Analisis Tekno-ekonomi dan Lingkungan Bioenergy Carbon Capture and Storage (BECCS) dari Pembangkit Listrik Berbasis Biohidrogen dan Biometana dari Digesti Anaerobik Palm Oil Mill Effluent (POME) Dua Tahap = Techno-economic and Environmental Analysis of Bioenergy Carbon Capture and Storage (BECCS) of a Power Plant Based on Biohydrogen and Biomethane from Two-Stage Anaerobic Digestion of Palm Oil Mill Effluent (POME)

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Abstrak

Bioenergi dengan Penangkapan dan Penyimpanan Karbon (BECCS) merupakan teknologi net-negatif yang mampu menghasilkan energi terbarukan sekaligus menyerap emisi CO2. Penelitian ini bertujuan untuk mengevaluasi efisiensi energi, intensitas emisi CO2-ek, biaya pokok produksi listrik (LCOE), dan biaya penghindaran karbon dari sistem BECCS berbasis biohidrogen dan biometana yang dihasilkan melalui proses digesti anaerobik dua tahap terhadap POME (Palm Oil Mill Effluent). Dilakukan simulasi sistem dua reaktor CSTR menggunakan Aspen Plus, dimana reaktor pertama menghasilkan H2 dan reaktor kedua menghasilkan CH4. Aspen HYSYS digunakan untuk simulasi gas sweetening hingga penangkapan CO2. Aliran gas dimurnikan melalui proses Thiopaq menggunakan kolom absorpsi NaOH dan bioreaktor regenerasi. Gas bersih kemudian dibakar dalam gas engine, menghasilkan listrik 2,2 MWh dan flue gas yang ditangkap menggunakan larutan MDEA. Gas CO2 selanjutnya dikompresi dan didehidrasi menggunakan TEG, lalu diinjeksikan ke reservoir geologis di Central Sumatra Basin, tepatnya di sumur injeksi Kab. Kampar, Riau. Pendekatan lingkungan dilakukan menggunakan metode life cycle assessment (LCA) dengan batasan sistem cradle to grave, sedangkan pendekatan ekonomi menggunakan metode LCOE. Hasil menunjukkan efisiensi energi sistem sebesar 23,98%, intensitas emisi sebesar 25,67 kg COek/MWh, LCOE sebesar USD 151,40/MWh, dan biaya penghindaran karbon sebesar USD 71,69/ton CO2.
.....Bioenergy with Carbon Capture and Storage (BECCS) is a net-negative technology capable of generating renewable energy while simultaneously capturing CO emissions. This study aims to evaluate the energy efficiency, CO-equivalent emission intensity, levelized cost of electricity (LCOE), and cost of avoided carbon from a BECCS system based on biohydrogen and biomethane produced through a two-stage anaerobic digestion process of Palm Oil Mill Effluent (POME). A two-reactor CSTR system was simulated using Aspen Plus, where the first reactor produces H and the second reactor produces CH. Aspen HYSYS was used to simulate the gas sweetening process through to CO capture. The gas stream was purified using the Thiopaq process, which consists of a NaOH absorption column and a bioreactor for solvent regeneration. The cleaned gas was then combusted in a gas engine, generating 2.2 MWh of electricity and flue gas, which was captured using an MDEA solution. The captured CO was subsequently compressed and dehydrated using TEG before being injected into a geological reservoir in the Central Sumatra Basin, specifically into an injection well located in Kampar Regency, Riau. The environmental assessment was conducted using a cradle-to-grave life cycle assessment (LCA), while the economic assessment used the LCOE approach. The results showed an overall energy efficiency of 23,98%, a net CO-equivalent emission of 25,67 kg COeq/MWh, an LCOE of USD 151,40/MWh, and a carbon avoidance cost of USD 71,69/ton CO.