

Designing robust energy policy packages under deep uncertainty: A multi-metric decision support framework

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Abstract-

The complexity of transitioning to sustainable energy systems requires policy frameworks capable of balancing multiple objectives while addressing deep uncertainty. However, existing approaches often lack systematic methods to identify combinations of policy levers that remain effective across a wide range of uncertain futures. This study aims to develop and demonstrate a structured decision-support framework for designing robust energy policy packages under deep uncertainty. The proposed method leverages a large ensemble of scenarios and applies scenario discovery techniques to identify influential policy levers. We introduce new indicators to assess the robustness of policies by evaluating their ability to mitigate adverse outcomes across metrics. These indicators support an iterative process to build a robust policy package. Finally, we map the technological and energy pathways associated with the robust policy package by leveraging an energy system optimization model. We illustrate the application of this framework to the Spanish energy system, providing insights into how specific combinations of policy levers shape decarbonization pathways under uncertainty.

Index Terms- Energy policy; Robust decision-making; Policy package design; Deep uncertainty; Decision-support methods

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