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POLICY BRIEF

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HOW GREEN IS BIOMASS CO-FIRING AS AN EMISSIONS ABATEMENT STRATEGY?

Limited availability of biomass waste and difficulty of tracking carbon released from lands could undermine coal phaseout strategies in Indonesia

Several coal-powered countries look to biomass co-firing in coal plants as a means to draw down on energy sector emissions while seeing out the lifetime of plants, thereby reducing the financial cost of the energy transition. Biomass is considered by many as a renewable energy resource (in the form of wood chips, palm kernel shells, rice husks, sawdust, and other feedstocks) and the use and international trade of biomass feedstock is growing. Biomass sourcing is fundamentally bound to land use, however, either in the form of waste from already-existing agricultural practices, for example, or from conversion of forest land for the sake of generating biomass feedstock (often in the form of wood pellets). Land use change emissions through deforestation, agricultural conversion, and other activities typically constitute one of the major sources of emissions. It is therefore vital that an accurate accounting of emissions from co-firing coal plants include land use change emissions and other impacts of biomass feedstock production, particularly if feedstock demand outstrips existing biomass waste supply. An overall emissions abatement strategy that lowers emissions in one sector only to increase them in another may do little to mitigate emissions and, indeed, could increase total emissions. Countries relying on biomass co-firing as a coal abatement strategy could undermine their overall emissions reduction goals, conservation of biodiversity, and the welfare of local and indigenous communities unless guided by comprehensive carbon accounting and clear, robust, and enforceable policy.

Indonesia's two largest sources of emissions are land-use change and energy production (Climate Watch, n.d.). Indonesia seeks to have 52 coal plants co-firing biomass by 2025, while Indonesian biomass exports also continue to grow, particularly in the form of palm kernel shells (PKS) (PT PLN (Persero), 2021). The country's nationally determined contribution (NDC) states that Indonesian coal plants will co-fire 9 million tons of biomass per year by 2030, and the Just Energy Transition Partnership investment plan projects that bioenergy will contribute to 7% of the coal generation mix by 2030 and 9% beyond 2040 (JETP Secretariat, 2023; Republic of Indonesia, 2022). Effectively reducing emissions in Indonesia's energy sector requires mitigating coal plant emissions while avoiding additional emissions from land use change, which remains Indonesia's largest sector for carbon emissions. At present, the extent to which implementing biomass co-firing provides a plausible and effective mitigation strategy within the country remains unclear.

In this brief, we investigate the viability and emissions reductions potential of using biomass waste for co-firing at coal plants in Indonesia. We first surveyed biomass waste availability and calculated unutilized residues under the assumption that the use of biomass waste requires little to no further land use change. We then compared the supply of biomass waste with coal-plant level demand at the national and provincial levels under three scenarios. Additionally, we determined seasonal biomass availability, given varying levels of supply of different types of feedstock per tropical wet and dry seasons, and the emissions reduction potential under the implementation of each scenario.

Our key findings include:

- When accounting for current alternate utilizations, less than a third of all biomass residues generated remain available for use in co-firing.
- Even at modest co-firing ratios, available biomass supply struggles to meet demand in eastern Indonesia, where captive coal capacity is projected to rise over the coming decade.
- Across the country, waste supply cannot meet ambitious co-firing ratios. Limited biomass supply, technical constraints, and the possibility of increased land emissions from bioenergy production reduce the efficacy of co-firing as a mitigation strategy.

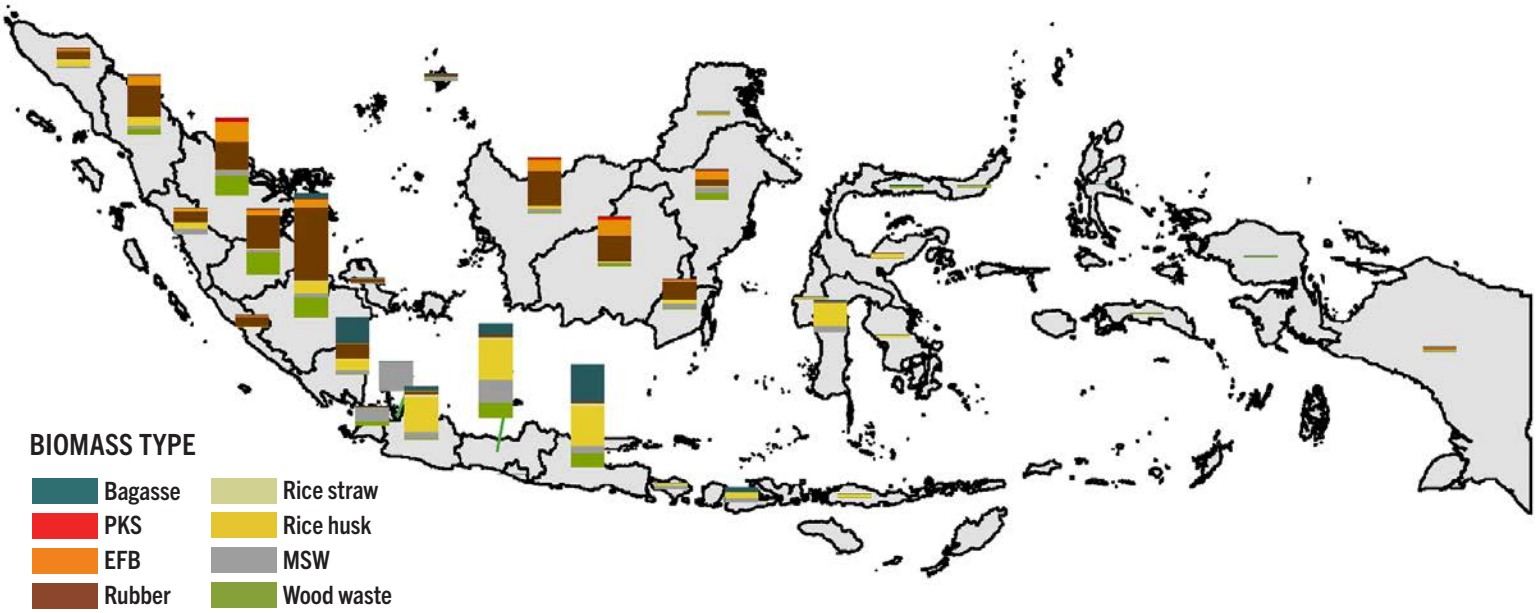
Key policy recommendations:

- For effective carbon accounting, biomass must be sourced from residues rather than energy plantation forests (EPFs).
- To support increased use of biomass residues, the state-owned power company, Perusahaan Listrik Negara (PLN), should implement programs to finance procurement and transport of feedstocks from collection points to coal plants.
- Countries importing bioenergy or biofuel to meet renewable targets must consider biomass sourcing and land use impacts in the source country.

Background

Indonesia is home to the sixth largest coal fleet in the world, one which is predominantly composed of plants 20 years or younger, and is still growing (Dahl et al., 2023). Present growth is driven by construction of captive plants, coal power stations that lack grid connection and are built to provide energy for localized industries, particularly critical mineral smelting. To abate energy sector emissions in these difficult-to-retire plants, policymakers have proposed greater implementation of biomass co-firing, the blending of biomass feedstocks with coal to feed boilers, in order to reduce coal combustion while utilizing existing infrastructure. To effectively implement co-firing as an emissions abatement strategy, production of bioenergy feedstocks cannot induce additional deforestation. Historically, land use change is responsible for 63% of emissions in Indonesia (Republic of Indonesia, 2022), and use of EPFs to source biomass, as PLN describes in decarbonization plans (PLN, 2022), risks accelerating emissions. Any calculation of co-firing as a mitigation tool must thus account for predicted land use impacts. In our analysis, we only consider biomass wastes as a co-firing feedstock, using unutilized oil palm (kernel shells and empty fruit bunches), wood (both forest residues and industrial by-products), rubber wood, bagasse, rice (husk and straw), and municipal solid waste in our co-firing scenarios to test the bounds of this emissions abatement strategy.

FIGURE 1 Biomass residue supply by type and province



Policy Landscape

Indonesia's NDC calls for use of 9 million tons of biomass for co-firing by 2030, and PLN's 2022 targets indicate that biomass will provide 10% of power generation by 2050 (PLN, 2022; Republic of Indonesia, 2022). Although most co-firing supply is currently met through sawdust or other waste biomass, Indonesia has emphasized EPF expansion as a means of meeting future demand, providing companies tax exemptions, early access to land for development, and larger concessions, while relaxing ecosystem rehabilitation requirements to meet supply through expanded bioenergy production (Ministry of Environment and Forestry, 2021; PLN, 2022). Increased biomass subsidy requests from PLN indicate that securing supply has been costly thus far, but further policies to enable widespread waste use are lacking (Ministry of Finance, 2023). Our analysis considers scenarios under which waste is utilized, which may require further policy support to become feasible.

Biomass Supply

After accounting for alternate utilizations, including diversion into processing mills, biomass power plants, onto fields as fertilizer, into export markets, and other uses, we find that 491.4 billion MJ of biomass remain, only 29.9% of the original feedstock quantity of 1,641.2 billion MJ. Diversion for use as fertilizer, local industrial fuel, or to run processing mills, are primary drivers of current displacement of supply. Available biomass residues are concentrated on Sumatra, Kalimantan, and Java, where rubber, oil palm, and rice husks dominate supply.

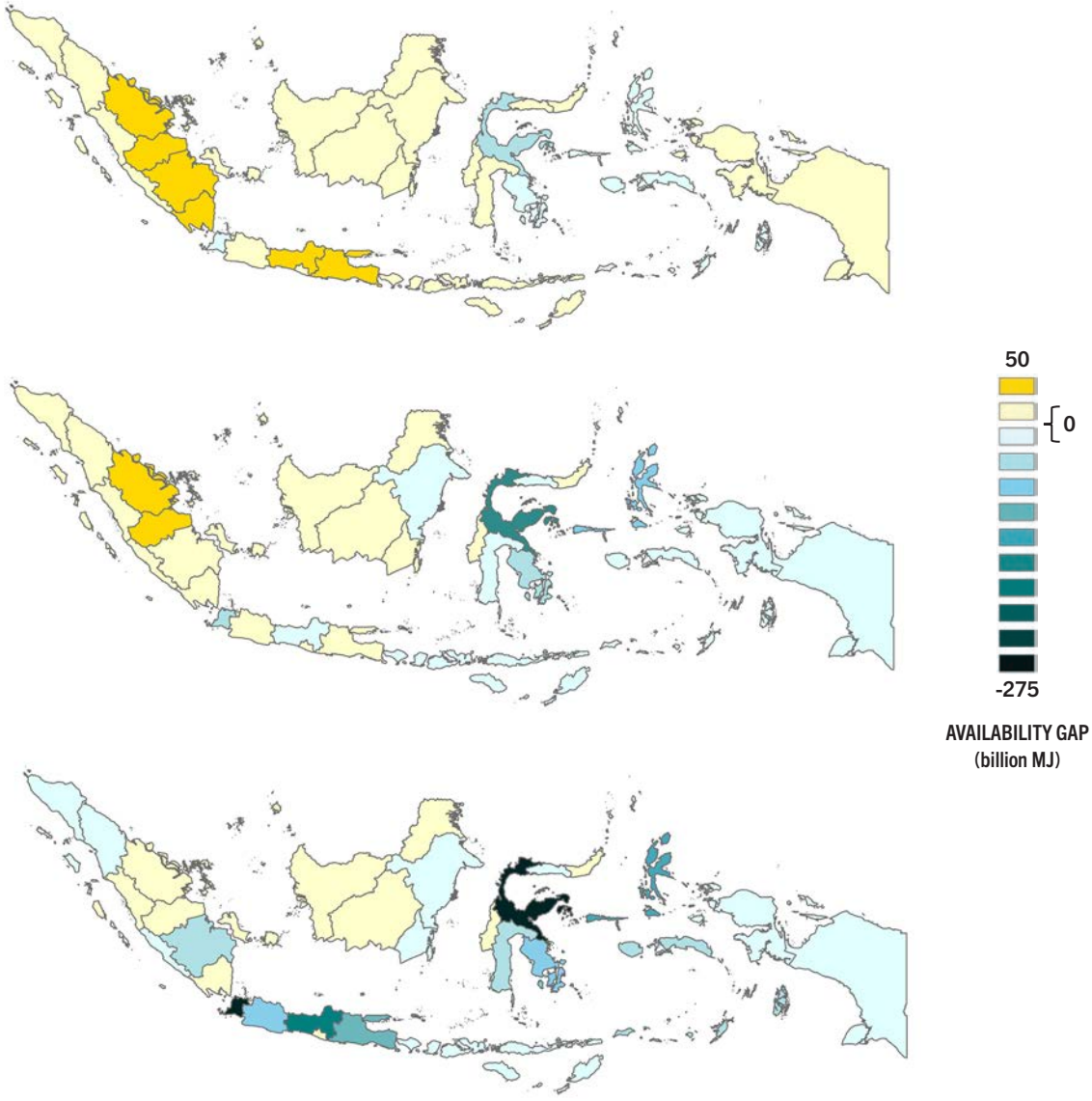
CO-FIRING RATIOS BY SCENARIO

Boiler Type	Low	Mid	High
PC	3%	10%	40%
CFB	10%	30%	50%
Stoker	20%	70%	100%

BIOMASS SUPPLY AND DEMAND (billion MJ)

	Low	Mid	High
Supply	491.4	491.4	491.4
Demand	196.8	651.7	1,608.6
Total	+294.6	-160.3	-1,117.2

FIGURE 2 Gap between biomass demand and supply across scenarios (from top: low, medium, and high co-firing ratios)



Biomass Demand

Plant-level biomass demand is determined by the co-firing ratio, or the percentage of fuel input supplied by biomass, a metric which varies under each scenario depending upon boiler type, given their variable capacity to incorporate biomass feedstocks. Total demand for biomass ranges from 196.8 to 1,608.6 billion MJ, rising across scenarios as co-firing ratios grow. As circulating fluidized bed (CFB) and stoker plants are able to co-fire at higher ratios, they replace greater quantities of coal than pulverized coal (PC) boilers, although given CFB's higher share of capacity (41.7% in 2030 compared to <1% for stokers), that boiler type ultimately drives demand.

At the provincial level, available supply cannot meet quantity demanded at coal plants even at the lowest co-firing ratio. In eastern Indonesia, particularly in Central and Southeast Sulawesi and North Maluku, biomass demand exceeds supply even at low ratios. Under more ambitious co-firing scenarios, other regions struggle to supply biomass, with a deficit at the nationally aggregated level beginning in a middle-ambition scenario. Notably, the greatest coal plant growth is expected in this region, where most capacity additions are captive plants, and minimal biomass supply, lack of grid connection, and young plants pose challenges

FIGURE 3 Spatial and temporal biomass residue availability in 2021

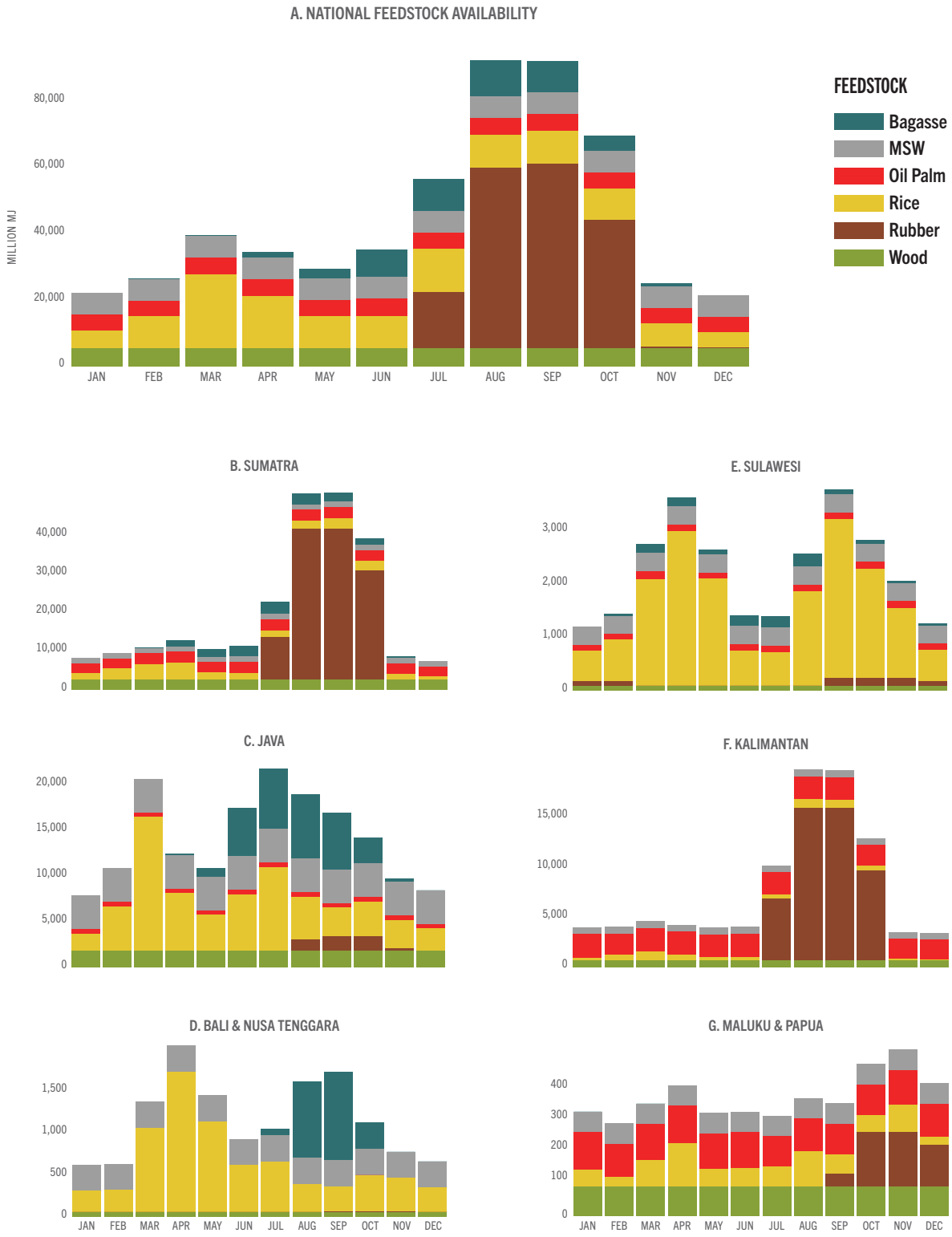
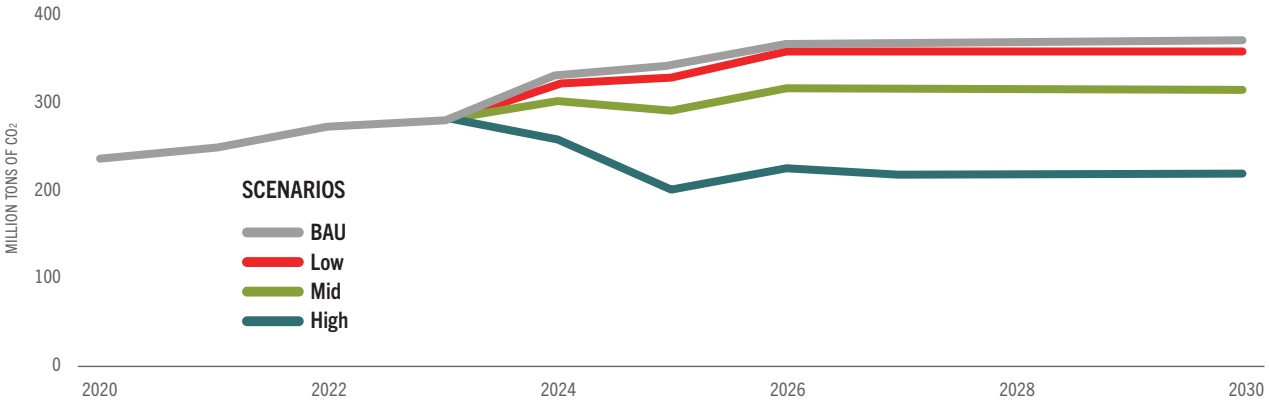


FIGURE 4 Emissions Reductions under Residue Co-firing and Wood Pellet Co-firing Scenarios



to coal phaseout. Even low-ratio preliminary co-firing initiatives have faced difficulty securing sufficient biomass supply. In 2022, PLN procured only 27% of their target (Bagaskara et al., 2023).

Biomass supply is highly variable across provinces and over the course of the year, depending on the region's primary biomass feedstock. In Kalimantan and Sumatra, seasonal availability is dependent upon rubber replanting, after which the felled logs that make up a high percentage of their biomass supply become available. In Java and Bali & Nusa Tenggara, rice harvests drive biomass availability, given that rice husks make up a large share of biomass supply. Supply is most consistent in Maluku and Papua, while sharp peaks differentiate seasons of high and low supply in the rest of the archipelago. Meeting biomass demand in areas with growing need would require investment in transportation from other regions as well as capital investment in processing and storage to enable co-firing throughout the year and overcome gaps in supply.

Emissions Reductions Potential

Biomass residue supply limits the emissions abatement delivered under co-firing. Assuming in each scenario that wastes provide all biomass supply, thus avoiding land use change emissions caused by expansion of EPFs, co-firing abates between 14.2-152.5 million tons of CO_2 per year by 2030. Projected capacity additions leading up to 2030, including projects already under construction in July 2023 and excluding those in pre-permit stages, result in an additional 91.8 million tons of baseline CO_2 emissions from coal power generation. Under a medium scenario, in which co-firing ratios match biomass inputs at ratios recommended for pilot projects by PLN (PLN, 2022), but are applied across the whole fleet, emissions reductions of 58 million tons of CO_2 are achieved, enabling coal power emissions to nearly flatten when accounting for expected growth in capacity.

To understand the potential land-use ramifications of the co-firing scenarios described in this study, we tested a scenario in which all coal plants in the country achieve their co-firing ratios by burning wood pellets made of acacia, a fast-growing tree cultivated at operating EPFs. Based on predicted deforestation from concessions noted in the methodology used by (Muhajir et al., 2022), the respective emission factor values by type of forest lost, and the capability of industrial acacia plantations to sequester carbon, deforestation from wood pellet co-firing will result in estimated emissions of 13.3, 43.9, or 108.3 million tCO_2 across the three scenarios. These emissions hamper the efficacy of co-firing as an emissions abatement strategy and underscore the necessity of including land-use change in a tabulation of emissions. A full accounting of emissions from co-firing is otherwise incomplete.

Policy Recommendations

Biomass co-firing is only green if sourced from biomass waste feedstock, which is already fraught if that waste supply is simply a byproduct of unsustainable practices, such as deforestation for plantation agriculture. We have not considered the latter point in this analysis, however.

Nor have we calculated potential emissions from transportation of biomass between regions or included other important values such as biodiversity conservation or local community well-being. A growing biomass export market will further alter the picture of land use stress. Tracking emissions from the commercial biomass and land sector is already quite difficult; further expansion of EPFs risks transferring emissions from the relatively easy-to-monitor stationary power sector to the more complex realm of land use. However, under an ambitious co-firing strategy, biomass waste supply struggles to meet co-firing demand, particularly in eastern Indonesia where coal capacity is projected to expand dramatically over the next decade. Land use change emissions are therefore inevitable under that scenario.

To support co-firing of biomass at a low-to-medium ratio, PLN should expand subsidies to support use of residues where locally feasible with no new land conversion. Highly ambitious co-firing ratios cannot be met under current residue supply - alternative dispatchable green energy must instead be pursued.

Thus far, national policy regarding biomass sourcing appears to be limited to nonexistent, although there are some encouraging signs that it may be under development. National policy should require transparent total accounting of coal plant emissions reductions from biomass co-firing that includes land use impact and emissions. A rigorous and consistent system of monitoring, evaluation, and enforcement mechanisms coordinated clearly across governance scales could help ensure accurate accounting and mitigate land use conversion.

Internationally, inclusion of bioenergy into renewable energy and net-zero targets should take into account sourcing of bioenergy, and include land use impacts when tabulating contribution to mitigation, as well as transport emissions when biomass is not sourced locally. Climate policies within Indonesia and abroad should not incentivize rapid growth in concessions within forested regions. In order to pursue biomass as an effective mitigation tool, biomass demand must be met through supply that does not merely transfer emissions from the power sector to the land sector, but which meaningfully contributes to overall national decarbonization.

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