Techno-economic and Ai-driven Optimization of Carbon-negative Bio-lng Production from Palm Oil Mill Effluent (pome)

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Objectives/Scope: The growing demand for carbon-negative bio-LNG production as energy solutions has intensified interest in bio-LNG production from agro-industrial waste. Palm Oil Mill Effluent (POME), an abundant waste stream in palm oil-producing regions, presents a significant opportunity for renewable fuel generation (Bio-LNG) while achieving negative carbon emissions. It explores the integration of Artificial Intelligence (AI) into the bio-LNG production pathway from POME to enhance process efficiency, reduce emissions, and support accurate carbon monitoring.

Methods, Procedures, Process: A hybrid AI framework that combines machine learning algorithms with process modeling to optimize key operational parameters in anaerobic digestion, biogas upgrading, and liquefaction stages. Supervised learning models are trained using real-time and historical pilot plant data to predict methane (LNG) yield, system performance, and process stability under varying feedstock compositions. Additionally, AI-assisted Life Cycle Assessment (AI-LCA) and Techno-Economic Analysis (TEA) tools are deployed to estimate cradle-to-gate greenhouse gas emissions and quantify net carbon sequestration potential.

Results, Observations, Conclusions: To ensure robust environmental monitoring, the system integrates AI-enabled IoT sensors for real-time tracking of fugitive emissions and equipment health, enabling predictive maintenance and emissions compliance. Preliminary results demonstrate up to a 20% power saving and 0.5 % mol methane loss in liquid CO_2 stream, validating the potential of AI to unlock further environmental and economic value in bio-LNG systems.

Novel/Additive Information: This work highlights the strategic role of AI in transforming waste-to-energy systems into intelligent, self-optimizing platforms capable of delivering measurable climate benefits. The approach offers a scalable model for integrating digital intelligence into carbon-negative bio-LNG production, especially in resource-rich, emission-intensive sectors like palm oil processing and biogas upgrading.