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Evaluating the viability of co-firing biomass waste to mitigate coal plant emissions in Indonesia

The Center for Global Sustainability, University of Maryland

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Biomass co-firing and its relevance in Indonesia

Biomass co-firing

- Partial substitute of fuel within coal boilers
- Potential biomass sources include waste from agriculture, forestry, or human waste, or from dedicated biomass plantations
- Use of biomass in place of coal can drive down point-source emissions

Co-firing in Indonesia

- Increasing emissions from growing coal fleet
- High biomass availability
- Emissions target
  - LUC as historical emissions driver in country

Energy Sector Emissions in Indonesia over Time

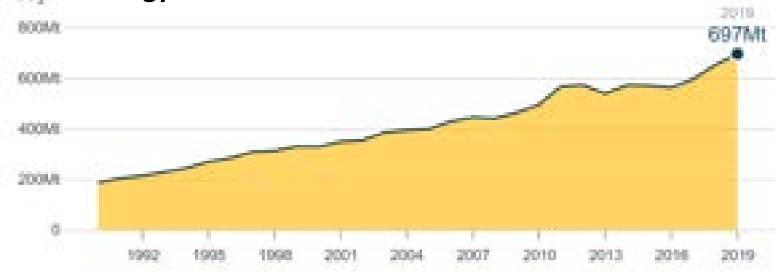
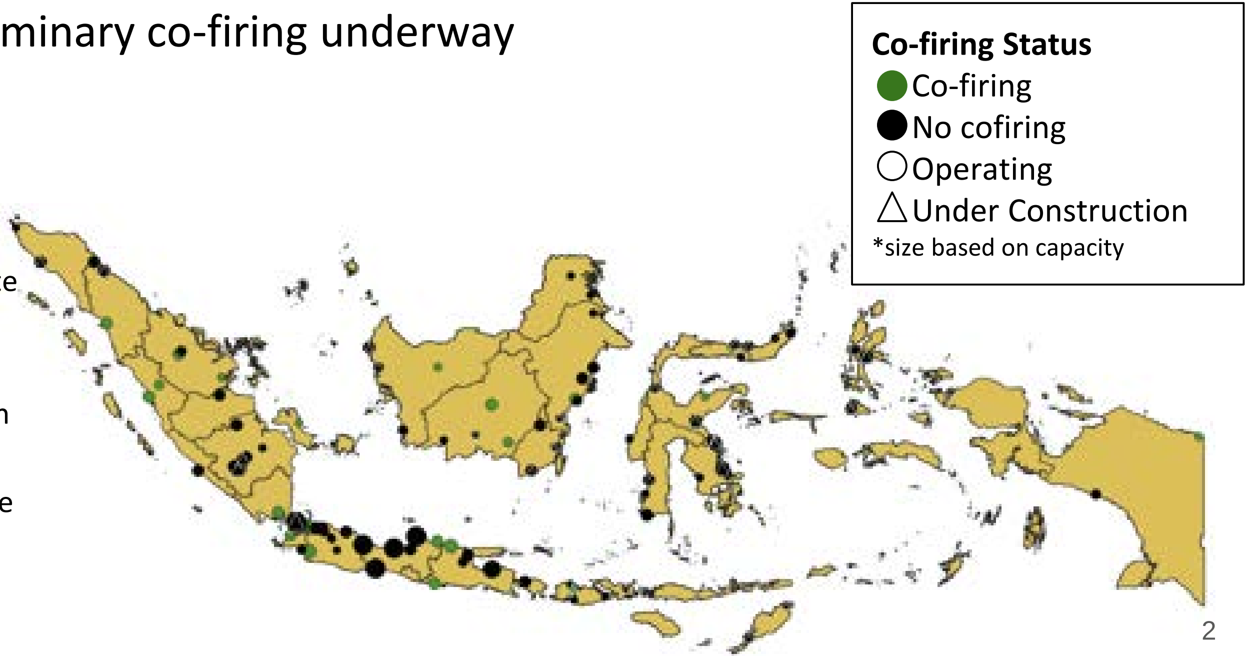


Photo credits: Biomass Energy, National Geographic. Climate Watch & WRI.

Current policies encourage implementation of co-firing at PLN-owned plants using plantation waste

- Indonesia's NDC calls for co-firing, with biomass utilization of 9 million tons
- Current testing and preliminary co-firing underway
  - PLN has targeted 52 PLTU co-firing locations
  - Perhutani, state forestry firm, providing sawdust and woodchips
  - Perkebunan Nusantara (PTPN), state plantation holding firm, supplying empty oil palm fruit bunches (EFB), palm kernel shell (PKS) & plantation waste
    - Rubber and sugarcane waste use also discussed



Benefits associated with co-firing

- Reductions in CO_2 emissions *(Shafie et al., 2013; UNFCCC, 2022)*
- Utilization of otherwise uneconomical product, which can allow for waste diversion and management *(Ismawati et al., 2022,; Sukarni, 2016)*, or mitigate air quality impacts of open burning of waste *(Shafie et al., 2013)*
- Economic growth through expansion of local jobs *(Siarudin, 2023; Wahyudi, 2022)*; intermediate incomes *(USAID, 2020)*, and export market *(Adhiguna, 2021; Sato et al, 2022)*

Global and national trend toward increased biomass use

Global trends

- Many countries have policies encouraging biomass expansion, including a feed-in tariff in Japan, which incentivizes biomass cofiring *(METI, 2021)*; RPS in South Korea that includes biomass subsidies, most supplied from forest biomass *(Hammel, 2020)*; the EU, where bioenergy provides 60% of all renewable energy *(EU Commission, 2019)*; a National Biomass Strategy in Malaysia that aims to use 30% of all waste as biofuel *(Nyakuma et al., 2021)*
- Renewable obligations are being met by biomass, but imports often required in the UK *(Mauro et al., 2017)*, Japan *(Sato et al, 2022)*, where PKS imports have tripled in a decade *(METI, 2021)*, South Korea (wood pellet import dependence of 98%) *(Hammel, 2020)*, and the EU *(Hansson et al., 2009)*

Trend in Indonesia

- Push for biomass & biofuel development (B30/B40) *(Casson et al., 2014; Conceição et al., 2021)*
- Bioenergy plantations have been incentivized through legislation *(Casson et al., 2014)*

Challenges associated with co-firing

Negative environmental & social impacts

- Risk of accelerating deforestation through biomass industry *(Casson et al., 2014; Conceição et al., 2021)*, with impacts on biodiversity loss *(Sakai et al., 2022)* and community access to and use of forests *(Abdullah, 2003, Siarudin, 2023)*
- Extending the life of coal plants *(Adhiguna, 2021)* and disincentivizing retirement through further investment in retrofits/biomass technologies *(Garcia et al, 2021; Wiloso et al., 2020)*
- Emissions from transport & biomass production *(Shafie et al., 2013)*, especially pelletization or torrefaction *(Wiloso et al., 2020)*, or drying *(Sarwer et al. 2022)*

Technical & economic issues

- Unclear economic feasibility (*Adhiguna, 2021; Darmawan et al., 2017; Idris & Hashim, 2021; Rodrigues et al., 2020)*
- Boiler type, and biomass ratio limitations of pulverized coal *(Adhiguna, 2021)*
- Difficulties burning biomass, including ash content (*Darmawan et al. 2017; Loh, 2017; Singh et al, 2020*), sulfur content *(Unchaisri et al., 2019)*, NO emissions *(Kuprianov et al. 2019)*, fouling of boilers and efficiency loss *(Milledge et al., 2014),* moisture content *(Ra et al., 2020; Singh et al, 2020*, *Sukarni, 2016)*
- Other challenges associated with biomass use include difficulty accessing residues *(Griffin et al., 2014*), and the need for suitable storage *(Griffin et al., 2014, Marganingrum et al., 2021; Sukarni, 2016)*

Uncertainty calculating supply

- Energy adjustment *(Adhiguna, 2021)*
- Potential of export market growth *(Adhiguna, 2021; Sato et al, 2022)*

Research questions and contributions

Research Questions:

- Are available biomass wastes sufficient to meet the current and future feedstock requirements for co-firing at coal plants without additional biomass production and associated land use emissions?
- How does waste availability vary throughout the year (temporally) and across the archipelago (spatially)?

Contributions:

- Quantify the supply of biomass for co-firing by determining availability and existing utilization of various biomass waste feedstocks suitable in Indonesia
- Quantify the demand for biomass for co-firing by determining range of co-firing feedstocks needed to displace coal that can be replaced at variable cofiring ratios
- Quantify the emissions impacts of co-firing, considering both point-source reductions at coal plants and the potential for land-use change to support a growing biomass industry

Methodology

Supply

Biomass Waste

Oil palm
Rice
Bagasse
Wood (forestry, industrial waste, pulp, rubber)
MSW

Calorific value, dried

Unutilized

Utilized

- Firing processing mills
- Biomass power plants
- Existing co-firing
- Exports
- Household fuel
- Industrial fuel
- Fertilizer
- Lumber industry

Demand

Coal Plants

45.2 GW operating
14.9 GW under construction;
Omitting pre-permit

1. Age
2. Ownership
3. Boiler Technology

Data Sources

Type	Level	Source
Coal plant details (location, heat rate, boiler type, coal type, capacity, age, status, coal emissions coefficient)	Coal plant	Global Energy Monitor, 2023
Cross-checking coal plant details	Coal plant	Institute for Essential Services Reform, 2023
Emissions coefficient for co-firing	Global	IRENA, 2013
Production of rice, crude palm oil, sugarcane, wood, & rubber in 2021	Provincial	Badan Pusat Statistik, 2022
Municipal solid waste collected in 2021	Provincial	Ministry of Environment and Forestry, 2023
Biomass plant details (location, capacity, feedstock, status); Processing facilities (location, capacity, feedstock), Calorific value of coal by type	Provincial	ESDM, 2017; Ministry of Energy and Mineral Resources, 2023

Biomass feedstocks in Indonesia

Potential biomass feedstocks

- Oil palm *(ESDM, 2023*; *Hardhi, 2022*; *Wahyudi, 2022)*, including palm kernel shells *(Adhiguna, 2021; Prasetiyo, 2023)*, empty fruit bunches, trunks
- Wood products, including biomass plantations *(Adhiguna, 2021; Prasetiyo, 2023; Hardhi, 2022),* logging residues, wood industry waste *(Adhiguna, 2021; ESDM, 2023*; *Prasetiyo, 2023)* & pulp *(ESDM, 2023)*
    - Rubber wood specifically *(Hardhi, 2022*; *Wahyudi, 2022)*
- Municipal solid waste *(ESDM, 2023*; *Hardhi, 2022; Prasetiyo, 2023)* or Refuse Derived Fuel *(Adhiguna, 2021)*
- Rice husk *(ESDM, 2023*; *Hardhi, 2022)* and straw *(Shafie et al., 2013)*
- Sugar cane bagasse *(ESDM, 2023*; *Hardhi, 2022*; *Wahyudi, 2022)*
- Corn cobs *(Hardhi, 2022; Prasetiyo, 2023)*
- Coconut shells *(Hardhi, 2022; Prasetiyo, 2023)*
- Cassava *(Hardhi, 2022)*

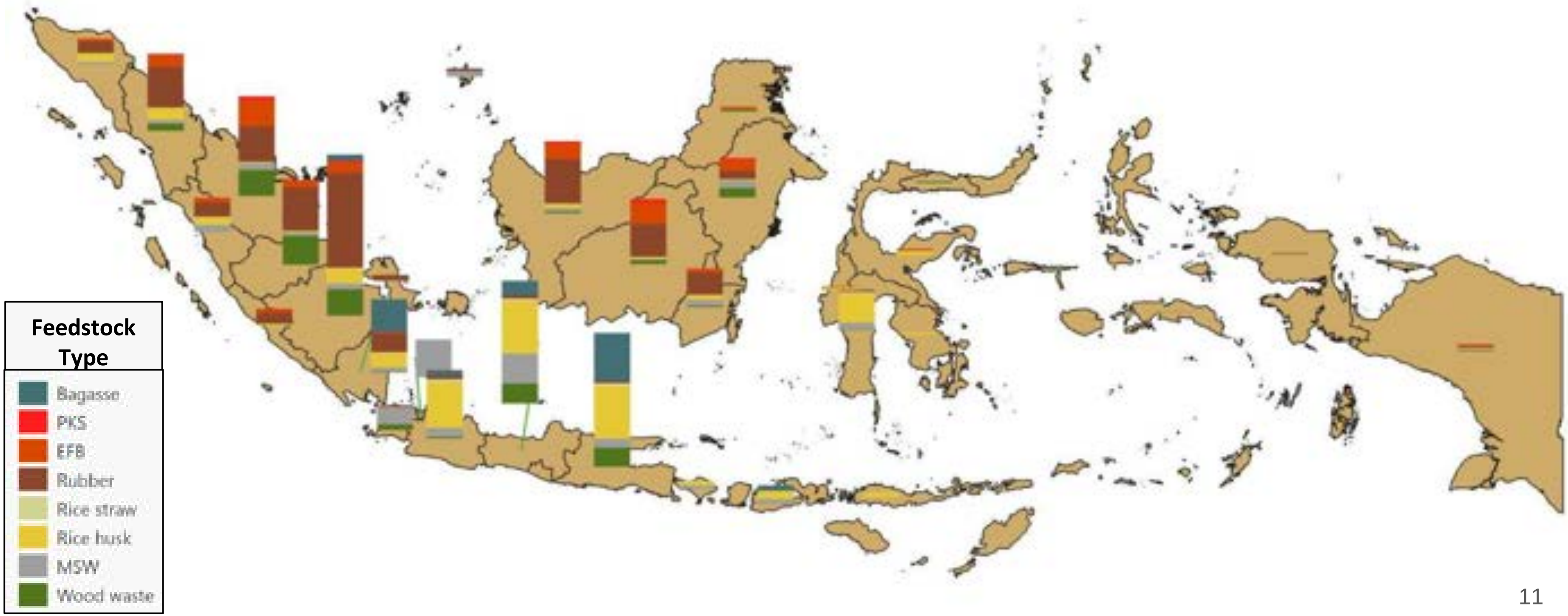
Considerations

- Existing use of waste products
- Spatial *(Hardhi, 2022)* and temporal feedstock availability

Current utilization has a variable impact on availability for co-firing, greatly limiting some feedstocks (billion MJ)

	Bagasse	Rice husk	Rice straw	PKS	EFB	Wood	Rubber	MSW
Waste (dry)	92.1	139.7	339	163.4	219.9	406.5	207.3	73.4
Processing	-30.7			-81.7	-51.1			
PLTBm	-17.1			-1.1	-2.3	-1.5		-1.4
Existing co-firing		-5.8		-1.1		-17.6		-3.6
Household fuel						-60.1		
Industrial fuel		-17.3			-16.6	-146.2		
Lumber industry						-12.3	-56	
Fertilizer or animal feed		-3.9	-332.2		-170.5			
Exports				-57.9		-19		
Total	44.3	108	6.8	8.9	47.2	56.2	151.3	68.4

Biomass waste feedstocks, when accounting for other uses, are concentrated on Sumatra and Kalimantan



Demand for biomass driven by coal replacement in CFB plants

National Biomass Demand				
	Co-Firing Rate		**Coal Consumption Replaced (MJ/year)**	
Boiler Type	Lower Range	Upper Range	Lower Range	Upper Range
Pulverized coal	3%	5%	41,866,805,502	70,905,583,206
Fluidized bed	15%	20%	231,002,225,534	308,650,158,335
Stoker	55%	100%	28,323,085,948	52,086,925,867
Total			**301.2 billion**	**431.6 billion**

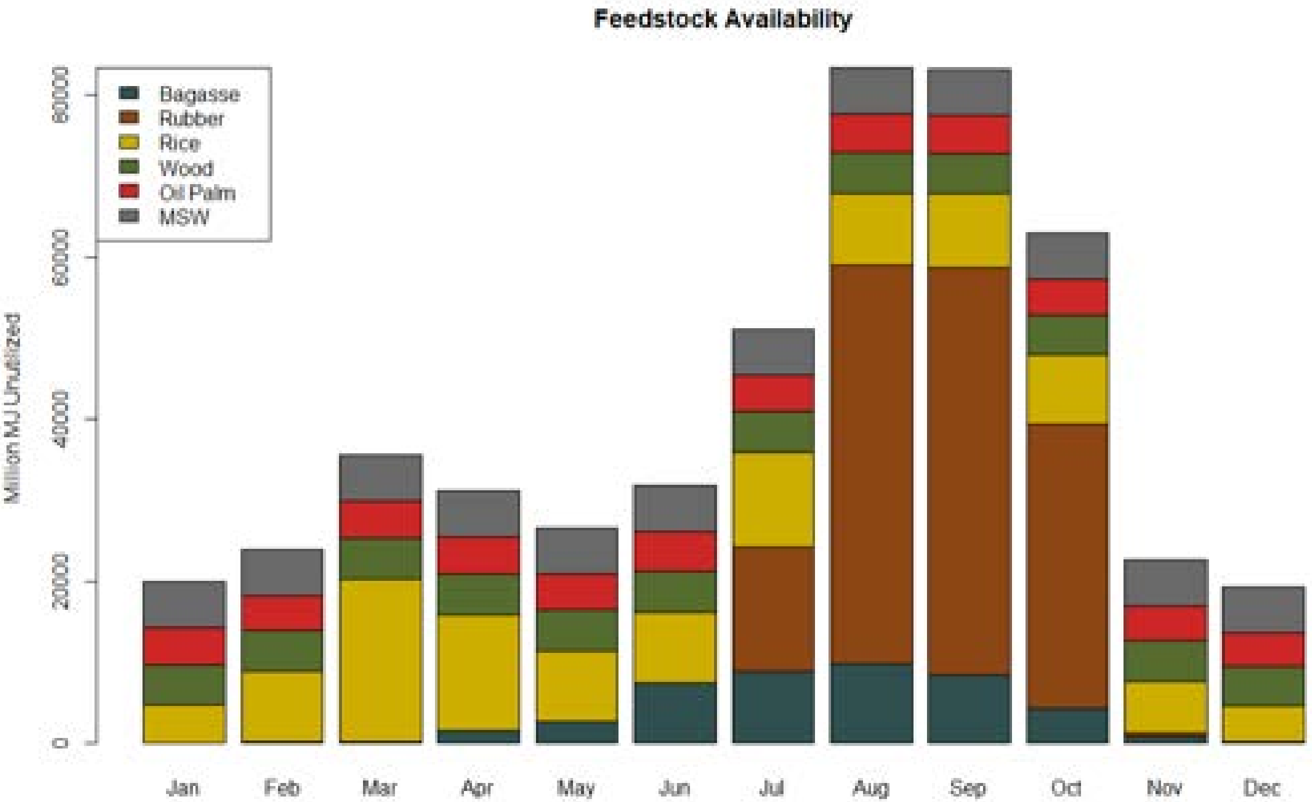
Nationally, unutilized biomass residues capable of coal replacement, but only half of all provinces can meet demand

Insufficient Supply		
Province	Lower Range	Upper Range
Yogyakarta	-0.1	-0.8
Papua Barat	-0.3	-1.2
Papua	-0.3	-1.6
Sulawesi Barat	-0.3	-1.7
Bali	-0.9	-2.1
Sulawesi Utara	-2.0	-3.0
Nusa Tenggara Timur	-1.5	-3.7
Gorontalo	-1.9	-4.3
Kalimantan Utara	-3.1	-6.0
Nusa Tenggara Barat	-0.9	-6.4
Sulawesi Selatan	-3.1	-9.4
Maluku	-8.0	-10.8
Bangka Belitung	-7.4	-12.0
Bengkulu	-8.4	-16.6
Sulawesi Tenggara	-18.2	-25.2
Maluku Utara	-38.0	-48.4
Sulawesi Tengah	-73.5	-99.5

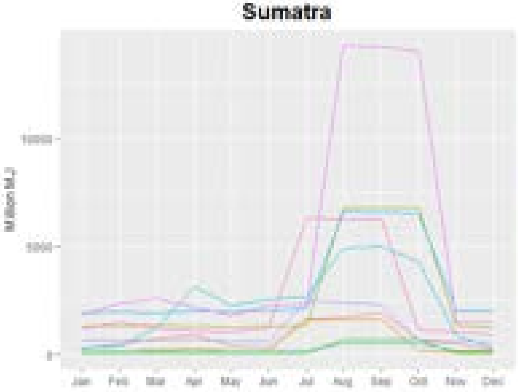
National	
Biomass Supply	491.3 billion MJ
Biomass Demand	301.2-431.6 billion MJ
Remaining	+59.6-190.1 billion MJ

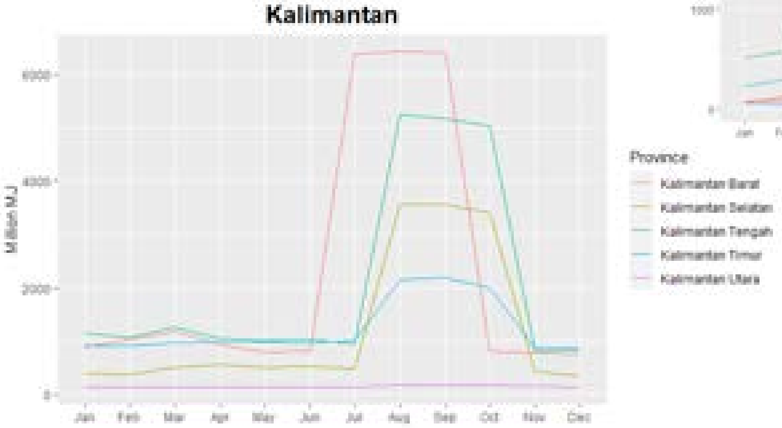
Sufficient Supply		
Province	Lower Range	Upper Range
Jawa Timur	[illegible]	[illegible]
Sumatera Selatan	33.4	32.5
Riau	32.6	30.3
Jambi	29.9	29.1
Lampung	24.1	22.7
[illegible]	[illegible]	[illegible]
Kalimantan Barat	23.0	21.6
Sumatera Utara	24.6	21.4
Jawa Barat	22.8	20.7
Jakarta	13.6	13.1
Kalimantan Selatan	12.6	11.9
Kalimantan Timur	12.4	10.8
Sumatera Barat	11.0	10.0
Banten	9.8	9.6
Kalimantan Tengah	14.9	9.6
Aceh	7.2	5.8
Kepulauan Riau	2.4	1.8

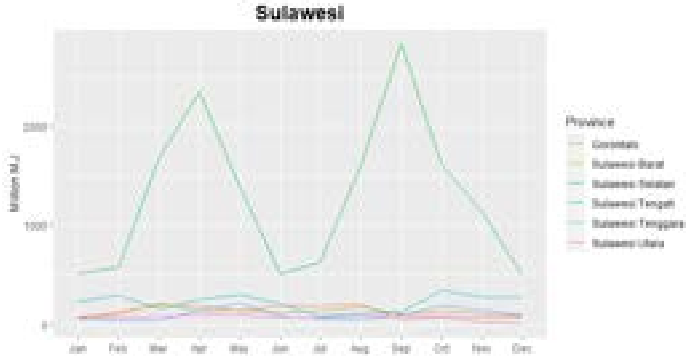
Biomass waste production fluctuates throughout the year, peaking in late summer during rubber replanting

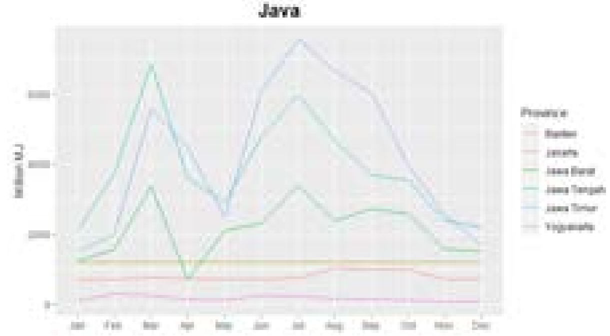


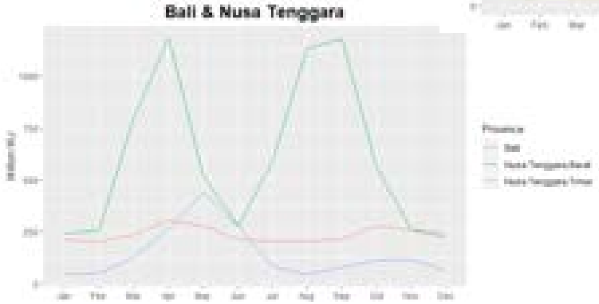
Variance in seasonal availability of waste by island





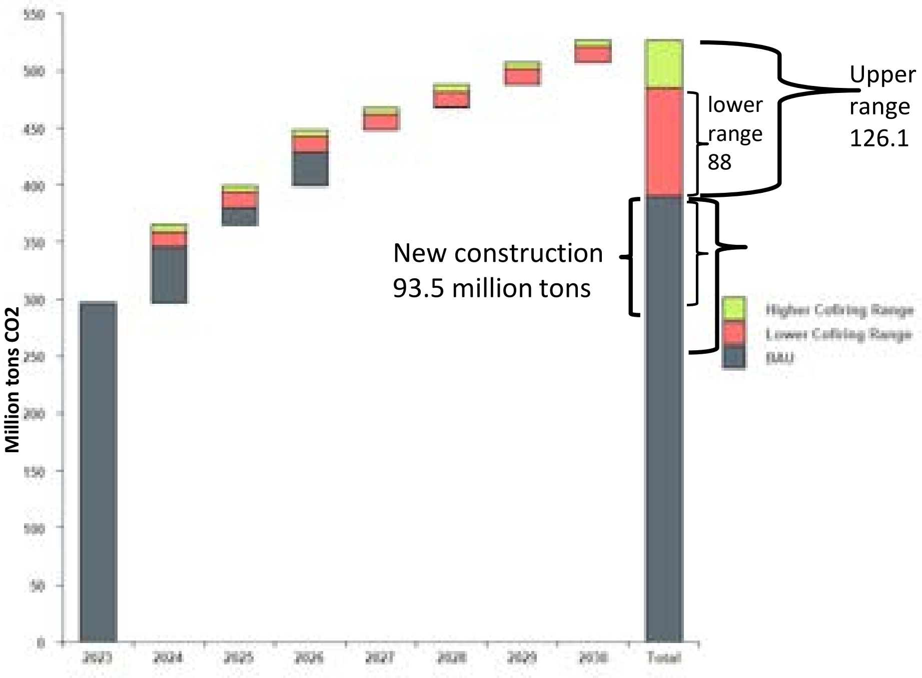






Emissions reductions under ambitious scenario can offset growth in capacity, but have minimal impact on baseline

BAU Emissions Growth and Reductions from Co-firing



	Co-Firing Rate		**Emissions Reductions (tons CO2/year)**	
Boiler Type	Lower Range	Upper Range	Lower Range	Upper Range
Pulverized coal	3%	5%	12,193,071	20,649,778
Fluidized bed	15%	20%	67,473,998	90,156,620
Stoker	55%	100%	8,319,898	15,298,827
Total			**88 million**	**126.1 million**

Policy implications

Land Use Change

- Nationally, unutilized biomass waste products capable of offsetting coal in low or high co-firing scenarios
    - Feedstock availability varies by province, domestic transport necessary
- However, policy decisions regarding biomass industry could nonetheless drive LUC
    - Plantation crops v. waste residues
    - Expansion of export markets cutting into domestic supply

Emissions

- Only high co-firing scenario sufficient to offset emissions from growth in capacity
    - An additional 93.5 million tons of CO_2 by 2030 from plants under construction
    - Low ambition scenario (88 million tons abated) cannot offset growth in capacity, let alone make further cuts

Conclusion

- At nationally aggregated level, biomass wastes are sufficient to meet co-firing demand at coal plants (including those currently operating and under construction, excluding those in pre-permitting stage)
- Provincial and temporal discrepancies in biomass supply and demand suggest challenges meeting demand in some regions
- Emissions reductions from biomass co-firing only offset growth in emissions from expanding capacity if a high ratio of biomass is utilized and that biomass is sourced from waste products
- Highlights limitations of biomass co-firing as an emissions reductions tool and risk of implementation inducing deforestation

Future Research and limitations

- Growth in biomass export markets
- Drivers of decision to utilize waste or plantation feedstocks
- Cost of emissions reductions from biomass co-firing
    - Transportation cost, especially from regions with excess biomass supply to eastern islands
- Impact on waste diversion, air quality

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Thank you!

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Supporting slides

Coal Fleet Assumptions

Coal fleet

- Includes PLN & Captive plants
- Includes plants operating & under construction, assumes pre-permit plants will be cancelled
- 45.2 GW operating, 14.9 GW under construction

Technical assumptions

- Direct co-firing (excludes consideration of indirect or parallel)
- No retrofits to plants
- No pelletization or torrefaction of feedstocks, no conversion to RDF of MSW

Calorific Values

Feedstock	Calorific Value (MJ/kg, dried) *Average of all sources*
Oil Palm PKS	18.77
Oil Palm EFB	17.12
Wood*	18.29
Rubber	17.28
Rice husk	13.83
Rice straw	13.42
MSW	21.79
Bagasse	16.94
Pulp	15.02

Boiler technology

- Boiler technology impacts range of % of thermal input that can come from biomass, moisture requirements, & particle size requirements

	Co-Firing Ratio	
Boiler Type	Lower Range	Upper Range
Pulverized coal (PC)	3%	5%
Fluidized bed (CFB)	15%	20%
Stoker	55%	100%