

Studi Tekno-Enviro-Ekonomi Integrasi BECCS pada sistem poligenerasi pembangkit listrik tenaga biomassa dan green methanol berbasis hidrogen terbarukan = Techno-Enviro-Economic study of the Integration of BECCS in the polygeneration system of biomass power plant and Renewable Hydrogen-Based green methanol

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Abstrak

Bioenergy with carbon capture and storage (BECCS) memiliki potensi besar dalam mengurangi emisi karbon dari atmosfer hingga dapat mencapai emisi negatif. Teknologi ini dapat diintegrasikan pada sistem poligenerasi pembangkit listrik biomassa dan green chemicals seperti metanol. Penelitian ini bertujuan untuk memperoleh efisiensi energi sistem secara keseluruhan, biaya produksi dan CO₂ avoidance cost (CAC), serta nilai emisi CO₂eq dari integrasi BECCS pada sistem poligenerasi. Aspen Plus v.11 digunakan untuk simulasi proses sistem poligenerasi, sedangkan unit CCS disimulasikan dengan Aspen HYSYS v.11. Dengan memvariasikan kapasitas produksi listrik, tandan kosong kelapa sawit (TKKS) digunakan sebagai bahan bakar pembangkit listrik biomass integrated gasification combined cycle (BIGCC) sehingga dihasilkan gas buang mengandung CO₂ yang ditangkap untuk sintesis metanol dan CCS. Hidrogen untuk sintesis green methanol diproduksi melalui elektrolisis PEM dengan variasi dua sumber energi listrik terbarukan, yaitu energi surya (PV-PEM) dan energi geotermal (GEO-PEM). Analisis lingkungan dilakukan dengan metode life cycle assessment (LCA) dengan lingkup cradle-to-gate dan analisis keekonomian dilakukan dengan metode leveled cost. Hasil penelitian menunjukkan bahwa efisiensi sistem keseluruhan lebih tinggi pada skema PV-PEM (11,33%) daripada GEO-PEM (7,05%). Sistem BECCS yang diintegrasikan pada pembangkit listrik BIGCC menunjukkan emisi negatif (-1,00 sampai -0,76 kg CO₂eq/kWh). Untuk sintesis metanol, nilai emisi dengan skema PV-PEM (-1,14 sampai -1,28 kg CO₂eq/kg MeOH) lebih tinggi daripada skema GEO-PEM (-1,52 sampai -1,65 kg CO₂eq/kg MeOH). Pembangkit dengan kapasitas 30,87 MW memiliki biaya produksi dan nilai CAC (0,181 USD/kWh dan 67,66 USD/ton CO₂) yang lebih besar daripada kapasitas 50 MW (0,139 USD/kWh dan 56,06 USD/ton CO₂). Skema PV-PEM menghasilkan biaya produksi metanol (1.011-1.049 USD/ton) yang lebih besar daripada skema GEO-PEM (967-1.005 USD/ton).

.....Bioenergy with carbon capture and storage (BECCS) has enormous potential to reduce carbon emissions from the atmosphere that may reach net-negative emissions. This technology may be integrated within the polygeneration system of biomass power plant and green chemicals, such as methanol. This research aims to obtain the system's overall energy efficiency, the production and CO₂ avoidance cost, as well as the emission factor of integrating BECCS in the polygeneration system. The processes of polygeneration system are simulated in Aspen Plus v.11; meanwhile, the CCS unit processes are simulated in Aspen HYSYS v.11. By varying the electricity production capacities, oil palm empty fruit bunches (OPEFB) are used as fuel for biomass integrated gasification combined cycle (BIGCC) power plant to produce exhaust gas containing CO₂, which is captured for the methanol synthesis and CCS. Hydrogen for green methanol synthesis is produced through PEM electrolysis powered by two different renewable energy sources, i.e., solar (PV-PEM) and geothermal energy (GEO-PEM). The environmental aspects are assessed with the life cycle

assessment (LCA) with a cradle-to-gate scope, and the economic aspects are analyzed with the leveled cost method. The research shows that the overall system efficiency is higher in the PV-PEM scheme (11.33%) than in the GEO-PEM scheme (7.05%). The BECCS system integrated into the polygeneration system exhibits negative emissions (-1.00 to -0.76 kg CO₂eq/kWh). The emission value for the methanol synthesis with the PV-PEM scheme (-1.14 to -1.28 kg CO₂eq/kg MeOH) is higher than that with the GEO-PEM (-1.52 to -1.65 kg CO₂eq/kg MeOH). The 30,87 MW-capacity BIGCC has a higher production cost and CAC value (0.181 USD/kWh and 67.66 USD/ton CO₂) than the 50-MW capacity (0.139 USD/kWh and 56.06 USD/ton CO₂). The PV-PEM scheme results in higher methanol production costs (1,011-1,049 USD/ton) than of the GEO-PEM scheme (967-1,005 USD/ton).