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Circular economy-driven performance assessment of electricity generation options for decarbonization of Islands

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ABSTRACT

The large-scale integration of renewable energies in the electricity sector is a key driver of reducing the dependence on conventional fossil duels towards favoring long-term sustainability (Paraschiv and Paraschiv, 2023). In alignment with the commitments and objectives set by the EU, the deployment of autonomous hybrid power systems integrating different renewable energy technologies, with and/or without energy storage options, can contribute to reliable and circular economy-driven electrification, especially for off-grid applications (Roy et al., 2022). Numerous published studies have been dedicated to the design and optimization of hybrid power systems, considering the trade-offs between design cost and energy production (Ahmadi et al., 2023; Bacha et al., 2024; Roy, 2023; Vaziri Rad et al., 2024). Motivated by the necessity to substantially increase the levels of renewable energies in current electricity generation systems, the present study intends to provide a consistent methodology combining life cycle thinking and multi-criteria decision analysis to evaluate and prioritize different autonomous hybrid structures /design options that combine wind turbines, solar photovoltaics (PVs) and batteries, with back-up electric diesel generators. Implementing a hybrid AHP-TOSPIS approach, this methodology addresses in a simultaneous manner technical (i.e., renewable energy penetration rate), economic (i.e., levelized cost of energy), and environmental (i.e., life cycle GHG emissions) aspects, to select the most efficient, reliable, environmentally-friendly, and cost-competitive power generation option. The proposed circular-economy driven decision-making framework is applied in an off-grid island, in particular, the Island of Lesvos, located in the Aegean Sea, Greece. Lesvos Island is a representative case study for investigating future perspectives of large, autonomous electricity generation systems in remote Islands, that are characterized by abundant wind and solar power potential, but their primary energy supply is based on expensive oil imports and electric diesel generators. It is envisaged that computational results and suggestions included in this study could provide valuable insights to the decision-makers to identify sustainable ways of electricity generation, so as, in collaboration with local communities, to establish

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a roadmap for the transition towards decarbonization of the isolated/stand-alone Islands.

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