World Academy of Science, Engineering and Technology
International Journal of Environmental and Ecological Engineering
Vol:19, No:03, 2025

Powering Circular Agriculture: Economic Analysis of Renewable Energy Integration for Sustainable Poultry Farming

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Abstract : The significance of this study lies in its comprehensive exploration of renewable energy integration in poultry farming, a highly energy-intensive sector, to address pressing global food and energy crisis. As population growth amplifies these issues, innovative solutions are crucial for sustainable food production and energy security. This research investigated the potential of renewable energy sources, particularly anaerobic digestion and solar photovoltaics, to reduce energy consumption, mitigate greenhouse gas emissions, promote circular economy principles in agriculture, and reduce reliance on fossil fuels. By examining case studies from various countries and analyzing the economic and environmental benefits of these technologies, the study aimed to provide practical insights for farmers, stakeholders, and policymakers. Ultimately, this research developed a conceptual tool and framework to facilitate the transition towards more sustainable and circular agricultural practices, addressing critical gaps in renewable energy integration within agricultural systems, and aiming to attract potential investors and gain traction for sustainable practices. The study employed a mixed-methods approach, combining quantitative and qualitative analyses to provide a comprehensive evaluation framework for renewable energy integration in agriculture. Key components included a case study analysis utilizing data from a poultry operation in Armenia, an anaerobic digestion plant in Pakistan, and a solar photovoltaic project in Lebanon. A comprehensive literature review was conducted to understand the current state of renewable energy adoption, challenges, and opportunities in poultry farming. For quantitative analysis, the study used Cost-Benefit Analysis (CBA) to assign monetary values to costs and benefits of renewable energy investment projects, including economic valuation, financial budgeting, and cash flow considerations to compare two modes of renewable energy sources. The qualitative approach utilized Multi-Criteria Decision-Making (MCDM) to evaluate and prioritize alternatives based on multiple criteria, incorporating both objective and subjective factors beyond economic viability. Additionally, sensitivity analysis was conducted for more accurate modeling. Key findings revealed that on-farm anaerobic digester plants focusing on biogas and digestate production, rather than electricity generation, demonstrated economic viability with a Net Present Value of $621,386.3 and an Internal Rate of Return of 149%. Solar PV implementation showed moderate economic potential. The Multi-Criteria Decision-Making analysis, incorporating economic, technical, environmental, and social criteria, ranked anaerobic digesters (0.91) higher than solar PV (0.64) for agricultural applications. The findings suggest that small-scale anaerobic digesters offer the most promising pathway for agricultural waste valorization and renewable energy generation. However, successful implementation requires addressing limitations such as financial uncertainties, lack of accurate data, industry collaboration, and policy support. This research contributes to the growing body of knowledge on circular economy implementation in agriculture, offering practical insights for sustainable development in similar economic contexts.

Keywords : circular economy, renewable energy integration, sustainable poultry farming, anaerobic digestion, solar photovoltaics, sustainability, cost-benefit analysis, multi-criteria decision making, economic modeling
Conference Title : ICCES 2025 : International Conference on Circular Economy and Sustainability
Conference Location : Miami, United States
Conference Dates : March 10-11, 2025