Valorization of Recycled Materials and Organic Residues of Agricultural, Livestock and Industrial Origin for Energy and Compost Production within the Circular Economy Framework

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The increasing pressure to address the challenges posed by agricultural, livestock, and industrial waste has brought forward the need for sustainable and innovative management strategies. In this context, the adoption of **circular economy (CE)** principles has emerged as a key solution, promoting the efficient use of resources, waste minimization, and value recovery. By focusing on the transformation of organic residues and recycled materials into renewable energy sources and soil amendments, the CE model offers a pathway to reduce environmental pollution while simultaneously supporting agricultural productivity and energy autonomy.

This study aims to explore the potential of circular economy practices in converting organic waste into valuable resources. By assessing existing technologies, processes, and real-world applications, the research will highlight how the valorization of organic residues contributes to sustainability, resource efficiency, and the reduction of the environmental footprint. In addition, the study seeks to underscore the importance of implementing innovative waste management systems that align with CE principles, fostering long-term environmental, economic, and social benefits.

The primary purpose of this research is to examine the role of CE in converting agricultural, livestock, and industrial residues into valuable resources such as bioenergy and soil improvers. Specifically, the study aims to assess the technologies and processes used to transform organic waste into renewable energy and soil amendment products, evaluate the environmental benefits—particularly the reduction of pollution and greenhouse gas emissions—and explore the impact on agricultural productivity and energy autonomy through the creation of sustainable systems. Furthermore, the research will focus on designing and analyzing a real-world CE system using experimental data to draw concrete conclusions.

The expected outcomes include a clear demonstration of how the valorization of organic residues can lead to the production of renewable energy, improve soil quality, and promote energy autonomy in agricultural systems. Additionally, the study aims to underscore the benefits of circular resource management in reducing environmental pollution, fostering sustainability, and creating a more efficient, environmentally friendly model for waste management.

The research methodology comprises a combination of literature review, data collection, and experimental analysis. Specifically, the study will involve:

- **Literature Review**: Comprehensive analysis of scientific articles, university textbooks, doctoral/master's theses, and publications in academic journals and conference proceedings.
- **Data Collection**: Collaboration with relevant stakeholders (e.g., environmental agencies, industries, and research institutes) to obtain real-world or experimental data.
- **Technological Assessment**: Examination of innovative technologies such as anaerobic digestion, composting, and thermochemical processes (e.g., pyrolysis and gasification) for transforming organic residues into energy and soil amendments.
- **Experimental Validation**: Small-scale trials and modeling of circular systems to analyze the transformation processes and validate their effectiveness.

The study highlights the critical role of various technologies in the transformation of organic waste, offering innovative solutions for sustainable management. **Anaerobic digestion** is a key biological process that produces biogas, serving as a renewable energy source and contributing to energy autonomy. **Composting and biochar production** convert organic residues into high-quality soil amendments, enhancing soil fertility and boosting agricultural productivity. In addition, **thermochemical methods**, such as pyrolysis and gasification, enable the efficient recovery of energy from organic residues, further supporting renewable energy generation. These technologies collectively help reduce the environmental footprint, optimize resource utilization, and promote sustainable agricultural practices.

The adoption of circular economy principles in the management of agricultural, livestock, and industrial residues holds significant potential for creating a greener and more sustainable future. By transforming organic waste into valuable products such as bioenergy and soil improvers, this study demonstrates how energy autonomy, enhanced agricultural productivity, and reduced environmental pollution can be achieved. Through the implementation of innovative technologies and real-world circular economy systems, substantial environmental, economic, and social benefits can be realized, fostering a more resilient, resource-efficient, and sustainable model for the future.

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