

## Operational Feasibility, Emission Mitigation, and Pollutant Abatement of High-Ratio Solid-Fuel-Natural Gas Co-Firing in a Sub-Critical Boiler for Thermal Power Plants

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### Abstract

In support of Malaysia's clean energy transition, a full-scale solid-fuel-gas co-firing trial was conducted on a 300 MW sub-critical pulverized-fuel boiler to evaluate emission abatement potential, combustion behavior, and operational feasibility. The two-day trial tested co-firing ratios of 20% and 50% natural gas (via burner allocation) with bituminous-grade solid fuel, monitoring flue gas composition, boiler performance, and furnace conditions. At 50% co-firing, the unit achieved significant pollutant reductions, including a 42.5% decrease in  $\text{NO}_x$  concentration (from 628 mg/Nm<sup>3</sup> to 361 mg/Nm<sup>3</sup>) and a 54.4% decrease in  $\text{SO}_x$  concentration (from 581 mg/Nm<sup>3</sup> to 265 mg/Nm<sup>3</sup>), while carbon monoxide remained within regulatory limits (<50 mg/Nm<sup>3</sup>), confirming stable combustion. Critical boiler parameters, including steam temperature and pressure, were unaffected, and post-operation inspections revealed no evidence of slagging or major fouling, indicating reduced ash deposition risk compared to solid-fuel-only operation. However, several challenges were identified: higher heat input was required to sustain equivalent steam generation due to the higher moisture content of natural gas, and economic assessment showed gas costs (RM 28.43/GJ) were higher than those of conventional solid fuel (RM 27.21/GJ). These results confirm the technical viability of solid-fuel-gas co-firing as a near-term emissions reduction measure in sub-critical units, offering quantifiable improvements in flue gas quality and boiler cleanliness, albeit with trade-offs in fuel economics and efficiency. The findings provide empirical evidence for solid-fuel-gas co-firing as a transitional decarbonization pathway, aligning with Malaysia's long-term Net Zero 2050 objective while enhancing the environmental performance of the existing thermal generation fleet.