# Techno-economic analysis and optimization of the integrated system of anaerobic digestion and pyrolysis

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**Abstract-** A novel system has been developed involving anaerobic digestion (AD) fed with sewage sludge and food waste (FW), and pyrolysis (Py) which is inputted by the digestate from the output of AD. This system has been investigated comprehensively in terms of energy, exergy, exergoeconomic, and environmental analysis. To that end, Aspen Plus has been used for designing, and MATLAB for developing a code for the aforementioned analysis.

## I. Introduction

Waste management has become more important as the population tends to grow as well as the need for energy. In this regard, there has to be a suitable approach to providing energy and managing waste, simultaneously. In this virtue, anaerobic digestion (AD) and pyrolysis (Py) have shown promising results to be recruited for this purpose (Inyang et al., 2010; Monlau et al., 2013). Recently, a new concept has been proposed to develop integrated systems of AD and Py that can highly efficiently convert biomass to bioenergy (Feng & Lin, 2017). Among different integrations, AD-Py in which Py is fed with anaerobic digestate has shown promising results in terms of environmental impact and industrialization (Wang et al., 2021) that can contribute to the cost reduction of digestate management and the generation of biofuels (Monlau et al., 2015). However, the information on the energy and economic benefits of this integration is scarce and yet to be confirmed. For instance, although there are a few studies in terms of economy, economic analysis of this integration has to be further discussed to verify the economic benefits (Lee et al., 2023). According to the literature, different analysis has been investigated including thermodynamics (Ebrahimi & Houshfar, 2022), and energy flow (Yang et al., 2023) but to the best of the author's knowledge exergoeconomic analysis has not been investigated for the integration of the proposed system.

In this study, a novel integration of AD-Py has been developed to be investigated in terms of energy, exergy, exergoeconomic, and environmental analysis to provide more information on the economic benefits of this integration which can make an outstanding contribution to the commercialization of this system. After validation, a sensitivity analysis based on the important parameters has been carried out to provide insight into multi-objective optimization through genetic algorithms to find optimum points of working conditions in different scenarios.

## II. Methodology

As it can be seen from the Fig. 1, a novel system has been developed in which sewage sludge (SS) with food waste (FW) is fed to AD to be digested and then utilizing the produced biogas from the digestion for drying the anaerobic digestate to be delivered to pyrolysis unit. SS is rich in nitrogen which can hinder inhibition in the process. Thus, it requires substrate to be mixed to produce a higher carbon-to-nitrogen ratio (C/N) which can benefit the digestion process (Cheong et al., 2022). In this context, Aspen Plus has been recruited for the design and MATLAB for the development of a code for analysing different aspects. The AD can be affected by several influential parameters such as temperature (Aguilar et al., 2017), Hydraulic retention time (Tyagi et al., 2019), organic loading rate (OLR) (Jiang et al., 2020) and in this case, co-digestion, mixing ratio (Chow et al., 2020) which can, as a result, have several effects on the performance of the anaerobic digestate fed to Py and affects its products and economic analysis, simultaneously. In this regard, by increasing OLR up to a point, biogas yields increase and by increasing the OLR further, biogas production decreases, showing the requirement of optimization and its effects on the performance of the system (Jiang et al., 2020). These parameters will be investigated to find optimum points in this system through the genetic algorithm based on energy, exergy, and exergoeconomic analysis. In Fig. 1, SS is mixed with water and flows to R1 which is RStoic where the hydrolysis reaction starts followed by R2 (CSTR) where acidogenesis, acetogenesis, and methanogenesis stages are completed. The produced digestate will be dried, crushed, and then flow to R3 (RYield) to decompose and R4 (RGibbs) to pyrolyze, and then different phases will be separated through SEP2.

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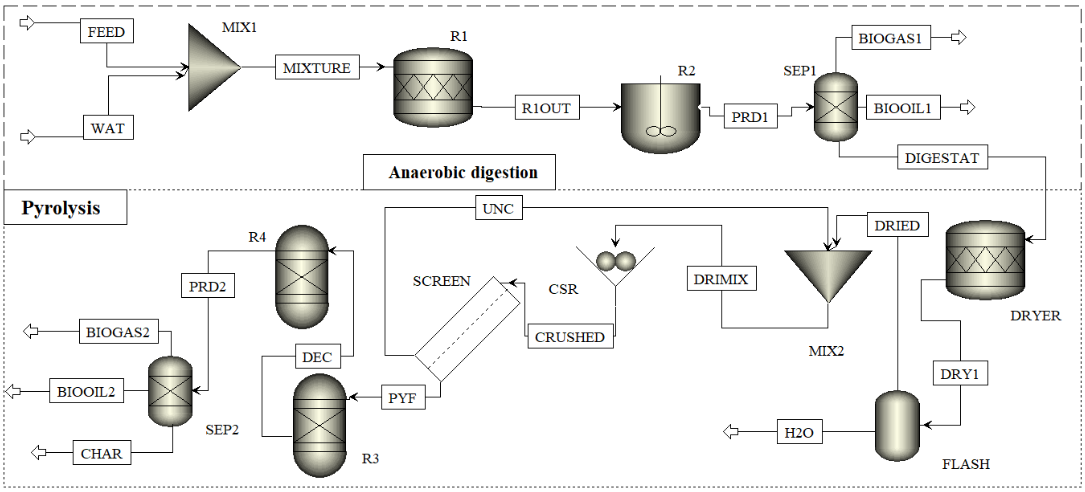

Figure 1. Schematic of the proposed integrated system

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