

Assessing the Environmental and Social Sustainability of Innovative Waste-to-Biomethane Pathways: The LIFE-W2B Project Approach

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The transition towards a circular bioeconomy requires innovative solutions to overcome the current limitations of anaerobic digestion (AD) and gasification (GF). Traditional AD processes often struggle with woody lignocellulosic residues and the management of large volumes of digestate, while gasification remains sensitive to feedstock moisture and consistency.

The LIFE-W2B project ("Sustainable Transformation of Waste to Biomethane, through Innovative Upgraded Anaerobic Digestion and Gasification") aims to address these challenges by integrating Solar Drying (SD), AD, and GF into a holistic waste management system. This paper illustrates the methodology and planned activities for evaluating the real impact of this integrated process, a task led by the University Niccolò Cusano (UNC).

The LIFE-W2B project proposes a technical solution where solar drying is used as a core pretreatment to optimize subsequent energy recovery. Specifically:

- Anaerobic Digestion: Applied to the easily biodegradable fraction of waste
- Gasification: Utilizing solar-dried residues (including those from AD) to produce syngas
- Biomethanation: Converting both biogas and syngas into high-purity biomethane
- Nutrient Recovery: Producing biochar from gasification, which serves as a long-term carbon sink and a nutrient-rich soil amendment.

UNC leads Work Package 4 (Evaluating the Real Impact of the Process). Since the project is in its early stages, the activities focus on establishing a robust framework for environmental and social assessment based on real-world data collected from the pilot facility in Crete.

UNC will conduct a comprehensive environmental Life Cycle Assessment (LCA) to compare the LIFE-W2B approach against conventional scenarios (e.g., landfilling, traditional AD with CHP). The assessment follows a multi-criteria approach focused on protecting the ecosystem, human health, and resources. By aligning with the European Commission's Product Environmental Footprint logic and prioritizing primary data collected directly from the pilot unit, the methodology ensures high reproducibility and verifiability. This robust framework allows for a precise evaluation of the process's capacity to act as a carbon sink through carbon dioxide fixation and the substitution of fossil fuels, shifting away from generic databases to provide a more accurate representation of the project's environmental performance.

Further, LIFE-W2B extends innovation to the assessment of social footprints. UNC will implement the Social-LCA (S-LCA) methodology to analyze the effects on various stakeholders, including waste producers, local residents, and potential end-users of biomethane and biochar. Following the UN Environment Guidelines (2021) and the ISO 14075, this activity will evaluate factors such as community well-being, health and safety, and social equity within the waste management chain.

The final phase of UNC's activities involves evaluating the "real value" of W2B by-products. By integrating environmental and social results with techno-economic data, the project will provide a clear, verifiable picture of the sustainability of upgrading biogas and syngas to biomethane. These findings will support the development of online tools for environmental and cost-benefit estimation, facilitating the replication of the W2B model across Mediterranean urban and rural contexts.

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