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Robust design of off-grid water-energy systems under climate and socio-economic changes

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Small Mediterranean islands represent a paradigmatic example of remote, off-grid systems, where water supply and electricity generation are intrinsically coupled and interdependent.
Distance from the mainland, lack of accessible water sources, and high seasonal variability of both water and electricity demand strongly and critically influence the operations of both water and energy systems. Energy security is nowadays based on unsustainable carbon intensive diesel generators, usually oversized to meet peaking summer electricity demand driven by high touristic fluxes. Drinking water is produced by energy intensive desalination technologies, which strongly impact on the electricity system increasing air pollution and greenhouse gas emissions.
In order to improve the overall sustainability of small islands, the introduction of renewable energy sources coupled to power storage technologies and an efficient management of the water-energy system represent a viable and interesting solution to produce clean energy at lower costs.
However, the identification of the optimal hybrid system design is strongly affected by the deep uncertainty in future climate and socio-economic drivers.
The aim of this work is to identify robust hybrid renewable energy systems by directly including different plausible future scenarios of the main exogenous variables (e.g., solar radiation, wind speed, water/electricity demand) within the optimal system design phase. By adaptively selecting a concise set of future scenarios as the most informative, our multi-objective optimization approach allows to identify robust system designs that do not degrade when re-evaluated over a large out-of-sample set of scenarios.
Results show the effectiveness of including the deep uncertainty in the main external drivers within the optimization process for generating solutions that are robust with respect to future changing conditions. Moreover, the adaptive selection of the most informative set of future scenarios allows to obtain satisfactory solutions in terms of system performance by considerably reducing the computational requirements.