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ECONOMICS ANALYSIS OF COAL TO BIOMASS SUBTITUTION: SYSTEM DYNAMICS APPROACH

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Abstract: *Biomass utilization has been promoted by Government of Indonesia to subtitute coal as source of energy for electricity production through co-firing method. Yet, the higher price of biomass compared to coal and fair puchase price of electricity from biomass hinders its subtitution. In this paper, we examine the dynamics of biomass to coal subtitution and economics factors that affect subtitution of coal to biomass. We propose integration of economic analysis and Sytem Dynamics approach to examine reasonable subsidy, electricity price and GHG emission. We find that without implementation of policy to consider coal externalities, utilisation of biomass will likely unsucessfull in implementation.*

Keywords: *system dynamics, externalities, policy, co-firing*

INTRODUCTION

The severity of climate change and the urgency of ecological environment protection make the transformation of coal power imperative. From the perspective of international development trends, it is an inevitable and irreversible objective law of international energy transformation to replace coal with renewable energy and gradually reduce coal consumption (Xu et al., 2020). The Indonesian government has committed to make an energy transition from fossil energy to cleaner energy. This commitment is shown by the implementation of strategies, regulations and policies. One of the strategies for developing renewable energy in Indonesia is through Presidential Regulation Number 22 of 2017 concerning the National Energy General Plan, where one of the methods is the substitution of fuel in coal-fired power plant with biomass through co-firing. As an agricultural country, Indonesia has the potential for energy sources from biomass which is quite large, reaching 32.7 GW (Kazuyuki et al., 2021).

As a kind of high-quality renewable energy source, biomass is widely distributed. In addition, during the combustion process, less SO2 and NOX are generated, thus causing less environmental pollution (Madanayake et al., 2017). Biomass co-firing with coal can help to reduce greenhouse gas emissions and can act as a low-cost stepping-stone for developing biomass supply infrastructures (Cutz et al., 2019). In nearly all cases, biomass utilization for electricity production produces lower life cycle greenhouse gas emissions compared to the coal baseline, with emission reductions as high as 76% (Beagle & Belmont, 2019).

One of the challenges in co-firing development is the suboptimal purchase price of electricity from biomass-fired power plants. The determination of electricity tariffs that are not yet optimal is shown by the existence of regulations through Minister of Energy and Mineral Resources Regulation Number 50 of 2017 article 8, which regulates, among other things, references to tariffs that are regulated based on cost that will be compared to national generation production cost. Another challenge is the higher price of biomass fuel compared to coal with a calorific value equivalent to coal.

In order to expand the portion of renewable energy, many countries in the world have implemented policies to encourage the development of renewable energy technologies. Price-based feed-in tarif (FIT) and market-based renewable portfolio standards (RPS's) schemes are the two most frequently-used support schemes (Kwon, 2015). To accelerate the deployment of renewable energy technologies and to secure the electricity supply, the Government of Indonesia has issued several feed-in-tariff regulations for various renewable energy sources, which were previously predominated by pilot projects using government funding (Yuliani, 2016). The government of Indonesia unsuccessfully implemented feed-in-tariff scheme as it has brought a heavy fiscal burden on to Indonesia's government. Then come a question, what kind of scheme that should be implemented to accelerate the development of renewable energy in Indonesia?

Compared with traditional power, renewable electricity has positive externalities. It can increase social benefits and reduce pollutant emissions (Yu et al., 2019). Positive externality refers to the beneficial effects of economic activities of one economic entity on other economic entities; the recipients of positive externalities do not need to pay any cost (Wang, 2002). The internalization of positive externalities is the fundamental way to solve this type of problem. That the government formulates policies to support the development of renewable electricity is a form of the internalization of positive externality. The positive externality of renewable electricity is the main reason why the government provides a subsidy to encourage its development (Yu et al., 2019).

The Indonesian government plans to apply co-firing to 52 coal-fired power plant or PLTU in Indonesia with a target PLTU capacity of 18 GW. Of the 52 PLTU units, 13 trials have been successfully carried out with many various type of biomass fuel, namely: PLTU Paiton of 800 MW, PLTU Jeranjang 150 MW, PLTU Sanggau 14 MW, PLTU Ketapang 20 MW, PLTU Suralaya 1600 MW, PLTU Barru 100 MW, PLTU Pacitan 630 MW, PLTU Anggrek 56 MW, PLTU Rembang 630 MW, PLTU Labuan 600 MW, PLTU Lontar 945 MW, PLTU Adipala 660 MW, and PLTU Pelabuhan Ratu 1050 MW. Of the total 13 PLTU units, PLTU Rembang PLTU 630 MW uses wood pellets as co-firing fuel (ESDM, 2021). Based on ESDM data (2021) the composition of the biomass in the PLTU co-firing process based on tests that have been carried out on the 13 PLTU units is a composition of 1%, 3% and 5% of the total coal composition. The next target is for all PLTU generators to be able to carry out co-firing with a composition of 5%.

The price of biomass is more expensive than the price of coal because the government has not included the externalities of coal. Table 1.1 shows a comparison of the prices of biomass and coal in Indonesia (IEEFA, 2021).

Table 1. Comparison of Biomass and Coal Price

Energy Source	Calorific Value (Kcal/kg)	Price (IDR/kg)
Wood pellet	3.940 – 4.400	1.040 – 2.000
Palm shell	3.500 – 4.200	825 - 960
Refuse Derifed Fuel (RFD)	2.600 – 3.400	300 - 550
Sawdust	±2.450	±350
Coal	3.500 – 4.900	766 - 782

Eventhough biomass price is higher than coal, electricity price from biomass power plant is same with coal power plant. The determination of electricity tariffs in Indonesia refers to the regulation of the Minister of Energy and Mineral Resources Number 50 of 2017 article 8, where the tariff is set based on the basic generation production cost. The value of the local generation production cost will be compared with national generation productrion cost. Based on PLN statistical data in 2020, the national average selling price for coal-fired power plant is 1071.36 IDR/kWh.

The Indonesian government's main concern at the moment is the affordability of tariffs and the financial health of state-owned electricity company PLN, so there is a need to close the gap between price and cost through renewable energy subsidies to PLN. The subsidy is in line with Law 19/2003 on State Owned Enterprises and Law 30/2007 on Energy. Subsidies should be calculated as the difference between the cost of supply from renewable energy projects and the financial costs that PLN should have incurred for generation in the electricity generation system in the absence of renewable energy projects, which are categorized as avoided costs. To ensure that the government does not overpay for renewable subsidies, the cost of renewable energy will be capped at its economic value, which is calculated as avoided economic costs plus social benefits from externalities [10].

METHODS

System dynamics methodology was developed to figure out the relation amongs variable and to examine the profitability of implementation of biomass-coal cofiring. System dynamics is the method which is used for developing and understanding models of complex real-world systems and their behavior over time [13). Model in this research was developed in Vensim PLE software. Three mixing composition of biomass and coal are calculated: 1% of biomass, 3% of biomass and 5% of biomass.

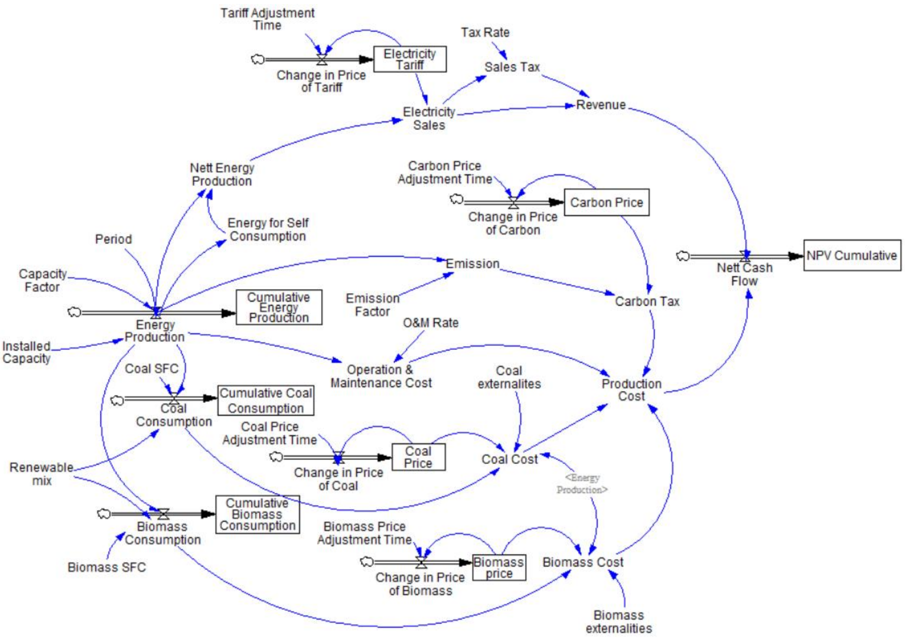

Figure 1. Economic Value Stock & Flow Diagram

Figure 1 shows the energy production process at the PLTU Rembang 630 MW using wood pellet biomass and coal with a composition of 1%, 3% and %5 biomass. The Stock & flow diagram illustrates the flow of revenue and costs with each constituent variable. In the revenue stream, the flow of energy production is illustrated by calculating the installed power of the generator, capacity factor, and the specified time period, so that the amount of energy produced is obtained. The electricity sales variable is obtained by calculating the price of the electricity tariff per energy production. By considering the tax rate at a certain number, total revenue will be obtained. In the flow of coal and biomass consumption, the value of the cost of fuel is obtained by calculating the consumption of biomass and coal per energy production, by calculating the price of biomass and coal. To calculate the price of coal, externality cost is added. Operation and maintenance costs are also calculated as components of total production costs. The cash flow value is obtained by calculating the difference between revenue and cost.

Since the unavailability of comprehensive research on coal and biomass externalities in Indonesia, in model development stage, there where asumption based on references from research in

China conducted by Wang et al in 2019. Referring to research in China where the external cost of electricity generation from coal is 0.16-0.18 CNY/kWh, much higher than the external cost of biomass, which is 0.06 CNY/kWh. By using the average price of the Chinese Yuan exchange rate with the Rupiah in 2019, the value of 1 Chinese Yuan is equivalent to 2050.91 Rupiah, so the externality cost of generating electricity from coal is 328-369 Rp/kWh and for the cost of generating electricity from biomass is 123 Rp/kWh.

Cahyo et al. (2021) conducted research on coal and biomass consumption in pulverized power plants, where the consumption of specific fuel coal with a calorific value of 4.536 Kcal/kg at is 0.56 kg/kWh. Meanwhile, the consumption of specific co-firing fuel with a composition of 95% coal with a calorific value of 4.536 Kcal/kg and 5% wood pellet biomass with a calorific value of 4.223 Kcal/kg obtained a value of 0.58 kg/kWh or an increase in consumption of 4.4%. Referring to these data, assuming the calorific values of coal and biomass have the same value, the figure of 0.56 kg/Kwh is used as a reference for coal and biomass consumption.

Referring to table 1.1 using the lowest price for wood pellet biomass of 1,040 Rp/kg and the lowest price for coal of 766 Rp/kg, the fuel cost per kWh for wood pellet biomass is 1,040 Rp/kg x 0.56 kg/ kWh = 582 Rp/kWh and coal is 766 Rp/kg x 0.56 kg/kWh = 429 Rp/kWh. Table 2 shows input data of power plant parameters, fuel prices and externality values.

Table 2. Fuel Cost & Externality Cost

Variable	Value	Unit	Source
Installed Capacity	639	MW	ESDM, 2020
Wood pellet consumption	0,56	Kg/kWh	Cahyo et al, 2021
Coal consumption	0,58	Kg/kWh	Cahyo et al, 2021
Wood pelet price	582	Rp/kWh	IEEFA, 2021
Coal price	429	Rp/kWh	IEEFA, 2021
Wood pellet externality cost	123	Rp/kWh	Wang et al, 2019
Coal externality cost	328	Rp/kWh	Wang et al, 2019
Electricity price	1071	Rp/kWh	PLN, 2020
Capacity factor	0,8		Assumption
Period	10	year	Assumption
Carbon price	30.000	Ton/MWh	Finance ministry, 2021
Price adjustment	1,5	1/year	Assumption
Tax rate	10	%	Assumption
Emmission factor	1136	Kg/kWh	Setya Budi & Suparman, 2013

RESULTS AND DISCUSSION

Economic analysis used in this study focuses only on calculating net cash flow by comparing the cash flow values between 2 conditions: PLTU only consume using coal and PLTU consume mixture of coal and wood pellet biomass, with variation in variable changes.

The initial comparison of coal used can be seen in Figure 1.3. The green line shows the graph of the net cash flow of the PLTU by only calculating 1 variable, which is coal price. The red line indicates the net cash flow of a coal-fired power plant by adding carbon tax variable. The blue line shows the net cash flow of PLTU by adding externality variables.

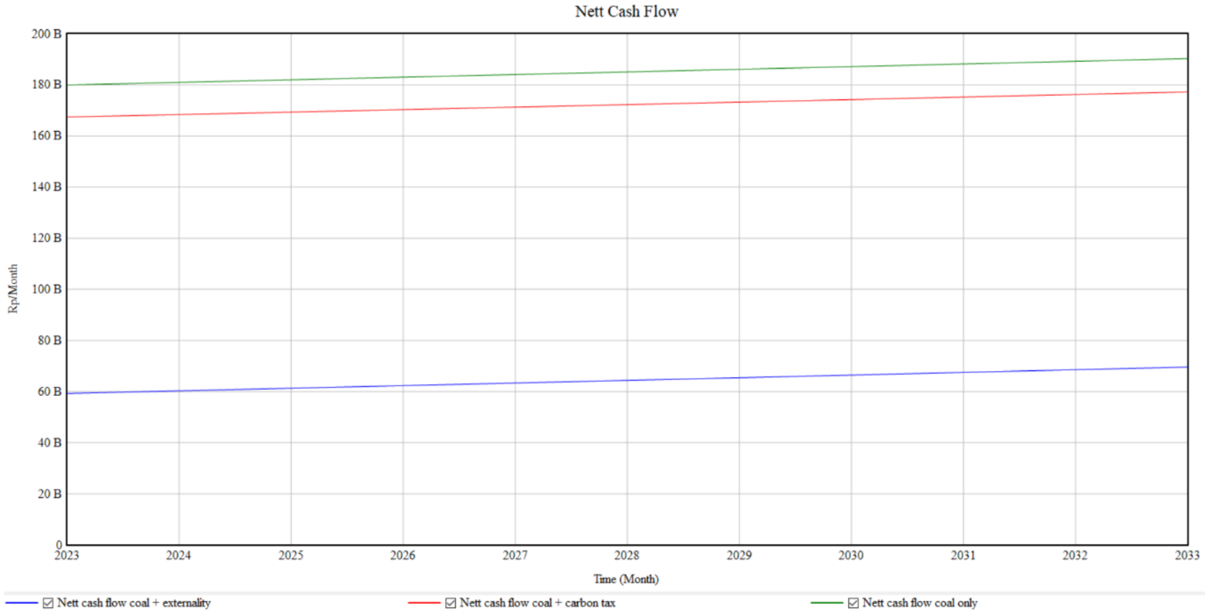

Figure 2. Net Cash Flow of Coal PLTU with Carbon Tax and Externality Variables

Figure 3 shows a graph of the net cash flow of PLTU with a comparison of changes in 4 variables, consist of: the coal price variable without carbon tax, 1% biomass composition variable, 3% biomass composition variable and 5% biomass composition variable.

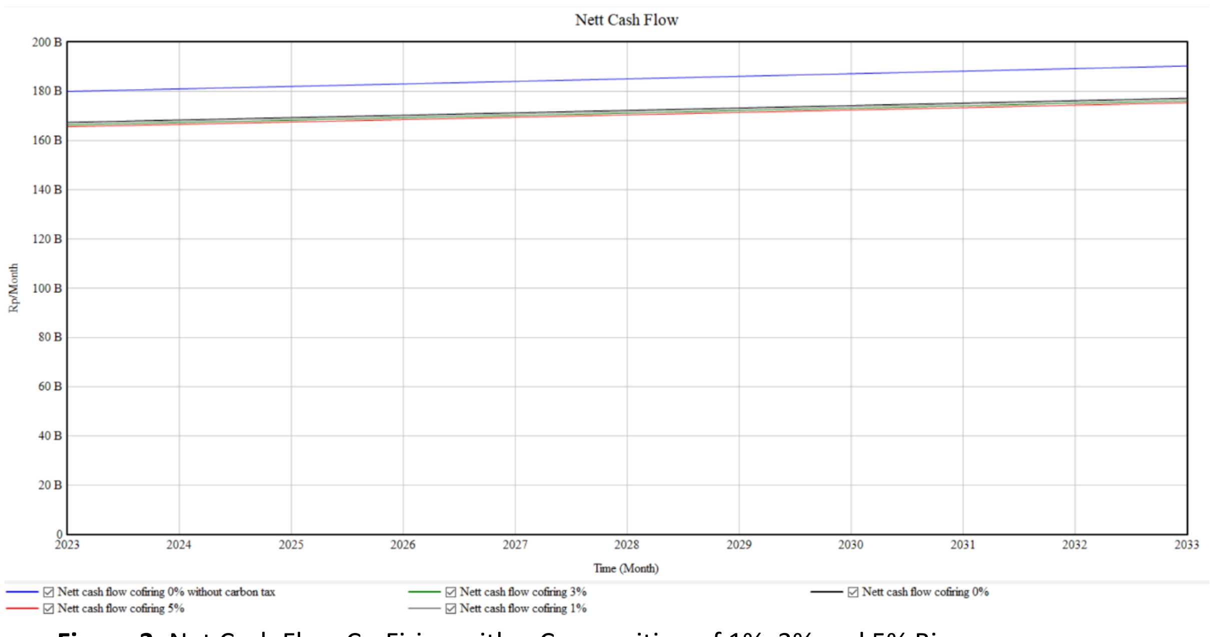

Figure 3. Net Cash Flow Co-Firing with a Composition of 1%, 3% and 5% Biomass

By comparing the 2 pictures above, it is found that there is a significant decrease in cash flow if you include the externality component.

CONCLUSION

In this study, net cash flow analysis was carried out based on data from calculation, reference, and assumption. It was found that by adding the externality components of two type of fuel: coal and wood pellet biomass, the impact will highly affect the cash flow value, because the externality value is 76% of the value of the fuel price. The most likely scenario to encourage the use of biomass is to apply only a carbon tax. The impact of implementing a carbon tax on reducing cash flow in co-firing with a composition of 1%, 3% and 5% is only 7%.

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