

INTISARI

Penerapan co-firing biomassa pada pembangkit listrik tenaga uap (PLTU) menjadi salah satu strategi yang efektif untuk mendukung dekarbonisasi sektor ketenagalistrikan tanpa mengurangi keandalan sistem pembangkit yang telah ada. PLTU Teluk Sirih menggunakan boiler tipe *Circulating Fluidized Bed* (CFB) yang memiliki fleksibilitas bahan bakar tinggi sehingga berpotensi menerapkan high co-firing biomassa hingga 80%. Penelitian ini bertujuan untuk menganalisis pengaruh rasio co-firing biomassa terhadap kinerja energi, eksergi, ekonomi, dan lingkungan (4E) PLTU Teluk Sirih.

Penelitian dilakukan menggunakan simulasi termodinamika berbasis perangkat lunak *Gatecycle* pada berbagai variasi rasio co-firing dan level beban operasi. Parameter yang dianalisis meliputi efisiensi boiler, *Specific Fuel Consumption* (SFC), *auxiliary power*, temperatur furnace, temperatur stack, *Exergy destruction*, biaya pokok pembangkitan, dan emisi gas buang. Analisis ekonomi dilakukan menggunakan parameter *Net Present Value* (NPV), *Internal Rate of Return* (IRR), dan *payback period*, sedangkan analisis lingkungan difokuskan pada emisi CO₂ dan SO₂. Penentuan rasio co-firing optimum dilakukan menggunakan metode *Multi-Criteria Decision Making* (MCDM).

Hasil penelitian menunjukkan bahwa peningkatan rasio biomassa hingga 80% menyebabkan efisiensi boiler dan *net plant efficiency* menurun akibat rendahnya nilai kalor dan tingginya moisture content biomassa. Namun demikian, peningkatan rasio biomassa mampu menurunkan emisi dan meningkatkan performa ekonomi pembangkit. Pada beban 100 MW, emisi CO₂ menurun dari 1.051,40 menjadi 218,20 kg/MWh, emisi SO₂ menurun dari 926,46 menjadi 379,91 mg/Nm³, serta BPP menurun dari 772,90 menjadi 702,27 Rp/kWh. Hasil analisis MCDM menunjukkan bahwa rasio co-firing optimum berada pada rentang 20–25% karena memberikan keseimbangan terbaik antara aspek energi, eksergi, ekonomi, dan lingkungan.

Kata Kunci : PLTU, co-firing biomassa, *Gatecycle*, analisis 4E

ABSTRACT

Biomass co-firing in coal-fired power plants has become one of the most feasible strategies to support decarbonization while maintaining the reliability of existing power generation systems. The Teluk Sirih Steam Power Plant utilizes a Circulating Fluidized Bed (CFB) boiler which has high fuel flexibility and potential for high-ratio biomass utilization. This study investigates the effect of biomass co-firing ratios up to 80% on the energy, exergy, economic, and environmental (4E) performance of the Teluk Sirih power plant.

A thermodynamic simulation using Gatecycle software was conducted under various co-firing ratios and load conditions. The parameters analyzed include boiler efficiency, Specific Fuel Consumption (SFC), auxiliary power, furnace temperature, stack temperature, Exergy destruction, generation cost, and exhaust gas emissions. Economic performance was evaluated using Net Present Value (NPV), Internal Rate of Return (IRR), and payback period, while environmental analysis focused on CO₂ and SO₂ emissions. In addition, the optimum co-firing ratio was determined using the Multi-Criteria Decision Making (MCDM) method.

The results showed that increasing the biomass ratio up to 80% reduced boiler efficiency and net plant efficiency due to the lower calorific value and higher moisture content of biomass. However, a higher biomass ratio was able to reduce emissions and improve the economic performance of the power plant. At a 100 MW load, CO₂ emissions decreased from 1,051.40 to 218.20 kg/MWh, SO₂ emissions decreased from 926.46 to 379.91 mg/Nm³, and the generation cost decreased from 772.90 to 702.27 Rp/kWh. Furthermore, the MCDM analysis indicated that the optimum co-firing ratio was in the range of 20–25%, as it provided the best balance among energy, exergy, economic, and environmental aspects.

Keywords : coal-fired power plant, biomass co-firing, Gatecycle, 4E analysis