

Stochastic simulation-optimization framework for the design and assessment of renewable energy systems under uncertainty

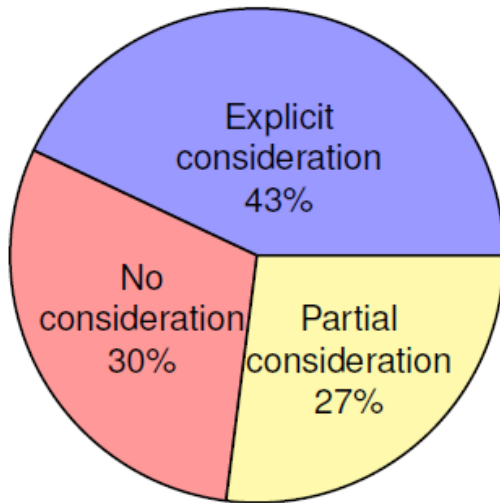
G.K. Sakki, I. Tsoukalas, P. Kossieris, C. Makropoulos, A. Efstratiadis (2022)

Presented by Tanya on 11 June 2026

Uncertainty!

“The discrepancy between summer peak demand in 1983 and earlier projections corresponded to an equivalent of \$750 billion in 1984 prices.”

Cooke (1991)



Distribution of uncertainty inclusion in existing literature

Source: my lit review lol

Stochastic optimization

[noun]

A mathematical framework used to quantify uncertainty before being surprised anyway.

Background

Context: Increasing RE penetration introduces multiple, interacting uncertainties

Internal uncertainty

- Efficiency curve of turbines / PV panels
- Model assumptions and parameters
- Equipment aging and degradation over time



External uncertainty

- Hydrometeorological inputs
- Electricity market price fluctuations
- Socioeconomic and land-use constraints

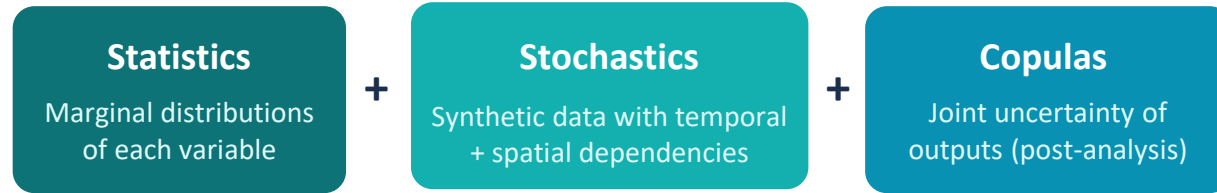


Implications

- Nonlinearities in inflow-to-energy conversion amplify combined uncertainty
- Most practice treats them separately; **combined effects not studied as much**
- Ignoring uncertainty results in **fully deterministic outcomes → risky decisions**

The research

Methodological triptych



Modular uncertainty settings

- A** Statistical only — marginal distributions, no temporal dependencies
- B** Stochastic — Setting A + seasonality and cross-scale dependencies
- C** Full — Setting B + internal efficiency uncertainty via parametric sampling

For all settings, generate 100 Monte Carlo scenarios × N-year synthetic ensembles

Case studies

Case A · Small hydro (Run-of-River)

- Achelous River, Western Greece
- Design problem: optimal mixing of 2 turbines
- Objective: maximise profit vs. investment cost; penalise low capacity factor

Case B · Wind power park

- Ikaria Island, Aegean Greece
- Assessment problem: long-term economic viability of 2 turbines
- Energy price modelled stochastically from 5 years of market data

Results and discussion

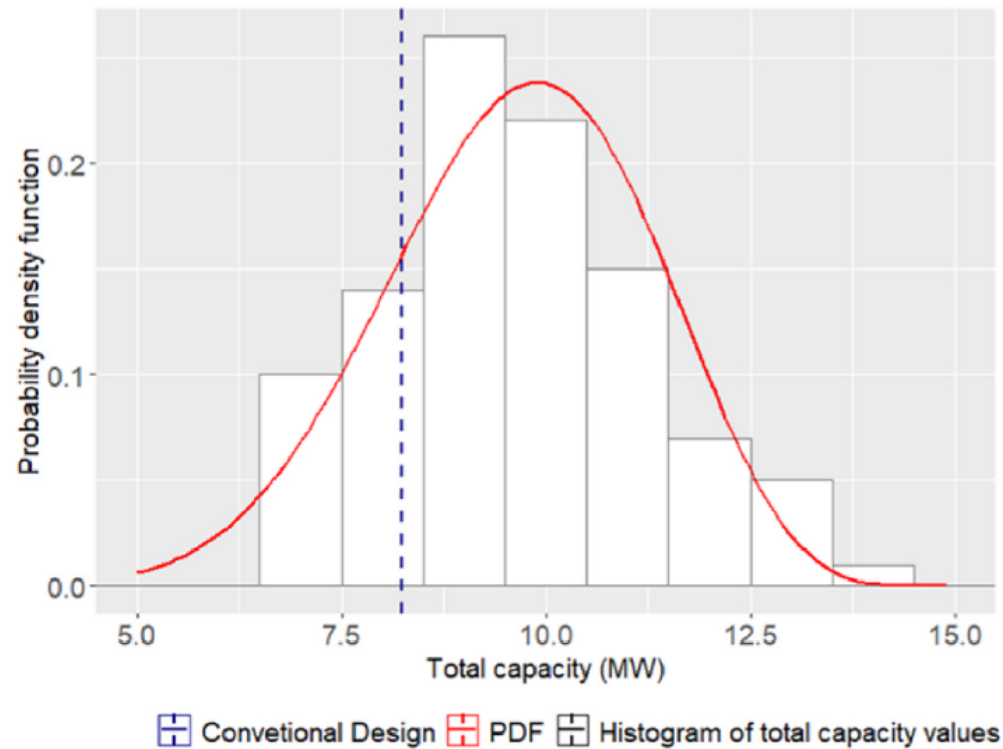


Fig. 8. Fitting of Beta distribution to the set of optimized total capacity values (setting C).

1. Hydro: deterministic optimisation results in a **single capacity value** (9.9 MW), while Setting C gives a **capacity range of 6.7–13.7 MW**
2. Wind: deterministic income estimate (€0.36M/yr) **fell below the stochastic range** (€0.37–0.66M/yr)
3. In both cases, Setting B (stochastic) revealed **substantially more uncertainty** than Setting A (statistical)
4. In the hydro design, Setting C **flipped the optimal turbine hierarchy!**
5. Uncertainty reveals the **viability** of planned projects and **weaknesses** of existing systems