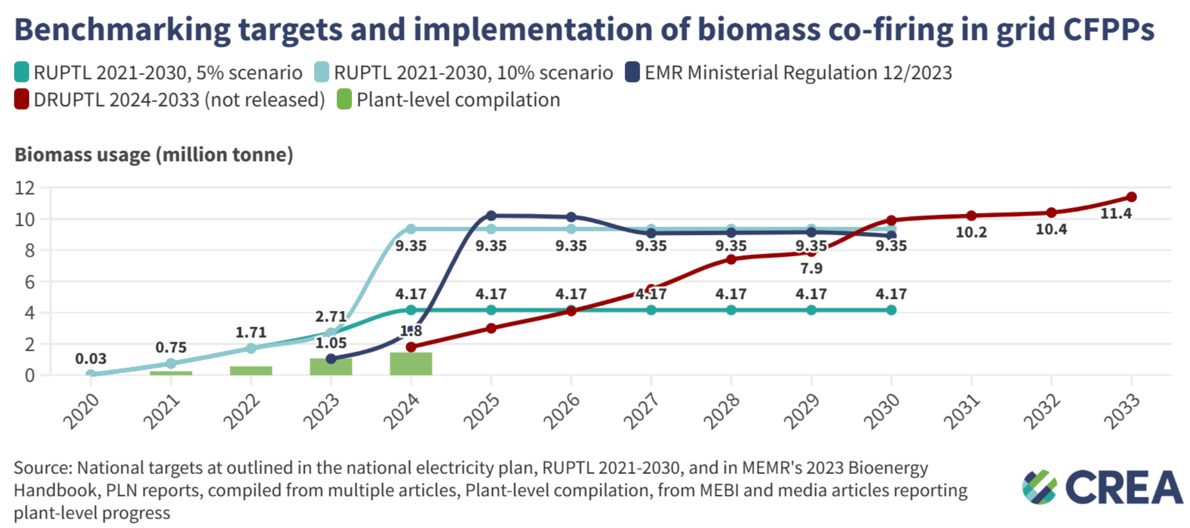


Figure 4. Biomass usage targets and implementation for co-firing in on-grid CFPPs

Tension between Indonesia's export-oriented biomass market's profitability and PLN's demand for affordable feedstock

Despite the recent initiative to increase the highest reference price for biomass co-firing feedstock – the multiplication factor increased from 0.85 to 1.20 times[5], which implies higher allowance exceeding coal Domestic Market Obligation (DMO) pricing reference set for PLN – **the pricing gap remains significant, even for the most commonly available biomass feedstock in Indonesia**.

High discrepancy in pricing has been flagged by the Indonesian Biomass Energy Society (*Masyarakat Energi Biomassa Indonesia*, MEBI) as the major issue in maintaining supply. While a DMO scheme similar to coal is stipulated for biomass, MEBI called it inappropriate for the current situation and raised a notable remark regarding the lack of consideration for the availability and supply required for the different boiler types (Kompas, 2023). Most CFPPs in Java designated for biomass co-firing use PC boilers would require smaller size inputs, such as sawdust and woodchips, while CFPPs in other islands using CFBs and Stokers are well equipped to handle larger-sized feedstock such as palm kernel shells, corn cobs, and pellets from RDF, agricultural waste, or other woody materials (MEBI, 2024).

PLN's role as the sole off-taker for biomass creates a monopolistic market environment that leaves producers vulnerable to unfavorable pricing schemes. The low reference price offered by PLN fails to adequately support the industry, stifling investment in the biomass sector (ERIA, 2022; Dunia Energi, 2021). With limited options for selling their products, producers are often forced to accept prices that do not cover their operational costs or allow for reasonable profit margins (Kompas, 2023; FWI, 2024).

The rough estimate for the highest pricing for biomass feedstock with a calorific value ranging from 4,300-4,600 kcal/kg is USD 51 per tonne, meanwhile, exports are priced at much higher ranges (MEBI, 2024). For instance, exports of wood pellets and wood chips prices reach USD 90 to 130 per tonne, palm kernel shells at USD 100 to 135 per tonne,[6] and corn cobs at USD 135 per tonne (CELIOS, 2024a; FWI, 2024; Suarabaru, 2023).

[5] Calculated against calorific value correction factor and the average coal pricing of the previous year. In 2024 to date, coal pricing for supply to PLN is set at Domestic Market Obligation (DMO) rate, at USD 70 per tonne. As defined in Ministerial Decree of EMR No. 267.K/MB.01/MEM.B/2022, the selling price of coal for the provision of electricity for public interest is USD 70 tonne Free On Board (FOB) Vessel, based on reference specifications at 6,322 kcal/kg GAR calories, 8% total moisture, 0.8% total sulfur, and 15% ash (MEMR, 2022)

[6] The prevailing FOB Indonesia price band for palm kernel shells range from between USD 100 to 110 per tonne for standard, non-certified supply, and a distinct premium exists for certified supply (for instance, International Sustainability and Carbon Certification (ISCC)) required by markets like Japan, placing its FOB price in the higher range of USD 125 to 135 per tonne (Argus Media, 2024, RIM Intelligence, 2025).

The distribution of market pricing shows the limited options of feedstock that would be economically feasible under the current highest reference pricing at 1.20 index. Domestic and export pricing for high-calorific biomass feedstocks such as palm kernel shell and wood pellets fall outside of PLN's buying range. Figure 5 illustrates current biomass pricing against the highest reference pricing based on calorific value correction and PLN's coal DMO FOB price cap at USD 70 per tonne.

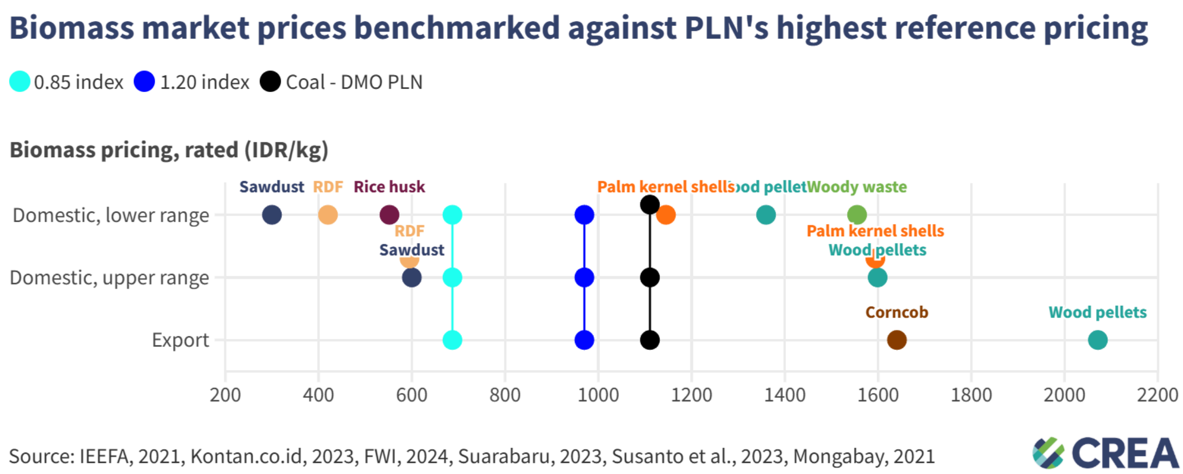


Figure 5. Typical market pricing of biomass against the highest reference pricing for supply to PLN for biomass co-firing

This implies that, **in spite of its vast biomass potential, feedstock highly favored for power generation, Indonesia is now left with low-cost options, generally low in energy density.** Using unsuitable biomass feedstock for co-combustion in coal power plants would negatively impact efficiency due to fouling and slagging, especially at higher co-firing ratios. It would also require more energy and cost to transport the feedstock.

Furthermore, global demands have been growing rapidly as countries race towards Net Zero. Japan and South Korea – the second and third major global wood feedstock importers – are in the spotlight as key importers, driving growth since 2021. Trade data for 2021-2023 shows that **Japan and South Korea markets virtually captured all Indonesia's wood chips and wood pellets exports — with wood pellets exports notably growing by 1,000 fold just in several years**. Wood pellet exports to South Korea grew from 50 tons in 2021 to over 68 thousand tons in 2023. Similarly, exports to Japan grew from 54 tons to 53 thousand tons in the same period. Wood chip exports to South Korea and Japan remained stable at around 7 thousand tons and nearly 800 thousand tons, respectively. China and Japan are major destinations of Indonesia's wood chip exports (Earth Insight et al., 2024).

These trade dynamics strongly suggest that Indonesia's biomass suppliers prioritize exports due to the higher prices offered in other international markets. "Force-fitting" the market to solely meet PLN's needs would likely disrupt the established biomass industry. The preferable approach may require the creation of a conducive domestic market through appropriate pricing mechanisms, infrastructure development, and supportive policies. This could potentially be done alongside a managed transition for export-oriented producers.

Meanwhile, it is crucial to take into account a recent large stride taken by South Korea — moving ahead with the phase down of indirect subsidies (RECs) for most biomass categories and halt REC eligibility for new biomass power plants from 2025. Starting in 2025, state-owned power plants will no longer receive RECs for coal-and-biomass co-firing (SFOC, 2025). **This acknowledges that economic policies should reflect the true environmental cost of energy sources and prioritise genuine renewables, such as solar and wind. The policy shift also signals a growing recognition that large-scale biomass, particularly imported wood, is a "false solution" that promotes deforestation and prolongs reliance on fossil fuels.**

Use of unused biomass waste in CFPPs only feasible under low co-firing ratios, to not induce land use emissions

Indonesia's vast biomass potential — the well-cited 147 million tonnes per year, equivalent to nearly 470 million GJ of technical energy potential — is scattered across the country; however, out of 1,641 million GJ total potential, about 30% or 504 million GJ is yet to be utilised (Abdullah, 2006; Squire et al., 2024). Figure 6 illustrates the distribution of uses for waste feedstocks available in Indonesia. Use as fertilizers, industrial fuels, processing mills feedstock makes up two-thirds of current use, while biomass power plants and the existing co-firing make up less than one-tenth.

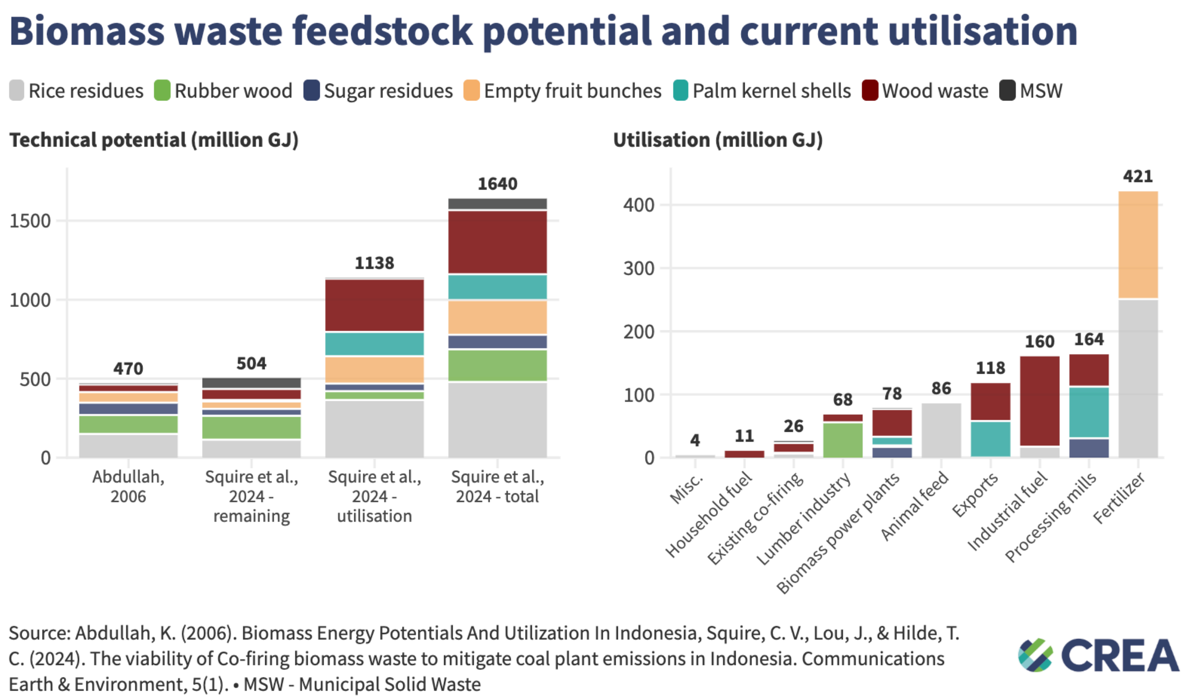


Figure 6. Technical energy potential and current utilisation by biomass waste feedstock

Biomass power plants currently take up three times as much feedstock as the existing co-firing, with feedstock mainly coming from wood waste, followed by sugar residues and palm kernel shells. Power generated from existing biomass co-firing in CFPPs mostly comes from wood waste (~60%), rice husk and rice straw (~25%), Municipal Solid Waste (MSW) (15%), and palm kernel shells (5%). While biomass power plants also rely mainly on woody biomass (56%), wider use of other types of biomass is possible, including bagasse or sugarcane residue (22%), empty fruit bunch (EFB) from palm oil residue (3%), palm kernel shells (17%), and MSW (2%) (Squire et al., 2024).

While the trend underlines the significant lag in biomass co-firing implementation – unable to pick up pace as compared to other uses, **incorporation of unused biomass waste in coal-fired power plants would be feasible but only under low co-firing ratios, not inducing land use emissions.** At higher ratios, supply becomes restrained, and other challenges become exacerbated, particularly deforestation risks (Squire et al., 2024).

Over the years, bioenergy generation has mainly been developed by off-grid industrial users, where biomass reached 21 GWh in 2023. On the other hand, no sizable growth can be seen for biogas and waste power generation, while rapid expansion for biomass co-firing is apparent through PLN's current initiatives, which started in 2021.

The total installed capacity of bioenergy power generation in 2024 is 3.40 GW – the majority, 3.15 GW, operate off-grid as dedicated power plants that are linked to industries, and the remaining 240 MW are grid-connected. A total of 3.2 GW is biomass-powered, while the remaining are biogas (155 MW) and waste plants (36 MW) (MEMR, 2024).

Figure 7 shows the trend for biomass, biogas, and waste power generation, as well as biomass co-firing.

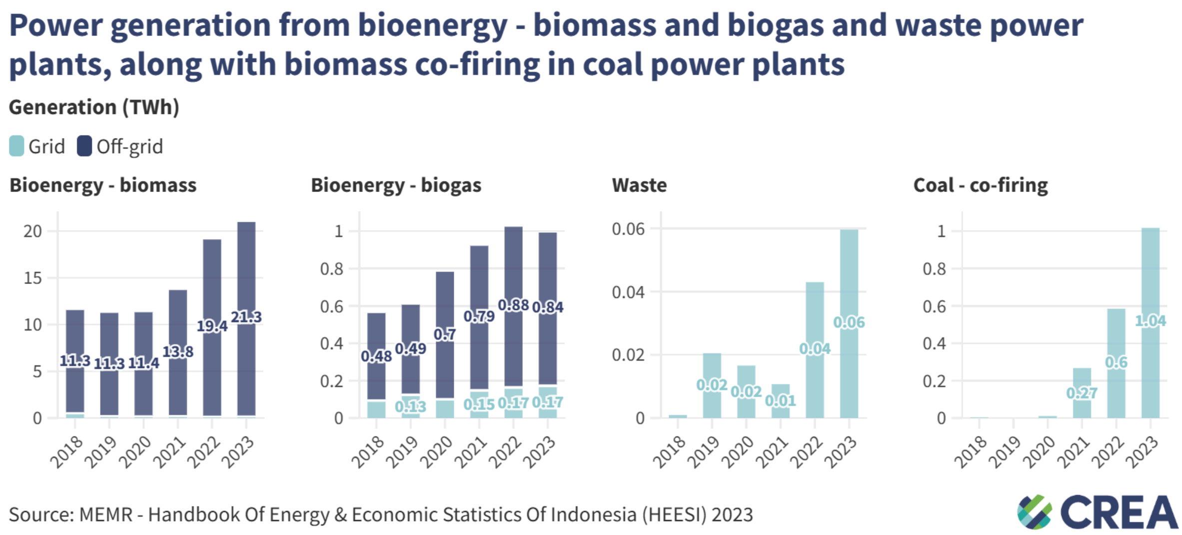


Figure 7. Trends in bioenergy generation compared to biomass co-firing from 2018 to 2023

Installed capacity by province, categorized by biogas, biomass, and waste-to-energy technologies, is provided in the Appendix, Table A3. East Java, North Sumatra, and South Sumatra are the top provinces contributing the largest shares to the national total of nearly 1.48 GW. Most capacities come from biomass (71%), and the remaining from waste-to-energy (19%) and biogas (10%).

Figure 8 shows the distribution of bioenergy power generation across the provinces, along with known operational and prospective power plants (MEMR, 2024a; MEMR, 2024b; Primadita et al., 2020; ABGI, 2021; MEMR, 2023a; MEMR, 2020a). The subsequent Figure 9 shows the distribution of unutilized biomass waste feedstocks. The two figures highlight the opportunity to identify the variabilities in order to optimise use and set realistic targets best suited for the major islands – notably Java, Sumatra, and Kalimantan.

For instance, in Kalimantan and Sumatra, where availability is high for palm, rubber, and woody residues, current supplies are routed mostly to biomass power plants, while in Java, rice residue and bagasse are abundant but neither are tagged for use as co-firing fuels to meet massive demands in CFPPs across the country's most populous island.

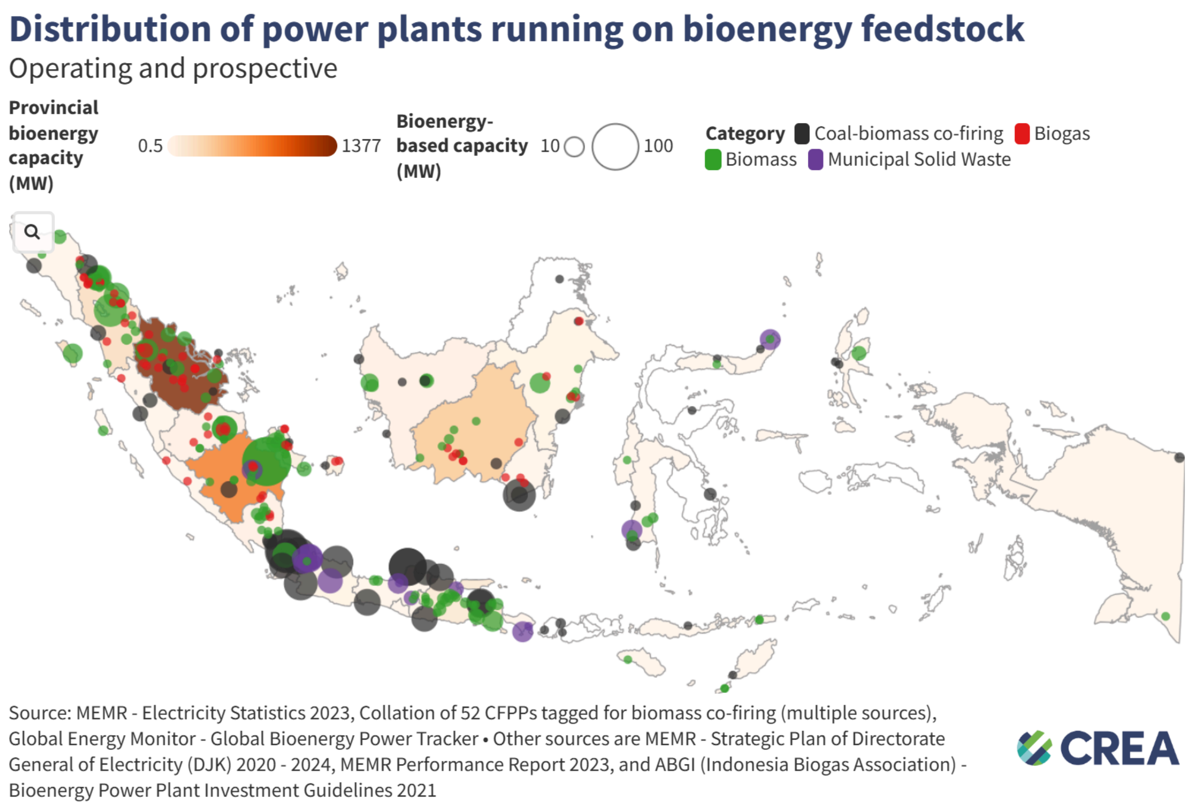
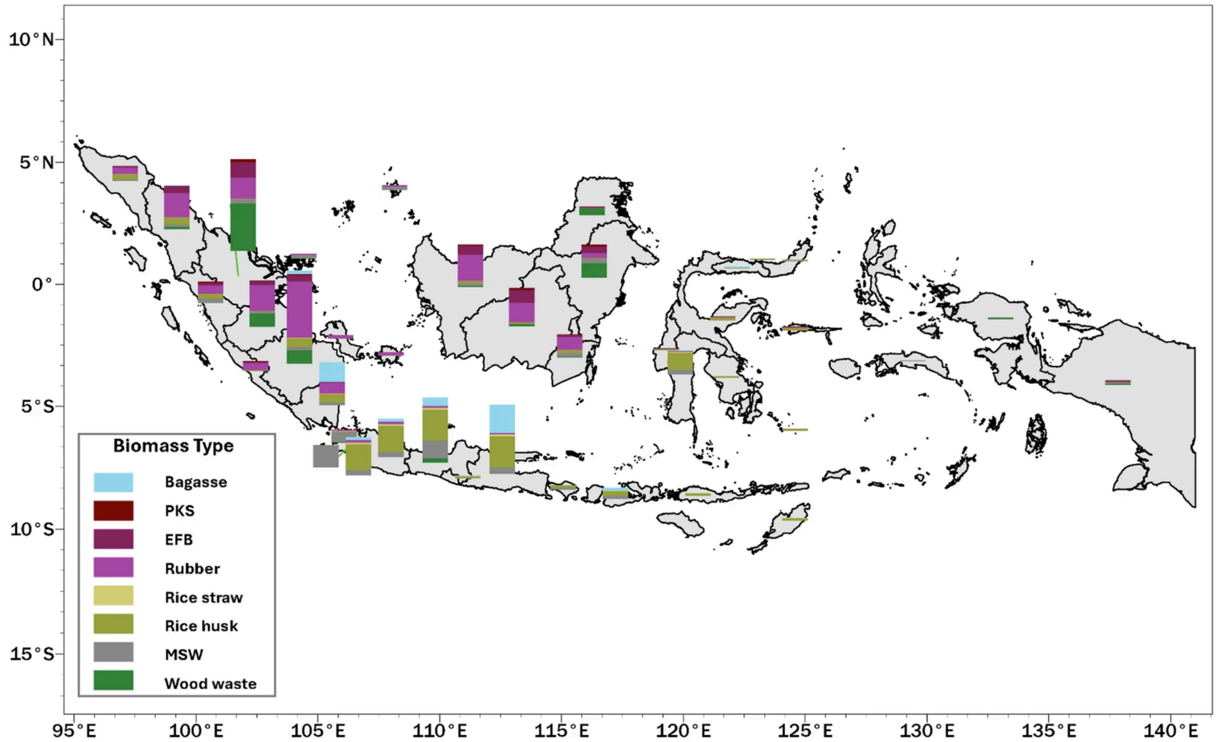


Figure 8. Plant-level distribution of coal-biomass co-firing plants, biomass, biogas, and waste plants across Indonesia by capacity (data available for access, here)



Source: Squire et al., 2024. Note: Total bar size indicates the magnitude of biomass supply. Shading indicates feedstock type (yellow for rice straw, fuchsia for empty fruit bunch (EFB), gray for municipal solid waste (MSW), pink for rubber, dark yellow for rice husk, green for wood waste, blue for bagasse, and red for palm kernel shell (PKS).

Figure 9. Distribution of Indonesia's unused biomass waste feedstocks (Squire et al., 2024)

Looking beyond now, MEMR prepares a 2023-2030 roadmap that assumes sustained domestic supply from unprocessed agricultural waste, processed plantation residues, and energy crops. The current reality is, however, riddled with challenges. Figure 10 illustrates MEMR's roadmap for biomass co-firing feedstock supply through 2030.

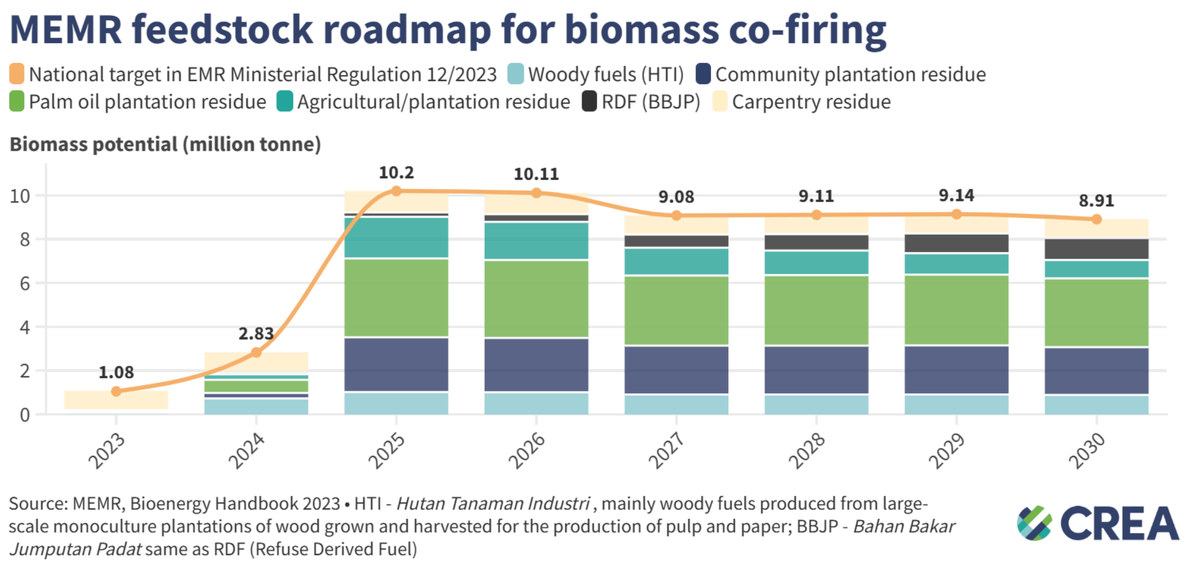


Figure 10. MEMR's biomass co-firing sourcing roadmap for on-grid power generation

Plantation residues, particularly from palm oil and rubber plantations, can be considered major biomass sources. While replanting activities could yield up to 65 million cubic meters annually, technical challenges and competition with export markets are projected to further constrain supply (ERIA, 2022; Squire et al., 2024). **Palm kernel shells alone generate USD 250 million annually in foreign trades, creating a financial disincentive to maintain domestic supply despite rising demands** (GAPKI, 2022; FWI, 2024).

Logistical issues in transporting the feedstock from the plantations to the designated power plants exacerbate supply bottlenecks. Resources are concentrated in Sumatra and Kalimantan, while provinces in Eastern Indonesia face significant deficits even at low co-firing ratios. Java, home to most power plants — also faces inter-island transportation inefficiencies that further constrain the supply (ERIA, 2022; Squire et al., 2024; FWI, 2024).

National roadmap shows feedstock would not only come from unutilised waste streams, but also from energy plantation forests — hiding risks in plain sight, behind the guise of energy transition

While the MEMR roadmap outlines sizable shares of feedstock to come from streams of agricultural industry residues, a notable initiative for the development of energy plantation forests or *Hutan Tanaman Energi* (HTE) has **sparked concerns for increased risk of deforestation since the policy was first introduced in 2015 and updated in 2019.**

The current regulatory framework for the development of industrial plantation forests or *Hutan Tanaman Industri* (HTI) includes energy plantation forests, HTE as a subcategory of HTI.[7] By definition, *Tanaman Industri* or industry plants include woody plants – both trees and cultivated woody perennials to be used as raw materials for pulp and paper, rayon, carpentry, and bioenergy industries, while *Tanaman Energi* or energy plants include biomass, biofuel and non-timber plants dedicated to meet renewable energy needs.

Under this regulatory framework, the roadmap anticipates outputs from energy plants produced from HTE to fulfill around 35% of the biomass co-firing demand, from 1.2 million hectares of plantation forests. The current development of HTE shows that one-third of the goal has been achieved. Further studies highlight that rapidly bridging the gap could lead to the deforestation of at least 2.3 million hectares of protected forests (FWI, 2024; Trend Asia, 2022). In the designated area, there are 400 thousand hectares of undisturbed tropical forests. Considering haul zones around the CFPPs and wood chip mills, the risk grows to 10 million hectares – 25-fold of HTE development (Earth Insight et al., 2024).

While the HTI scheme is claimed to support people's economy by creating jobs and new opportunities, its implementation is largely questioned. A case study of a single company with concession rights to 94,384 hectares of forest areas in two regencies, West Kotawaringin and Lamandau, highlights that the local communities are not fully involved in strategic discussions, and not at all in the decision-making process for management plans and utilization of 28 areas designated as community plantation forest or Hutan Tanaman Rakyat (HTR).[8]

---

[7] Ministerial Regulation of Environment and Forestry No. 12 Year 2015 concerning the Development of Industrial Plantation Forests. Definitions are maintained in the superseding regulation, Ministerial Regulation of Environment and Forestry No. 62 Year 2019. (MOEF, 2019)

[8] Local communities are given rights to maintain community plantation forests or HTR in order to ensure the sustainability of forest resources by applying silviculture techniques in designated HTR areas.

The study calls for urgent forest governance reforms, given the higher risks of deforestation and growing inequality in forest land ownership and access. High demand for biomass co-firing would only exacerbate these issues, since HTI-HTE projects could be exempted from standard procedures if categorized as national strategic projects (CELIOS, 2024b). **Under the guise of Indonesia's energy transition strategy, biomass co-firing requiring supply from HTI and/or HTE could significantly undermine the previously established forest use governance that prioritizes sustainability and people's sovereignty in the context of forestry.**

As highlighted in an info brief released by the Parliamentary Analysis Center of the Expert Body of the People's Representative Council of Indonesia (*Pusat Analisis Keparlemenan Badan Keahlian Dewan Perwakilan Rakyat Republik Indonesia*), **current forestry regulations have yet to specify restrictions on the types of energy crops, have not included ecological carrying capacity evaluation parameters, as well as the necessary spatial arrangements in HTE development**. The brief also notes the absence of clauses regarding the traceability and legality of raw materials. This allows for the potential use of wood from unsustainable sources and the expansion of HTE beyond its ecological carrying capacity (Pusaka BKDPRRI, 2025).

A closer look into common claims

“The use of biomass in co-firing technology at CFPPs would reduce carbon emissions.” - [PLN]

A briefing from Trend Asia and Environmental Paper Network (EPN) highlights that the **claimed reduction is not proven, and burning coal with biomass will actually increase carbon emissions, especially in the forest and land sector** (Trend Asia & EPN, 2023). The current co-firing scheme would instead produce 27 $MtCO_2$ annually from deforestation, improper land-use practices, and feedstock processing (FWI, 2024a; FWI, 2023; Betahita, 2022; IEEFA, 2021). Claims of GHG emissions reduction cannot be justified without supply chain transparency and governance on source identification and tracing.

Bioenergy impacts on climate are highly complex, dependent on socioeconomic and institutional context, lands used and feedstock types, program scale and production practices, conversion processes, and implementation rate (Chum et al., 2011). Extensive review on biopower life cycle assessment (LCA), including biomass co-firing in coal power plants, direct combustion, and gasification, shows a wide variation in range, from negative up to nearly -1,000 g CO2-eq/kWh to positive reaching +1,300 g CO2-eq/kWh (NREL, 2021).

Consistent and transparent benchmarking is necessary before claiming lower emissions, such as biopower and other renewables against coal, as shown in Figure 12.

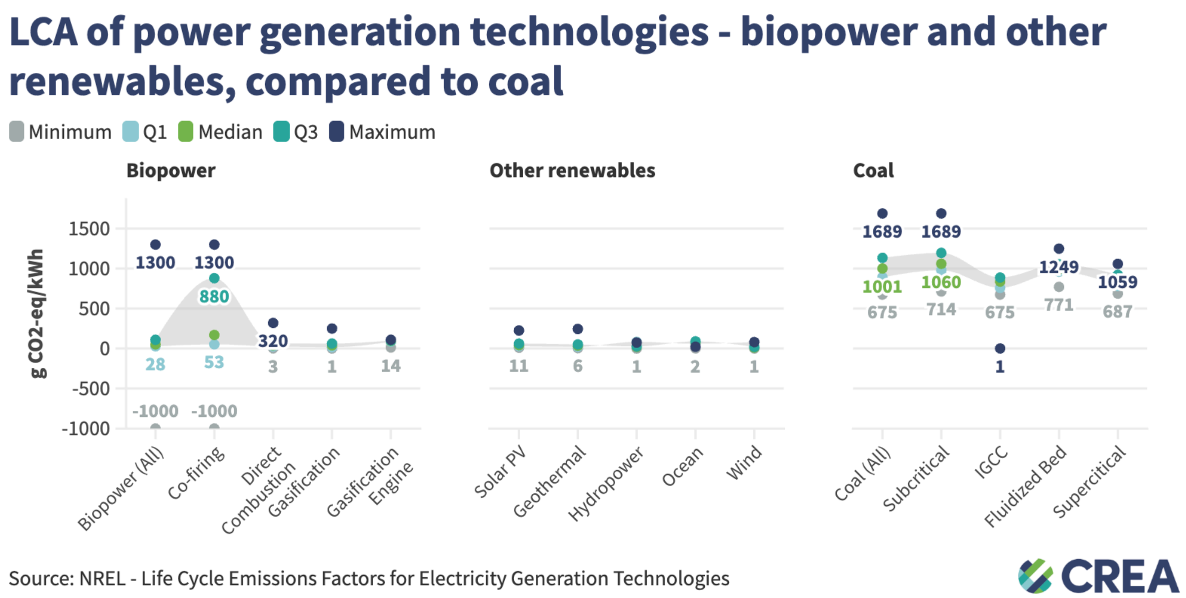


Figure 12. LCA of GHG emissions from biopower and other renewables, compared to coal

The benchmarked LCAs referenced in Figure 12 for biomass co-firing **only represent the biomass portion, without emissions and electricity output associated with coal**.[9] Estimates related to avoided emissions from biomass co-firing would only come from the use of the feedstock leading to the avoided methane emissions from landfills, currently most commonly available in literature (Chum et al., 2011).

The positive upper range in the LCAs for biopower systems, can be interpreted as positive release of GHG emissions, strongly insinuating that improper practices in land use conversion and forest management would lead to both direct and indirect carbon stock losses. Such practices negate the net positive GHG mitigation that could be achieved through best practices in bioenergy harvesting, strict management of protected areas, and close engagement with local communities.

"Development of biomass ecosystems as the main raw material for coal substitute fuel or co-firing in coal-fired power plants, is for people-based economy" - PLN

PLN claims that co-firing supports a people-based economy. PT Pembangkitan Jawa Bali (PLN Nusantara Power), a subsidiary of PLN, reports that a 5% biomass co-firing ratio in the Java-Bali system has created 160 biomass-related industries and 1,600 jobs. In 2024, the initiative was said to generate IDR 2 trillion annually, involving 250,000 people (PLN, 2024b; ERIA, 2022). In February 2025, PLN announced the launch of a people-based biomass development program through planting 50,000 multifunctional trees across 15 hectares of land area, and inaugurated a seedling house in Karang Asem, Gunungkidul, Yogyakarta, with Keraton Yogyakarta and the local community (PLN EPI, 2025).

On the other side of the coin, Forest Watch Indonesia projected that deforestation of natural forests to meet co-firing needs in 52 CFPPs could reach 4.65 million hectares, involving 43 HPH companies, 147 HTI companies, and 1,124 PS concessions (FWI, 2023).[10] Trend Asia's analysis revealed that community involvement is strictly limited, with farmers hired as plantation laborers, while wood-based small and medium enterprises are only provided a share to supply low-priced waste feedstock, such as sawdust. Wood-based bioenergy is dominated by long-time coal and timber industry corporate conglomerates, and even coal companies (Trend Asia, 2024).

[9] Co-firing refers to coal-biomass blend (coal unaccounted in the LCA), and the other biopower technologies use 100% bioenergy sources

[10] HPH (*Hak Pengusahaan Hutan*) - Natural Forest Concession, HTI (*Hutan Tanaman Industri*) - Industrial Plantation Forest, PS (*Perhutanan Sosial)* - Social Forestry

The real impact of land clearing and deforestation is not accounted for or discussed. Trend Asia notes poor governance that often leads to conflicts between the companies and local indigenous communities that have previously managed the land. Instances of conflict, such as in NTB between farming communities and PT Sadhana Arifnusa, and in Papua between indigenous communities and PT Selaras Inti Semesta, should become a warning sign for relevant national stakeholders (Trend Asia, 2024).

A "people-centered biomass economy" goes beyond new jobs and revenues, as it should prioritise equity and ensure just aspects for vulnerable populations, where key biodiversity areas and designated lands owned and managed by indigenous people and local communities should be a “no-go” for bioenergy extraction and cultivation. In addition, impacted communities must be given rights to free, prior, and informed consent (FPIC) and a right to veto designation of HTE on their lands, even those already converted (Earth Insight et al., 2024)

“Because most biomass fuels have less sulfur and nitrogen than coal, NOx and SOx emissions can often be reduced by co-firing biomass.” - Studies

Co-firing coal with biomass could reduce emissions of health-harming air pollutants – namely, nitrogen oxides (NO_x) and sulfur dioxide (SO_2); however, **the extent of reduction is largely dependent on the nitrogen and sulfur content of the biomass feed, as well as the mixing share and the combustion conditions (boiler technology, co-firing method, operational parameters of the coal mill, the boiler, and the furnace), and feedstock handling** (Sugiyono et al., 2022).

Common biomass feedstocks available in Indonesia have negligible sulfur content (mostly below 0.1%, and only certain types as high as 0.5%) – certainly much lower than that of domestic coal (0.2-2.5%) (Triani et al., 2022; Belkin and Tewalt, 2007). For this reason, a higher biomass share would mean less coal use and, hence, lower sulfur oxide release.

On the other hand, NO_x emission in biomass combustion has a linear relation with the nitrogen content of the biomass fuel. Nitrogen content of Indonesian coal is considerably low (0.5 to 1.4%), perhaps on par with the nitrogen content of rice husk, palm kernel shells and palm fruit bunches, and certain types of woods (0.2-0.6%), and lower than some types of feedstock such as eucalyptus pellets (3.1%), tea waste (3.5%), and food waste (1.3%). Small changes in NOx concentration have been observed in studies – one study noted reduction by 2 to 3%, another a slight increase by 3.5%, and added a remark of decreased combustion quality (Triani et al., 2022).

Particulate matter (PM) emission is similarly heavily influenced by the elemental composition of the biomass fuel, namely potassium, chlorine, and sulfur. For instance, wheat bran co-fired in a CFB at a 50% share shows significant reduction up to 90%, while wood chips fired at 4% share have no impact on PM release (Al-Naiema et al., 2015).

CREA's analysis shows that reaching a minimum of 20% co-firing share at all grid-connected power plants will not only be challenging in terms of supply limitations, but also, more notably, that **biomass co-firing has little impact on the emissions of air pollutants from Indonesia's coal power plants**. Reduction of air pollution from coal power plants can only be achieved through the proper installation of emission control technology. Therefore, **without consideration for strengthened emission standards, biomass co-firing strategy alone virtually cannot be linked to clean air effort**.

As shown in Figure 13, the current 10% scenario target would deliver a 9% emission reduction in PM release, about 7% in NOx, and 10% in SOx at coal power plants where biomass co-firing is implemented. Given that the analysis includes the entire country's coal fleet and considers plant-level variations, the results showing negligible aggregated reduction between 1.5 to 2.4% can well represent the projected outcome. **Meaningful air pollution reduction requires the installation of efficient emission control technology in all coal power plants operating beyond 2035.** Installation of Air Pollution Control (APC) technologies, as enforced through stringent emission standards, would reduce emissions of SO_2 by 73%, NO_x by 64%, PM by 86%, as well as mercury by 71% (CREA, 2023).

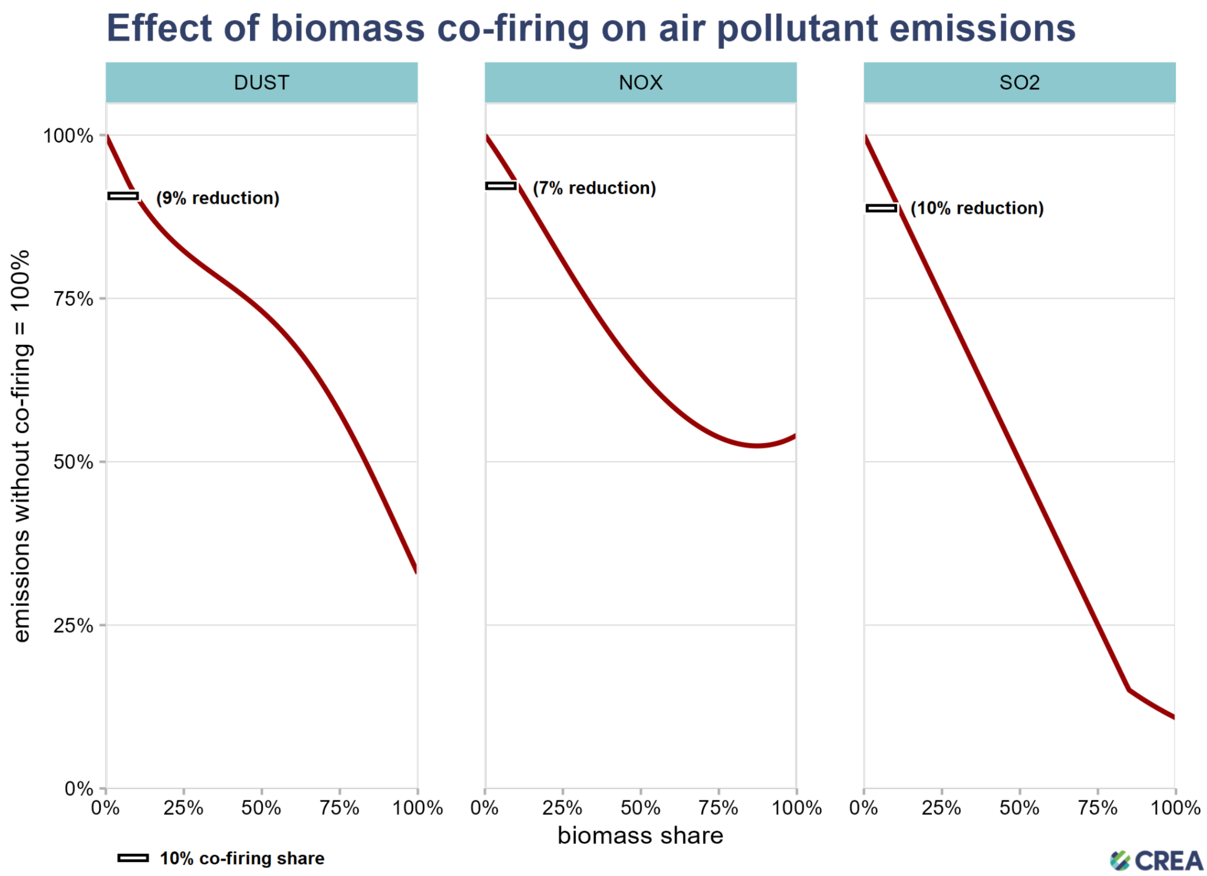


Figure 13. Air pollutant emissions change based on the biomass co-firing share

In addition, there should be awareness that the **emission threshold limits set for coal and biomass power generation differ, where biomass power plants are allowed to release higher concentrations of SO_2, NO_x, and PM or dust**, illustrated in Figure 14. The limit for mercury release in biomass power generation is about 150 times higher than what is currently enforced for all coal power plants at 0.03 mg/m^3 (MOEF, 2019).

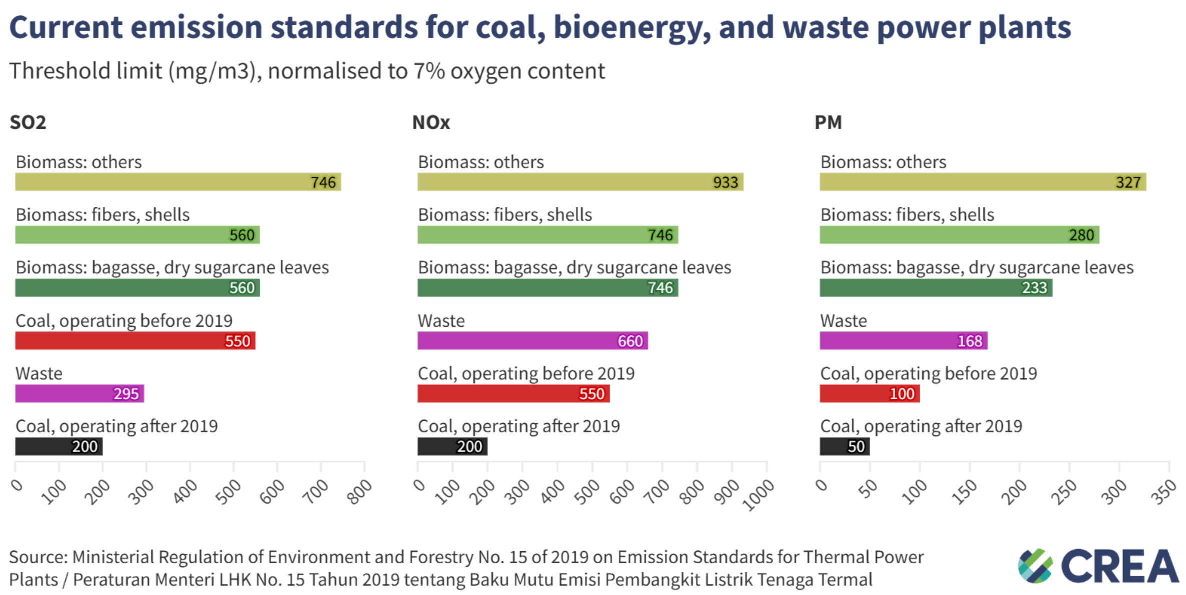


Figure 14. Indonesia's emission standards for power generation using coal before and after 2019, different types of biomass, and waste

Furthermore, there are limits set for gaseous releases of air pollutants not enforced for coal power plants. For biomass power plants, these include carbon monoxide (CO), hydrogen sulfide (H_2S), ammonia (NH3), hydrogen chloride (HCl), chlorine (Cl_2), hydrogen fluoride (HF), as well as traces of heavy metals such as arsenic (As), antimony (Sb), cadmium (Cd), zinc (Zn), and lead (Pb). For waste power plants, a limit for dioxins and furans, which are persistent organic pollutants or forever chemicals known to bioaccumulate and pose risks to human health, is also set and monitored every five years (MOEF, 2019).

While the regulation defines limits for thermal power plants that operate using a blend of coal, oil, and natural gas, there are no specific air pollution limits set for coal-fired power plants where biomass co-firing is implemented (MOEF, 2019). **If the 52 CFPPs only adhere to emission standards set for coal power plants, other air pollutants linked to specific feedstock combustion and regulated in biomass power plants might end up simply released without any monitoring**.

Conclusion and policy recommendations

Despite Indonesia's climate-aligned plans emphasizing bioenergy for its net-zero emissions target by 2060, the recent national electricity plan (RUKN 2024-2060) has significantly reduced bioenergy targets, prioritizing abated coal power through CCS in coal-biomass co-firing plants. The ambitious goal of implementing biomass co-firing in 52 CFPPs faces consistent setbacks due to PLN's low reference prices for biomass feedstock, limiting economically viable options to low-cost, low-calorific materials like sawdust and rice husk.

This is further compounded by a growing export market to Japan and South Korea. Instead of addressing these fundamental issues or shifting focus to other promising renewable sources such as solar, wind, geothermal, and hydropower, national stakeholders remain committed to biomass co-firing, merely pushing the 2025 target of 10.2 million tonnes of biomass use to 2031.

PLN's promotion of biomass co-firing as a strategy for a people-centered green economy and emissions mitigation lacks transparent and thorough assessment, raising questions about the undisclosed "true" costs and emissions associated with feedstock supply and co-firing operations, as well as the absence of a transparent and economically viable supply chain. Claims of air pollution mitigation through biomass co-firing are also dubious, as its impact on reducing health-harming pollutants from coal power generation is negligible at current targets.

Effectively tackling air pollution necessitates a clear coal power plant retirement pathway, considering health benefits and economic gains. Furthermore, meaningful emissions reduction in thermal power plants during the transition requires stringent emissions standards and the widespread adoption of APC technologies, aligning national thresholds with the most stringent existing levels for newer coal power plants.

CREA outlines the following recommendations to enable effective utilisation of bioenergy as one of Indonesia's abundant renewable sources for power generation;

Prioritising accountability and transparency through monitoring and evaluation – A framework that enables proper assessment of plant-level implementation of bioenergy use – co-fired in coal power plants, single-type or blended in bioenergy power plants, would provide data-driven insights to stakeholders, informing the flow of supply, utilisation, and operational costs. The collected data could serve as a basis to develop a roadmap for bioenergy, which could help provide clarity for suppliers, allowing the market to naturally develop to fill unmet demands.

Implementing Life Cycle Assessment (LCA) for a comprehensive quantification of emission mitigation – Claims on emission mitigation from biomass co-firing in PLN's coal power plants currently only account for reduction in fossil fuel emissions. The environmental impact of the biomass supply chain tied to specific feedstocks remains unquantified and undisclosed. To justify the use of bioenergy as a sustainable initiative, PLN should require independent verification of emissions released throughout the value chain — enabling origin tracing and covering harvesting, processing, and transportation.

Raising the urgency to prioritise phase out of coal power generation and accelerate deployment of renewable energy for a genuinely sustainable and just energy future — Biomass co-firing is a false climate strategy that enables prolonged coal use throughout the transition decades, while raising risks of deforestation, as well as negatively impacting the livelihood of local communities and indigenous peoples. Furthermore, there is virtually nothing to gain for climate and clean air from co-firing coal and biomass. Quantifiable monetary losses from reduced efficiency and technical operational challenges associated with low-quality biomass should instead be used for renewables deployment, especially considering Indonesia's vast, widely diverse, and abundant potentials.

Methodology

This study investigates the biomass co-firing strategy in Indonesia's coal-fired power plants as promoted by national policies and PLN, the state-owned electricity company. It assesses the implementation, economic feasibility, and environmental implications of the approach, aiming to critically evaluate its role in decarbonisation against reality.

The analysis draws on a diverse range of primary and secondary data sources. Information on implementation was obtained from press releases from PLN's official website, PLN guidelines for co-firing biomass in existing coal-fired power plants, and presentation materials, including the August 2024 update referencing the draft RUPTL 2024–2033.

Plant-level data on biomass usage, the associated power generation, and emissions reduction from avoided coal use were obtained through MEBI. These documents show plant-level targets and actual usage, feedstock types, boiler technology, and co-firing ratios across the 52 CFPPs in the plan for biomass co-firing.

Complementing these sources, the study incorporates policy documents, namely RUKN 2024–2060, RUPTL 2021-2030, Ministerial Regulation of EMR No. 12 Year 2023, LTS-LCCR 2050, and JETP CIPP 2023, to contextualise biomass co-firing within Indonesia's climate and energy planning framework.

Existing analysis of biomass potential, generation, and utilisation across provinces was included to complement datasets and visualisation, and map supply-demand mismatches and the geographic distribution of feedstock availability and power generation infrastructure. Sources include,

1) MEMR reports — Bioenergy Handbook 2023, Strategic Plan (Renstra) of Directorate General of Electricity (DJK) 2020-2024, Handbook Of Energy & Economic Statistics Of Indonesia (HEESI) 2023, Directorate General of New and Renewable Energy and Energy Conservation (DITJEN EBTKE) Performance Report 2023,
2) Association insights — MEBI on implementation insights and Indonesia Biogas Association (ABGI) on the Bioenergy power plants investment guidelines for biomass, biogas, and waste-to-energy power plants 2021,
3) Academic publications — Primadita et al., 2020 on the biomass electricity generation in Indonesia and Squire et al., 2024 on the biomass waste viability to mitigate coal plant emissions in Indonesia.

References

Abdullah, K. (2006, January). Biomass Energy Potentials And Utilization In Indonesia. https://www.researchgate.net/publication/228402035_Biomass_Energy_Potentials_And_Utilization_In_Indonesia

Al-Naiema, I., Estillore, A. D., Mudunkotuwa, I. A., Grassian, V. H., & Stone, E. A. (2015). Impacts of Co-firing biomass on emissions of particulate matter to the atmosphere. Fuel, 162, 111-120. https://doi.org/10.1016/j.fuel.2015.08.054

Argus Media. (2024, January 4). Viewpoint: Market eyes Asian PKS price dynamics in 2024. https://www.argusmedia.com/ja/news-and-insights/latest-market-news/2524318-viewpoint-market-eyes-asian-pks-price-dynamics-in-2024

Batampos. (2024, January 15). PLTU Karimun Sukses Uji Coba Biomassa dengan Woodchip Menuju Green Energy. https://kepri.batampos.co.id/pltu-karimun-sukses-uji-coba-biomassa-dengan-woodchip-menuju-green-energy/#google_vignette

Belkin, H. E., & Tewalt, S. J. (2007). Geochemistry of selected coal samples from Sumatra, Kalimantan, Sulawesi, and Papua, Indonesia. Open-File Report. https://pubs.usgs.gov/of/2007/1202/ofr2007-1202.pdf

Betahita. (2022, August 30). Co-firing Biomassa Berpotensi Menambah Emisi GRK Dan Deforestasi. https://betahita.id/news/detail/7908/co-firing-biomassa-berpotensi-menambah-emisi-grk-dan-deforestasi.html?v=1671327516

Bisnis.com. (2025, February 12). Indonesia Targetkan Bauran EBT 35% dalam RUPTL 2025-2034. https://hijau.bisnis.com/read/20250212/652/1838906/indonesia-targetkan-bauran-ebt-35-dalam-ruptl-2025-2034

Bloomberg Technoz. (2025, February 3). Energi Fosil Dominasi 85% Listrik RI pada 2024, EBT Baru 15 GW. https://www.bloombergtechnoz.com/detail-news/61842/energi-fosil-dominasi-85-listrik-ri-pada-2024-ebt-baru-15-gw

Center of Economic and Law Studies (CELIOS). (2024b, November 12). Energy transition and deforestation: How regulations facilitate the escalation of agrarian conflicts. https://celios.co.id/energy-transition-and-deforestation-how-regulations-facilitate-the-escalation-of-agrarian-conflicts/

Center of Economic and Law Studies (CELIOS). (2024a, December). BORNEO FOREST'S SILENT SACRIFICE: Japan's Energy Transition and the Shadow of Indonesia Illegal Biomass Trade. https://celios.co.id/wp-content/uploads/2025/01/Global-Supply-Chain-of-Biomass-cus.pdf

Centre for Research on Energy and Clean Air (CREA). (2023, August 16). Health benefits of just energy transition and coal phase-out in Indonesia. https://energyandcleanair.org/publication/health-benefits-of-just-energy-transition-and-coal-phase-out-in-indonesia/

Chum, H., A. Faaij, J. Moreira, G. Berndes, P. Dhamija, H. Dong, B. Gabrielle, A. Goss Eng, W. Lucht, M. Mapako, O. Masera Cerutti, T. McIntyre, T. Minowa, K. Pingoud. (2011). Bioenergy. In IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation [O. Edenhofer, R. Pichs-Madruga, Y. Sokona, K. Seyboth, P. Matschoss, S. Kadner, T. Zwickel, P. Eickemeier, G. Hansen, S. Schlömer, C. von Stechow (eds)], Cambridge University

Press, Cambridge, United Kingdom and New York, NY, USA.
https://www.ipcc-wg3.de/report/IPCC_SRREN_Ch02.pdf

Climate Action Tracker (CAT). (2024, August 30). Indonesia's new climate goals: Positive developments but some red flags. Home | Climate Action Tracker.
https://climateactiontracker.org/blog/indonesias-new-climate-goals-positive-developments-but-some-red-flags/

Dunia Energi. (2021, March 17). Penggunaan Biomassa di PLTU Bisa Timbulkan Beban Keuangan Negara dan PLN, Ini Alasannya.
https://www.dunia-energi.com/penggunaan-biomassa-di-pltu-bisa-timbulkan-beban-keuangan-negara-dan-pln-ini-alasannya/

Earth Insight, Auriga Nusantara, Forest Watch Indonesia, Solutions for Our Climate, Trend Asia, and Mighty Earth. (2024, October). Unheeded Warnings: Forest Biomass Threats to Tropical Forests in Indonesia and Southeast Asia.
https://earth-insight.org/report/forest-biomass-asia/

EMBER. (2024, October 15). Yearly electricity data.
https://ember-energy.org/data/yearly-electricity-data/

ERIA. (2022, May). Forecast of Biomass Demand Potential in Indonesia: Seeking a Business Model for Wood Pellets. ERIA Research Project Report FY2022 No. 01, Jakarta: ERIA, pp.57-58.
https://www.eria.org/uploads/media/Research-Project-Report/2022-01-Biomass-Demand-Potential-Indonesia/9_Ch.3-Biomass-Supply-Potential.pdf

Forest Watch Indonesia (FWI). (2023, November 14). Ilusi Hutan Tanaman Energi.
https://fwi.or.id/ilusi-hutan-tanaman-energi/

Forest Watch Indonesia (FWI). (2024, July 24). Utak Atik Target Bauran Energi Nasional: Potret Ugal-Ugalan Proyek Biomassa.
https://fwi.or.id/potret-ugal-ugalan-proyek-biomassa/#:~:text=Biomassa%20Adalah%20Komoditas%20Mahal&text=Dari%20data%20ekspor%20yang%20kami,harga%20Rp%201500%20per%2Dkilogram

Forest Watch Indonesia (FWI). (2024a, January 12). Membongkar FAKTA : Terobosan Teknologi Co-firing PLN Tidak Sepenuhnya Mampu Tekan Emisi Karbon.
https://fwi.or.id/teknologi-co-firing-pln-tidak-mampu-tekan-emisi-karbon/

Gabungan Pengusaha Kelapa Sawit Indonesia (GAPKI) or Indonesian Palm Oil Association (IPOA). (2022, November 11). Palm shells becoming more promising at global market.
https://gapki.id/en/news/2022/11/11/palm-oil-shells-becoming-more-promising-at-global-market/

Indonesia Biogas Association - Asosiasi Biogas Indonesia (ABGI). (2021, August). Pedoman Investasi Pembangkit Listrik Tenaga Bioenergi - Pembangkit Listrik Tenaga Biomassa, Pembangkit Listrik Tenaga Biogas, Pembangkit Listrik Tenaga Sampah.
https://www.abgi.or.id/wp-content/uploads/2023/06/Pedoman_Investasi-PLT-Bioenergi-PLTBm-PLTBg-PLTSa-id.pdf

Indonesian Biomass Energy Society - Masyarakat Energi Biomassa Indonesia (MEBI). (2024, October 1). Biomass Producers Reject PLN's DMO Proposal, Potential Investment Hamper.
https://mebi.or.id/news/biomass-producers-reject-pln-s-dmo-proposal-potential-investment-hamper

Infosawit. (2025, April 15). DPR Dukung Co-Firing di PLTU: Cara Baru Kurangi Emisi dan Atasi Sampah.
https://www.infosawit.com/2025/04/15/dpr-du

kung-co-firing-di-pltu-cara-baru-kurangi-emisi-dan-atasi-sampah/amp/

Institute for Energy Economics and Financial Analysis (IEEFA). (2021, February 21). Indonesia's Biomass Cofiring Bet - Beware of the Implementation Risks. https://ieefa.org/wp-content/uploads/2021/02/Indonesias-Biomass-Cofiring-Bet_February-2021.pdf

Institute for Essential Services Reform (IESR). (2024, September 5). Minimnya Ambisi Energi Terbarukan di RPP KEN. https://iesr.or.id/minimnya-ambisi-energi-terbarukan-di-rpp-ken/

Investor.id. (2023, March 1). PLTU Paiton Akan Gunakan Biomassa 100%. https://investor.id/business/323298/pltu-paiton-akan-gunakan-biomassa-100

Jakarta Post. (2024, January 16). Indonesia to abandon 23% renewable energy target. https://www.thejakartapost.com/business/2024/01/16/indonesia-to-abandon-23-renewable-energy-target-by-2025.html

Just Energy Transition Partnership (JETP) Indoenesia. 2023. JETP Comprehensive Investment and Policy Plan. https://jetp-id.org/storage/official-jetp-cipp-2023-vshare_f_en-1700532655.pdf

Kompas. (2023, July 12). Purchase Price Becomes a Challenge for Biomass Business Actors. https://www.kompas.id/baca/english/2023/07/11/en-harga-beli-jadi-tantangan-pelaku-usaha-biomassa

Kompas. (2025, February 14). Dokumen Janji Iklim Indonesia Tunggu Persetujuan Presiden Prabowo. https://lestari.kompas.com/read/2025/02/14/110000286/dokumen-janji-iklim-indonesia-tunggu-persetujuan-presiden-prabowo?page=all

Kompas. (2025a, February 4). DPR RI Setujui RPP Kebijakan Energi Nasional, Adaptasi Pertumbuhan Ekonomi 8 Persen. https://lestari.kompas.com/read/2025/02/04/090000486/dpr-ri-setujui-rpp-kebijakan-energi-nasional-adaptasi-pertumbuhan-ekonomi-8

Kompas. (2025b, April 16). PLTU Paiton Didorong Terapkan "Co-firing" Biomassa hingga CCS. https://www.google.com/url?q=https://lestari.kompas.com/read/2025/04/16/110000386/pltu-paiton-didorong-terapkan-co-firing-biomassa-hingga-ccs&sa=D&source=docs&ust=1745792167357220&usg=AOvVaw0WbWhta_p0DLCbSO_75GJa

Kontan.co.id. (2024, September 14). Harga Patokan Tertinggi Biomassa 1,2 Kali Belum Cukup Menarik untuk Cangkang Sawit. (https://industri.kontan.co.id/news/harga-patokan-tertinggi-biomassa-12-kali-belum-cukup-menarik-untuk-cangkang-sawit

Madani Berkelanjutan. (2024, August). Rekomendasi SNDC: Demi Keadilan Iklim Yang Inklusif Di Indonesia. https://madaniberkelanjutan.id/rekomendasi-sndc-demi-keadilan-iklim-yang-inklusif-di-indonesia/

Ministry of Energy and Mineral Resources (MEMR) - Kementerian Energi dan Sumber Daya Mineral (KESDM). (2020, December 29). Cofiring Biomassa Pada PLTU, Strategi Terobosan Pemerintah Kejar Target EBT. https://www.esdm.go.id/id/berita-unit/direktorat-jenderal-ebtke/cofiring-biomassa-pada-pltu-strategi-terobosan-pemerintah-kejar-target-ebt

Ministry of Energy and Mineral Resources (MEMR) - Kementerian Energi dan Sumber Daya Mineral (KESDM). (2020a, December). Strategic Plan of Directorate General of Electricity (DJK) 2020 - 2024. https://gatrik.esdm.go.id/assets/uploads/down load_index/files/5b982-renstra-djk-2020-2024.pdf

Ministry of Energy and Mineral Resources (MEMR) - Kementerian Energi dan Sumber Daya Mineral (KESDM). (2021, June 17). Rencana Co-firing pada PLTU. https://www.esdm.go.id/assets/media/content/content-rencana-co-firing-pada-pltu.pdf

Ministry of Energy and Mineral Resources (MEMR) - Kementerian Energi dan Sumber Daya Mineral (KESDM). (2022, November 21). Keputusan Menteri Energi dan Sumber Daya Mineral Nomor 267.K/MB.01/MEM.B/2022 tentang Pemenuhan Kebutuhan Batubara Dalam Negeri - Decree of the Minister of Energy and Mineral Resources Number 267.K/MB.01/MEM.B/2022 concerning Fulfillment of Domestic Coal Needs. https://jdih.esdm.go.id/dokumen/view?id=2345

Ministry of Energy and Mineral Resources (MEMR) - Kementerian Energi dan Sumber Daya Mineral (KESDM). (2023, November 30). Peraturan Menteri Energi dan Sumber Daya Mineral Nomor 12 Tahun 2023 - Ministerial Regulation of Energy and Mineral Resources Number 12 Year 2023. https://peraturan.bpk.go.id/Details/291410/permen-esdm-no-12-tahun-2023

Ministry of Energy and Mineral Resources (MEMR) - Kementerian Energi dan Sumber Daya Mineral (KESDM). (2023a). Laporan Kinerja ESDM 2023. https://www.esdm.go.id/assets/media/content/content-laporan-kinerja-ditjen-ebtke-tahun-2023.pdf

Ministry of Energy and Mineral Resources (MEMR) - Kementerian Energi dan Sumber Daya Mineral (KESDM). (2024, July). Handbook of Energy & Economic Statistics of Indonesia (HEESI) 2023. https://esdm.go.id/assets/media/content/content-handbook-of-energy-and-economic-statistics-of-indonesia-2023.pdf

Ministry of Energy and Mineral Resources (MEMR) - Directorate General of New and Renewable Energy and Energy Conservation. (2024a, January 22). Bioenergy Handbook 2023. https://ebtke.esdm.go.id/elibrary

Ministry of Energy and Mineral Resources (MEMR), Directorate General of Electricity - Kementerian Energi dan Sumber Daya Mineral (KESDM), Direktorat Jenderal Ketenagalistrikan. (2024b, August). Statistik Ketenagalistrikan 2023. https://gatrik.esdm.go.id/frontend/download_index?kode_category=statistik

Ministry of Energy and Mineral Resources (MEMR), Directorate General of Electricity - Kementerian Energi dan Sumber Daya Mineral (KESDM), Direktorat Jenderal Ketenagalistrikan. (2025, March 3). RUKN 2024-2060, Rencana Umum Ketenagalistrikan Nasional. https://gatrik.esdm.go.id/assets/uploads/download_index/files/28dd4-rukn.pdf

Ministry of Energy and Mineral Resources (MEMR) - Kementerian Energi dan Sumber Daya Mineral (KESDM). (2025a, February 3). Setujui RPP KEN, Menteri ESDM: Selaras dengan target Pertumbuhan Ekonomi Dan Komitmen net zero emission. https://www.esdm.go.id/id/media-center/arsip-berita/setujui-rpp-ken-menteri-esdm-selaras-dengan-target-pertumbuhan-ekonomi-dan-komitmen-net-zero-emission

Ministry of Energy and Mineral Resources (MEMR) - Kementerian Energi dan Sumber Daya Mineral (KESDM). (2025b, February 3). KONFERENSI PERS - Capaian Kinerja Sektor ESDM Tahun 2024. https://esdm.go.id/assets/media/file/file-capaian-kinerja-sektor-esdm-tahun-2024.pdf

Ministry of Energy and Mineral Resources (MEMR) - Kementerian Energi dan Sumber Daya Mineral (KESDM). (2025c, April 15). Peraturan Menteri Energi dan Sumber Daya Mineral Nomor 10 Tahun 2025 - Ministerial Regulation of Energy and Mineral Resources Number 10 Year 2025. https://jdih.esdm.go.id/dokumen/download?id=2025pmesdm10.pdf

Ministry of Energy and Mineral Resources (MEMR) - Kementerian Energi dan Sumber Daya Mineral (KESDM). (2025d, May 26). Konferensi Pers - RUPTL PT PLN (Persero) Tahun 2025-2034 [Video]. https://www.youtube.com/watch?v=O5DJnLElf3A

Ministry of Environment (MOE) - Kementerian Lingkungan Hidup. (n.d.). SRN - Sistem Registri Nasional Pengendalian Perubahan Iklim. https://srn.menlhk.go.id/index.php?r=home%2Findex

Ministry of Environment (MOE) - Kementerian Lingkungan Hidup. (2020, November 20). SK.38/PPI/IGAS/PPI.2/11/2020 - MSEP-010 - Metodologi Penghitungan Reduksi Emisi dan/atau Peningkatan Serapan GRK dalam Kerangka Verifikasi Aksi Mitigasi - Pembangkit listrik tenaga biomassa (untuk kapasitas ≤ 15 MW) yang terhubung ke jaringan dan captive power - Methodology for Calculating Emission Reduction and/or Increased GHG Absorption in the Mitigation Action Verification Framework - Grid-connected biomass power plants (for capacities ≤ 15 MW) and captive power. SRN - Sistem Registri Nasional. https://srn.menlhk.go.id/index.php?r=metodologi%2Fdownload-metodologi-file&id=38

Ministry of Environment and Forestry (MOEF) - Kementerian Lingkungan Hidup dan Kehutanan (KLHK). (2019, April 23). Permen LHK No. 15 Tahun 2019. Database Peraturan | JDIH BPK. https://peraturan.bpk.go.id/Details/286526/permen-lhk-no-15-tahun-2019

Ministry of Environment and Forestry (MOEF) - Kementerian Lingkungan Hidup dan Kehutanan (KLHK). (2019, October 16). Peraturan Menteri Lingkungan Hidup dan Kehutanan Nomor P.62/menlhk/setjen/kum.1/10/2019 Tahun 2019 Tentang Pembangunan Hutan Tanaman Industri - Regulation of the Minister of Environment and Forestry Number P.62/menlhk/setjen/kum.1/10/2019 of 2019 concerning the Development of Industrial Plantation Forests. https://peraturan.go.id/id/permen-lhk-no-p-62-menlhk-setjen-kum-1-10-2019-tahun-2019

Mongabay. (2021, December 21). Tongkol Jagung, Bahan Bakar Alternatif Masa Depan Gorontalo. https://www.mongabay.co.id/2021/12/27/tongkol-jagung-bahan-bakar-alternatif-masa-depan-gorontalo/

National Renewable Energy Laboratory (NREL). (2021, August 3). Life cycle emissions factors for electricity generation technologies | NREL data catalog. NREL Data Catalog. https://data.nrel.gov/submissions/171

Palupi et al. (2024). Analisis Dampak Lingkungan dan Keekonomian Pembangkit Listrik Tenaga Co-firing Biomassa dan Baru bara sebagai Upaya Bauran Energi Terbarukan. https://journal-laaroiba.com/ojs/index.php/elmal/article/view/781

Parepos. (2024, February 2). PLTU Barru Sukses Melakukan Uji Coba Cofiring Biomass Woodpellet 100%. https://parepos.fajar.co.id/2024/02/pltu-barru-sukses-melakukan-uji-coba-cofiring-biomass-woodpellet-%F0%9D%9F%8F%F0%9D%9F%8E%F0%9D%9F%8E/

Perusahaan Listrik Negara (PLN) - State Electricity Company. (2020, March 5). Pedoman

Pelaksanaan Cofiring Pembangkit Listrik Tenaga Uap Berbahan Bakar Batubara dengan Bahan Bakar Biomassa. https://drive.google.com/file/d/1fRLyDc7YWmYr2Spa_kzXpWenU_wYmJeJ/view?usp=drive_link

Perusahaan Listrik Negara (PLN) - State Electricity Company. (2020a, September). Panduan Kajian Pengujian Co-firing Biomassa di PLTU Batubara Eksisting. https://drive.google.com/file/d/1t_9fda0PeGXEl-tFYKBt-1eP7Dh2bjaP/view

Perusahaan Listrik Negara (PLN). (2021, September 28). Rencana Usaha Penyediaan Tenaga Listrik (RUPTL) 2021-2030 - Electricity Supply Business Plan. https://web.pln.co.id/statics/uploads/2021/10/ruptl-2021-2030.pdf

Perusahaan Listrik Negara (PLN) - State Electricity Company. (2022, June 30). Wujudkan Ekosistem Energi Kerakyatan, PLN Sukses Terapkan Sukses Terapkan Co-Firing di 32 PLTU. https://web.pln.co.id/cms/media/siaran-pers/2022/06/wujudkan-ekosistem-energi-kerakyatan-pln-sukses-terapkan-sukses-terapkan-co-firing-di-32-pltu/

Perusahaan Listrik Negara (PLN) - State Electricity Company. (2022a, March 30). Tekan Emisi Lewat Co-Firing, PLN Hasilkan Listrik Hijau 96 Ribu MWh dari 28 PLTU. https://web.pln.co.id/media/siaran-pers/2022/03/tekan-emisi-lewat-co-firing-pln-hasilkan-listrik-hijau-96-ribu-mwh-dari-28-pltu

Perusahaan Listrik Negara (PLN) - State Electricity Company. (2022b). PLN Sustainability Report - Optimizing Strategy in Realizing Sustainable Energy Transition. https://web.pln.co.id/statics/uploads/2022/07/Laporan-Keberlanjutan-2021.pdf

Perusahaan Listrik Negara (PLN) - State Electricity Company. (2023). PLN Sustainability Report - Strengthening the Determination Towards a Sustainable Company. https://web.pln.co.id/statics/uploads/2023/06/SR-PLN-2022_High.pdf

Perusahaan Listrik Negara (PLN) - State Electricity Company. (2023a, February 3). High Percentage Co-Firing Biomassa pada PLTU Existing PLN Group. https://drive.google.com/file/d/1N4VIr7hdbVQBX6YMp-vdCTddzM60VBRz/view?usp=sharing

Perusahaan Listrik Negara (PLN) - State Electricity Company. (2024). PLN Sustainability Report - Collaboration for Sustainability. https://web.pln.co.id/statics/uploads/2024/06/SR-PLN-2023.pdf

Perusahaan Listrik Negara (PLN) - State Electricity Company. (2024a, August 21). Co-firing for Sustainable Energy & Local Community Empowerment [Presentation]. https://asset.kgmedia.id/2024/lestari-awards/pdf/Case%20Study%20Presentation%20-%20PLN_s%20Co-Firing%20Approach_%20A%20Path%20to%20Sustainable%20Energy%20and%20Local%20Community%20Empowerment%20-%20Iwan%20Agung%20Firstantara%20-%20Direktur%20Utama%20PLN%20Energi%20Primer%20Indonesia.pdf

Perusahaan Listrik Negara (PLN). (2024b, October 9). Berdampak positif, PLN Terus Kembangkan Ekosistem Biomassa Berbasis Masyarakat. https://web.pln.co.id/cms/media/siaran-pers/2024/10/berdampak-positif-pln-terus-kembangkan-ekosistem-biomassa-berbasis-masyarakat/

Perusahaan Listrik Negara (PLN) - State Electricity Company. (2025, February 1). Co-Firing Biomassa di PLTU PLN Hasilkan 1,67 Juta MWh Listrik Hijau Sepanjang 2024. https://web.pln.co.id/media/siaran-pers/2025/02/co-firing-biomassa-di-pltu-pln-hasilkan-167-juta-mwh-listrik-hijau-sepanjang-2024

Perusahaan Listrik Negara Energi Primer Indonesia (PLN EPI). (n.d.). Biomassa. https://www.plnepi.co.id/bisnis-kami/biomassa

Perusahaan Listrik Negara Energi Primer Indonesia (PLN EPI). (2025, February 11). PLN EPI Keraton Yogyakarta Dan Masyarakat Gunung Kidul Sinergi Kembangkan Ekosistem Biomassa Berbasis Kerakyatan. https://www.plnepi.co.id/media-informasi/ruang-media/siaran-pers/pln-epi-keraton-yogyakarta-dan-masyarakat-gunung-kidul-sinergi-kembangkan-ekosistem-biomassa-berbasis-kerakyatan

Primadita, Dony & Kumara, I Nyoman Satya & Ariastina, W.G.. (2020). A Review on Biomass for Electricity Generation in Indonesia. Journal of Electrical, Electronics and Informatics. 4. 1. 10.24843/JEEI.2020.v04.i01.p01. https://www.researchgate.net/publication/341749098_A_Review_on_Biomass_for_Electricity_Generation_in_Indonesia

Pusat Analisis Keparlemenan Badan Keahlian Dewan Perwakilan Rakyat Republik Indonesia (Pusaka BKDPRRI) - Parliamentary Analysis Center of the Expert Body of the People's Representative Council of Indonesia. (2025, April). Dampak Energi Hijau Jepang, Korea Selatan, dan Kebijakan Co-Firing Bagi Hutan Indonesia. https://berkas.dpr.go.id/pusaka/files/info_singkat/Info%20Singkat-XVII-7-II-P3DI-April-2025-189.pdf

Radio Republik Indonesia (RRI). (2023, Desember 18). PLTU Sintang Jalankan 100 Persen Firing Biomassa. https://www.rri.co.id/pontianak/bisnis/484597/pltu-sintang-jalankan-100-persen-firing-biomassa

Republic of Indonesia. (2021). Indonesia Long-Term Strategy for Low Carbon and Climate Resilience 2050 (Indonesia LTS-LCCR 2050). https://unfccc.int/sites/default/files/resource/Indonesia_LTS-LCCR_2021.pdf

Republic of Indonesia. (2022). Enhanced Nationally Determined Contribution. https://unfccc.int/sites/default/files/NDC/2022-09/23.09.2022_Enhanced%20NDC%20Indonesia.pdf

RIM Intelligence. (2025, March 6). Rim Biomass (Solid) Intelligence Weekly. https://www.rim-intelligence.co.jp/report/sample/ebio_sample.pdf

Solutions for Our Climate (SFOC). (2025, January 19). South Korea to reduce subsidies for biomass energy, explained. https://forourclimate.org/research/558

Suarabaru. (2023, January 27). Limbah Jagung Ternyata Mampu Menghasilkan Dolar. https://suarabaru.id/2023/01/27/limbah-jagung-ternyata-mampu-menghasilkan-dolar

Sugiyono, A., Febijanto, I., Hilmawan, E., & Adiarso. (2022). Potential of biomass and coal Co-firing power plants in Indonesia: A PESTEL analysis. IOP Conference Series: Earth and Environmental Science, 963(1), 012007. https://doi.org/10.1088/1755-1315/963/1/012007

Susanto et al. (2023). Analisa Teknis Uji Bakar Pelet Sekam Padi dan Kajian Keekonomian Co-Firing Pada Pulverizer Coal (PC) Boiler Sub-Critical 300 MW Studi di PLTU Indramayu = Technical Analysis Of Rice Husk Pellet Combustion Test And Economic Study Of Co-Firing In 300 MW Sub-Critical Pulverizer Coal (PC) Boiler Study in Indramayu Power Plant. https://lib.ui.ac.id/detail?id=9999920525850&lokasi=lokal#:~:text=Ditinjau%20dari%20keekonomiannya%2C%20harga%20pelet%20sekam%20padi

Squire, C. V., Lou, J., & Hilde, T. C. (2024). The viability of Co-firing biomass waste to mitigate coal plant emissions in Indonesia. Communications Earth & Environment, 5(1). https://doi.org/10.1038/s43247-024-01588-0

Trend Asia & Environmental Paper Network (EPN). (2023, November 22). Co-firing with biomass in Indonesia: Debunking Emission Reduction Claims. https://environmentalpaper.org/2023/11/co-firing-with-biomass-in-indonesia-debunking-emission-reduction-claims/

Trend Asia. (2022, November 17). Supposedly "Green" biomass energy plantations threatens deforestation in world's second largest rainforest. https://trendasia.org/en/supposedly-green-biomass-energy-plantations-threatens-deforestation-in-worlds-second-largest-rainforest/

Trend Asia. (2024, July 3). Penangguk Cuan Transisi Energi. https://trendasia.org/penangguk-cuan-transisi-energi/

Triani, M., Tanbar, F., Cahyo, N., Sitanggang, R., Sumiarsa, D., & Lara Utama, G. (2022). The potential implementation of biomass Co-firing with coal in power plant on emission and economic aspects: A review. EKSAKTA: Journal of Sciences and Data Analysis. https://journal.uii.ac.id/Eksakta/article/view/25105

Appendix

Table A1. Implementation of biomass co-firing in 52 CFPPs across Indonesia – 47 CFPPs in 2024 and 5 CFPPs targeted

#	CFPP name	Location	Boiler type	Unit and capacity (MW)	Type of biomass*	Co-firing portion (%)	Biomass usage (ton)*	Est. electricity production (MWh)*	Est. emissions of the co-fired biomass (ton CO2)*
	Region: Java, Madura, Bali (JAMALI)								
1	Paiton 1-2	Probolinggo, East Java	PC	2x400	Sawdust	5	145,302	158,094	154,977
2	Pacitan 1-2	Pacitan, East Java	PC	2x315	Sawdust	5	96,177	97,337	99,479
3	Rembang 1-2	Rembang, Central Java	PC	2x315	Sawdust	5	99,072	108,187	111,325
4	Paiton 9	Probolinggo, East Java	PC	1x660	Sawdust	5	33,829	37,051	36,903
5	Tanjung Awar Awar 1-2	Tuban, East Java	PC	2x350	Sawdust	3	53,120	56,672	58,372
6	Indramayu 1-3	Indramayu, West Java	PC	3x330	Sawdust	5	53,839	56,612	56,102
7	Suralaya 1-4	Cilegon, Banten	PC	4x400	Sawdust	5	74,403	72,789	70,751
8	Suralaya 5-7	Cilegon, Banten	PC	3x600	Sawdust	N/A	72,224	76,915	70,253
9	Lontar 1-3 + Lontar Expansion	Tangerang, Banten	PC	3x315	Sawdust	1	116,541	134,264	143,931
10	Labuan 1-2	Pandeglang, Banten	PC	2x300	Sawdust	5	59,287	69,997	73,147
11	Pelabuhan Ratu 1-3	Sukabumi, West Java	PC	3x350	Sawdust	5	61,011	58,114	61,717
12	Adipala	Cilacap, Central Java	PC	1x660	Sawdust	5	67,545	79,940	72,185
13	Suralaya 8	Cilegon, Banten	PC	1x625	Sawdust	N/A	56,832	59,977	63,456

#	CFPP name	Location	Boiler type	Unit and capacity (MW)	Type of biomass*	Co-firing portion (%)	Biomass usage (ton)*	Est. electricity production (MWh)*	Est. emissions of the co-fired biomass (ton CO2)*
	Region: Sulawesi, Maluku, Papua, Nusa Tenggara (SULMAPANA)								
14	Jeranjang 1-3	West Lombok, West Nusa Tenggara	CFB	3x25	Sawdust, Waste Pellet	3	26,121	23,137	32,971
15	Gorontalo 1-2	North Gorontalo, Gorontalo	CFB	2x25	Woodchip & Sawdust	5	861	558	924
16	Sulsel Barru 1-2	Barru, South Sulawesi	CFB	2x50	Sawdust	3**	17,071	18,283	26,237
17	Ropa 1-2	Ende, East Nusa Tenggara	Stoker	2x7	RDF Pellet	10	288	297	531
18	Kupang 1-2	Kupang, East Nusa Tenggara	CFB	2x16.5	Woodchip	5**	4,553	4,621	6,692
19	Nii Tanasa 1-3	Kendari, Southeast Sulawesi	Stoker	3x10	Palm Kernel Shell	N/A	8,016	6,656	12,800
20	Punagaya 1-2	Jeneponto, South Sulawesi	CFB	2x100	Corn Cob	5	15,495	17,439	20,107
21	Amurang 1-2	South Minahasa, North Sulawesi	CFB	2x30	Sawdust	5	1,075	964	1,686
22	Sumbawa Barat 1-2	West Sumbawa, West Nusa Tenggara	Stoker	2x7	Corn Cob	3	4,166	2,898	4,814
23	Holtekamp 1-2	Jayapura, Papua	Stoker	2x10	Woodchip	N/A	5,402	3,709	8,142
24	Ampana 1-2	Tojo Una-Una, Central Sulawesi	Stoker	2x3	Woodchip	5	-	-	-
25	Tidore 1-2	Tidore Islands, North Maluku	Stoker	2x7	Woodchip	5	676	409	722

#	CFPP name	Location	Boiler type	Unit and capacity (MW)	Type of biomass*	Co-firing portion (%)	Biomass usage (ton)*	Est. electricity production (MWh)*	Est. emissions of the co-fired biomass (ton CO2)*
	Region: Sumatera, Kalimantan (SUMKAL)								
26	Ketapang 1-2	Ketapang, West Kalimantan	CFB	2x10	Palm Kernel Shell	5	945	720	1,491
27	Sanggau 1-2	Sanggau, West Kalimantan	Stoker	2x7	Palm Kernel Shell	5	19,377	15,234	29,888
28	Bukit Asam 1-4	Muara Enim, South Sumatra	PC	4x65	Sawdust	5	10,011	9,149	8,463
29	Sintang 1-3	Sintang, West Kalimantan	Stoker	3x7	Palm Kernel Shell	5*	37,590	31,137	60,500
30	Pulang Pisau 1-2	Pulang Pisau, Central Kalimantan	CFB	2x60	Sawdust	5	31,235	30,470	39,276
31	Asam Asam 1-4	Tanah Laut, South Kalimantan	PC	4x65	Sawdust	5	10,867	11,945	15,087
32	Tarahan 3-4	South Lampung, Lampung	CFB	2x100	Woodchip	3	52,546	64,205	61,187
33	Nagan Raya 1-2	Nagan Raya, Aceh	CFB	2x110	Palm Kernel Shell	5	17,464	16,176	18,344
34	Suge 1-2	Belitung, Bangka Belitung	CFB	2x16.5	Palm Kernel Shell	5	5,486	4,356	6,865
35	Berau 1-2	Berau, East Kalimantan	Stoker	2x7	Palm Kernel Shell	5	2,170***	-	2,719***
36	Air Anyir 1-2	Bangka, Bangka Belitung	CFB	2x30	Woodchip	5**	33,839	26,612	43,537
37	Pangkalan Susu 1-2	Langkat, North Sumatra	PC	2x220	Rice Husk	N/A	43,120	41,810	50,674

#	CFPP name	Location	Boiler type	Unit and capacity (MW)	Type of biomass*	Co-firing portion (%)	Biomass usage (ton)*	Est. electricity production (MWh)*	Est. emissions of the co-fired biomass (ton CO2)*
38	Teluk Balikpapan 1-2	Balikpapan, East Kalimantan	CFB	2x110	Woodchip	5	892	880	1,305
39	Sebalang 1-2	South Lampung, Lampung	CFB	2x100	Woodchip	3	43,768	37,932	55,305
40	Malinau 1-2	Malinau, North Kalimantan	Stoker	2x3	Palm Kernel Shell	N/A	22	15	32
41	Ombilin 1-2	Sawahlunto, West Sumatra	PC	2x100	Sawdust	N/A	12,458	9,791	11,348
42	Bengkayang 1-2	Bengkayang, West Kalimantan	CFB	2x50	Palm Kernel Shell	N/A	3,756	3,900	5,710
43	Tenayan 1-2	Pekanbaru, Riau	CFB	2x110	Sawdust	5	31,295	32,370	49,397
44	Teluk Sirih 1-2	Padang, West Sumatra	CFB	2x112	Sawdust	N/A	23,268	21,034	28,101
45	Tembilahan 1-2	Indragiri Hilir, Riau	Stoker	2x7	Woodchip	25**	2,800	1,868	3,423
46	Tanjung Balai Karimun 1-2	Batam, Riau Islands	Stoker	2x7	Woodchip	N/A**	655	405	601
47	Labuhan Angin 1-2	Central Tapanuli, North Sumatra	CFB	2x115	Sawdust	N/A	1,250	1,147	1,585

#	CFPP name	Location	Boiler type	Unit and capacity (MW)	Type of biomass*	Co-firing portion (%)	Biomass usage (ton)*	Est. electricity production (MWh)*	Est. emissions of the co-fired biomass (ton CO2)*
	Remaining five targeted power plants								
48	Tanjung Jati 1-2	Jepara, Central Java	PC	2x660	Sawdust	-	-	-	-
49	Tanjung Jati 3-4	Jepara, Central Java	PC	2x660	Sawdust	-	-	-	-
50	Kalselteng	Central Kalimantan	Stoker	2x100	Palm Kernel Shell	-	-	-	-
51	Lombok FTP 2	Lombok, West Nusa Tenggara	CFB	2x50	Woodchip	-	-	-	-
52	Sofifi	Oba Tengah, North Maluku	Stoker	2x3	Woodchip	-	-	-	-
	Total of JAMALI region						**989,182**	**1,065,949**	**1,072,598**
	Total of SULMAPANA region						**83,724**	**78,971**	**115,626**
	Total of SUMKAL region						**384,814**	**361,156**	**494,838**
	Overall Total						**1,457,720**	**1,506,076**	**1,683,062**

**Data was gathered from the Indonesian Biomass Energy Society (MEBI) energy specialist, Ifnaldi Sikumbang, in March 2025*
***Successful trial for 100% biomass co-firing share in three locations, namely Tembilahan in Riau, Air Anyir in Bangka Belitung, and Bolok in East Nusa Tenggara in 2023 (Investor.id, 2023), Sintang unit 1 in West Kalimantan in 2023 (RRI, 2023), Tanjung Balai Karimun in Riau in 2024 (Batampos, 2024), and Barru in South Sulawesi in 2024 (Parepos, 2024)*
****Assuming average emission factor for sawdust at 1.25 ton CO_2/ton sawdust, calculated from MEBI shared data*

Table A2. National regulations on biomass co-firing

Information	PLN Director's Regulation No. 001 Year 2020*	Ministerial Regulation of EMR No. 12 Year 2023
In force	5 March 2020	27 November 2023
Biomass type	organic wood materials (wood chips and wood pellets), plantation waste (palm shells), forest waste, and waste that has been processed into Solid Refuse Fuel (SRF) — with 95% biomass content and moisture at or below 20%	a) derived entirely from organic materials; and b) derived partly from organic materials a) includes biomass pellets, wood dust, wood chips, palm shells, rice husks, coconut shells, forestry waste, agricultural waste, and other organic materials b) includes solid combustible materials from solid waste, and organic materials mixed with combustible inorganic materials
National target	not specified	Annual targets from 2023 to 2030 1.05 million tonnes in 2023 to 8.91 million tonnes in 2030
Pricing	Highest reference price** **Rated against 3-month averaged plant-specific coal pricing (inclusive of transportation cost), using two correction factors: calorific value ratio and 0.85 to account for addition or modification to existing infrastructure to accommodate biomass use	Highest reference price - applicable to PLN and IPPs in partnership with PLN*** Agreed price - applicable to other electricity producers not linked to PLN, generating for public and/or own use ***Same calculation as noted in **), with a correction factor of 1.20 instead of 0.85

** Amended through PLN Director's Regulation No. 004 Year 2022, highlighting biomass fuel specifications and parameters are based on applicable Indonesian National Standards (SNI) (PLN, 2023a). Existing SNI standardises the biomass pellets (SNI 8966-2021), SRF (SNI 9031-2021), sawdust (SNI 9032-2021), woodchips (SNI 9033-2021), and rice husk pellets (SNI 9125-2022)*

Table A3. Installed capacities of bioenergy power plants in Indonesia by province

Province	Bioenergy powerplant (MW)			Total (MW)
	Biogas	Biomass	Waste-to-energy	
Aceh		22		22
Bali		2	20	22
Bangka Belitung Islands	14	49		63
Banten		30	40	70
Bengkulu	3			3
Central Java		19	31	50
Central Kalimantan	12	19		31
DKI Jakarta			74	74
East Java	2	126	11	139
East Kalimantan	7	25		32
East Nusa Tenggara		4		4
Gorontalo		1		1
Jambi	17	65		83
Lampung	6	36		42
North Maluku		10		10
North Sulawesi		0	20	20
North Sumatra	18	265		283
Papua		4		4
Riau	42	66		108
Riau Islands	1	1		2
South Kalimantan	6	5		11
South Sulawesi		17	20	37
South Sumatra	10	235	20	265
West Java	5	2	46	53
West Kalimantan	2	42		44
West Nusa Tenggara		1		1
West Sulawesi		2		2
West Sumatra	1	5		6
Grand Total	**146**	**1052**	**281**	**1480**