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Environmental and techno-economic analysis of a biomethane energy community in southern Spain

P. Gómez-Sánchez de Rojas; J. Victoria Rodríguez; C. Morales Polo; M.M. Cledera Castro

Abstract-

The increasing focus on renewable energy has spotlighted bioenergy from waste materials, emphasizing waste-based biorefinery processes for waste management and renewable energy production. Anaerobic co-digestion has emerged as a viable alternative, producing higher energy–density biogas. This study conducts a comparative environmental life cycle analysis of current waste management practices, fertilizer consumption, and domestic heat consumption with the incorporation of a biomethane plant in a small municipality in South-Spain. It evaluates the combination of more than two substrates while conducting a comprehensive analysis of the full range of available waste to optimize biomethane production and minimize the carbon footprint.

Additionally, a novel business model is introduced, involving energy communities comprising municipal stakeholders, small businesses, and households engaged in gas self-consumption. This model aims to benefit the municipality economically and environmentally, ensuring local energy supply security and potentially offering affordable renewable fuel prices through European funding subsidies. Currently, while gas-based community energy models exist, the injection of biomethane into the grid for community consumption is yet to be realized. However, the European Union’s goals of promoting a circular economy and empowering rural sectors indicate progress towards this objective. From 2027, a new EU Emissions Trading System 2 scheme will impose emissions payments on buildings and small industries, highlighting the need for cost-effective decarbonization strategies where biomethane could play a crucial role.

The environmental impact assessment reveals that implementing a biomethane injection system significantly mitigates all environmental impact categories. A well-balanced co-digestion mixture enhances biomethane production and emission abatement, achieving an 89% reduction in CO2-eq emissions in domestic heating. Establishing a cooperative model with municipal collaboration proves viable, with a 17% internal rate of return and a possibility to decrease the price paid by the energy community below 40€/MWh. Potential revenue from biogenic CO2-eq, compost, and gas sales through Guarantees of Origin and Proof of Sustainability further enhances profitability, underscoring the environmental and economic potential of anaerobic co-digestion within energy communities.

Index Terms- Anaerobic co-digestion; Biomethane energy community; Environmental life cycle assessment; Cost-benefit analysis; Rural decarbonization

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