Pyrolysis of Dried Sewage Sludge for the Production of Energy and Biochar, as a Multifactor Process for Energy Efficiency and Reduction of Gas Emissions - Sludge2Energy

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Keywords: Sludge, Biochar, Pyrolysis, Energy efficiency
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Sewage sludge management represents a persistent environmental, economic, and public health challenge, particularly in regions experiencing increasing wastewater treatment demands. Wastewater treatment plants (WWTPs) generate large quantities of sludge as a by-product of treatment processes, while disposal and reuse options are increasingly constrained by stricter environmental regulations and sustainability requirements (Fytili and Zabaniotou, 2008; Gkogkou et al., 2026). In Mediterranean countries, solar drying is widely implemented as a low-energy pretreatment method that reduces sludge moisture content and facilitates subsequent treatment or valorization processes (Kelessidis et al., 2012).
Within this context, the Sludge2Energy project investigates the integration of solar drying and pyrolysis as a circular and low-carbon strategy for sustainable sludge management. Increasing evidence highlights environmental risks associated with the direct land application of sewage sludge, including the presence of emerging contaminants such as microplastics, pharmaceuticals, and antibiotic-resistant microorganisms (Zhang et al., 2021; Almashaqbeh et al., 2026). Recent studies have demonstrated that sewage sludge may act as a significant reservoir of pharmaceutical contaminants requiring advanced stabilization strategies (Almashaqbeh et al., 2026). Pyrolysis offers a promising mitigation pathway by thermochemically converting dried sludge into syngas for energy recovery and biochar, which can potentially serve as a soil amendment and a stable carbon sequestration material (Wang et al., 2019; Lehmann et al, 2015).
The project deploys four pyrolysis units—three installed at Mediterranean WWTPs and one existing unit at the Hellenic Mediterranean University (HMU)—to evaluate the operational feasibility of converting solar-dried sludge into syngas and biochar. During the operational phase of the units, the physicochemical properties of the sludge will be analyzed prior to pyrolysis, while key operational parameters such as temperature, residence time and feed rate will be monitored to assess process efficiency and product quality.
The produced biochar will be characterized and evaluated through controlled soil application experiments. Soil, crop and sediments samples will be analyzed to assess the effects of biochar on soil properties, nutrient retention and crop productivity, while additional tests will monitor the potential release of metals and other contaminants from sludge-derived biochar.
Environmental and socioeconomic performance will be evaluated through Life Cycle Assessment (LCA), Social Life Cycle Assessment (SLCA), and economic analysis (Gievers et al., 2021). By combining solar drying with decentralized pyrolysis systems, the Sludge2Energy project promotes circular sludge valorization pathways, contributing to reduced greenhouse gas emissions, renewable energy production, and more sustainable wastewater management. Such approaches are particularly relevant for Mediterranean countries, where sustainable sludge management and circular resource recovery are emerging environmental priorities.

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Acknowledgments: *Sludge2Energy is co-funded by the European Union under the Interreg NEXT MED Programme. Views and opinions expressed are those of the author(s) only and do not necessarily reflect those of the European Union or the Interreg NEXT MED Programme authorities*