

Is there no alternative?

It is time energy planning models looked beyond cost-optimal solutions

Francesco Lombardi, Koen van Greevenbroek, Aleksander Grochowicz, Michael Lau, Fabian Neumann, Neha Patankar, Oskar Vågerö

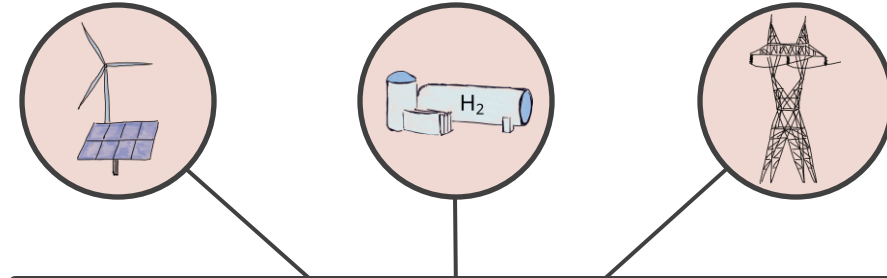


Based on: *Near-optimal energy planning strategies with modeling to generate alternatives to flexibly explore practically desirable options.* Joule, 2025. doi.org/p8b5

Part A.

What's wrong with conventional cost optimisation

We must deploy new renewable, transmission and storage capacity.
But **how much?** and **where?**



The standard. Optimising the system re-design

```
Example: brownfield design optimisation at different resolutions

[1]: import calliope
import pandas as pd
from plotting_utilities import plot_dispatch, plot_capacity, plot_network
calliope.set_log_verbosity('INFO', include_solver_output=False) # Defines how much information you get from the machine as the model gets built and

1. Simple run to find cost-optimal system design at different resolutions
+ 1.1 Default spatial resolution

[2]: # Load the model from the model.yaml file with a 'brownfield' design scenario, starting from current installed capacities
model = calliope.Model('model_files/model.yaml', scenario='brownfield_capacities')

[2025-05-20 09:45:42] INFO Model: initialising
[2025-05-20 09:45:42] INFO (scenarios, brownfield_capacities) | Applying the following overrides: ['brownfield_capacities'].
[2025-05-20 09:45:42] INFO Model: preprocessing stage 1 (model_run)
[2025-05-20 09:45:50] INFO Model: preprocessing stage 2 (model_data)
[2025-05-20 09:45:50] INFO Model: preprocessing complete

[3]: # Solve the model in 'planning' mode to find the cost-optimal system design
model.build()
model.solve()

[2025-05-20 09:46:17] INFO Model: backend build starting
[2025-05-20 09:46:17] INFO Math preprocessing | added file 'plan'.
[2025-05-20 09:46:17] INFO Math preprocessing | added file 'custom_math/import_export_share.yaml'.
[2025-05-20 09:46:17] INFO Math preprocessing | validated math against schema.
[2025-05-20 09:46:18] INFO Optimisation Model | parameters | Generated.
[2025-05-20 09:46:20] INFO Optimisation Model | Validated math strings.
[2025-05-20 09:46:21] INFO Optimisation Model | variables | Generated.
[2025-05-20 09:46:25] INFO Optimisation Model | global expressions | Generated.
[2025-05-20 09:46:34] INFO Optimisation Model | constraints | Generated.
[2025-05-20 09:46:34] INFO Optimisation Model | piecewise constraints | Generated.
[2025-05-20 09:46:34] INFO Optimisation Model | objectives | Generated.
[2025-05-20 09:46:34] INFO Model: backend build complete
[2025-05-20 09:46:40] INFO Optimisation model | starting model in plan mode.
[2025-05-20 09:46:58] INFO Backend: solver finished running. Time since start of solving optimisation problem: 0:00:17.999459
```

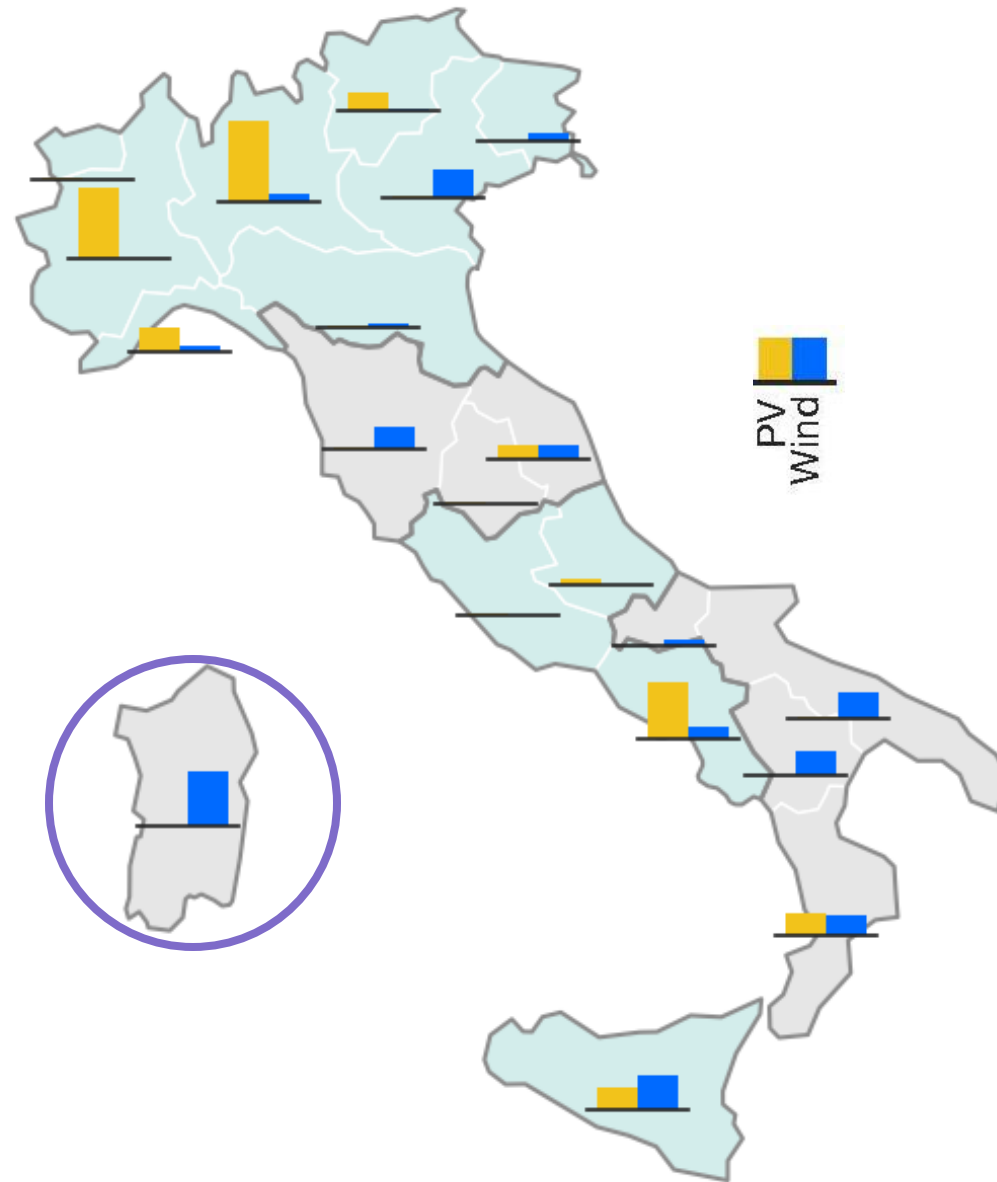
Energy planning models provide quantitative insights on such questions.

How? turning those into a mathematical problem, for which an 'optimal' solution can be found

minimum cost

Cost-optimality.

Is it desirable?

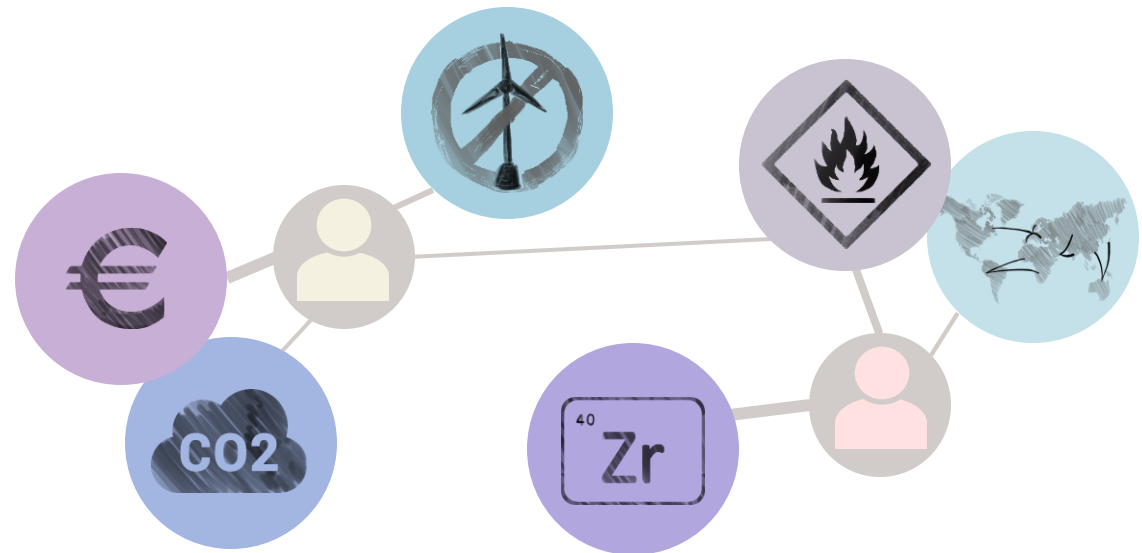


Cost-optimality.

Generalisable shortcomings

Two issues when applied to energy transition planning:

1. Real-world decisions involve much more than economic cost (social acceptance, environmental impact, ...)

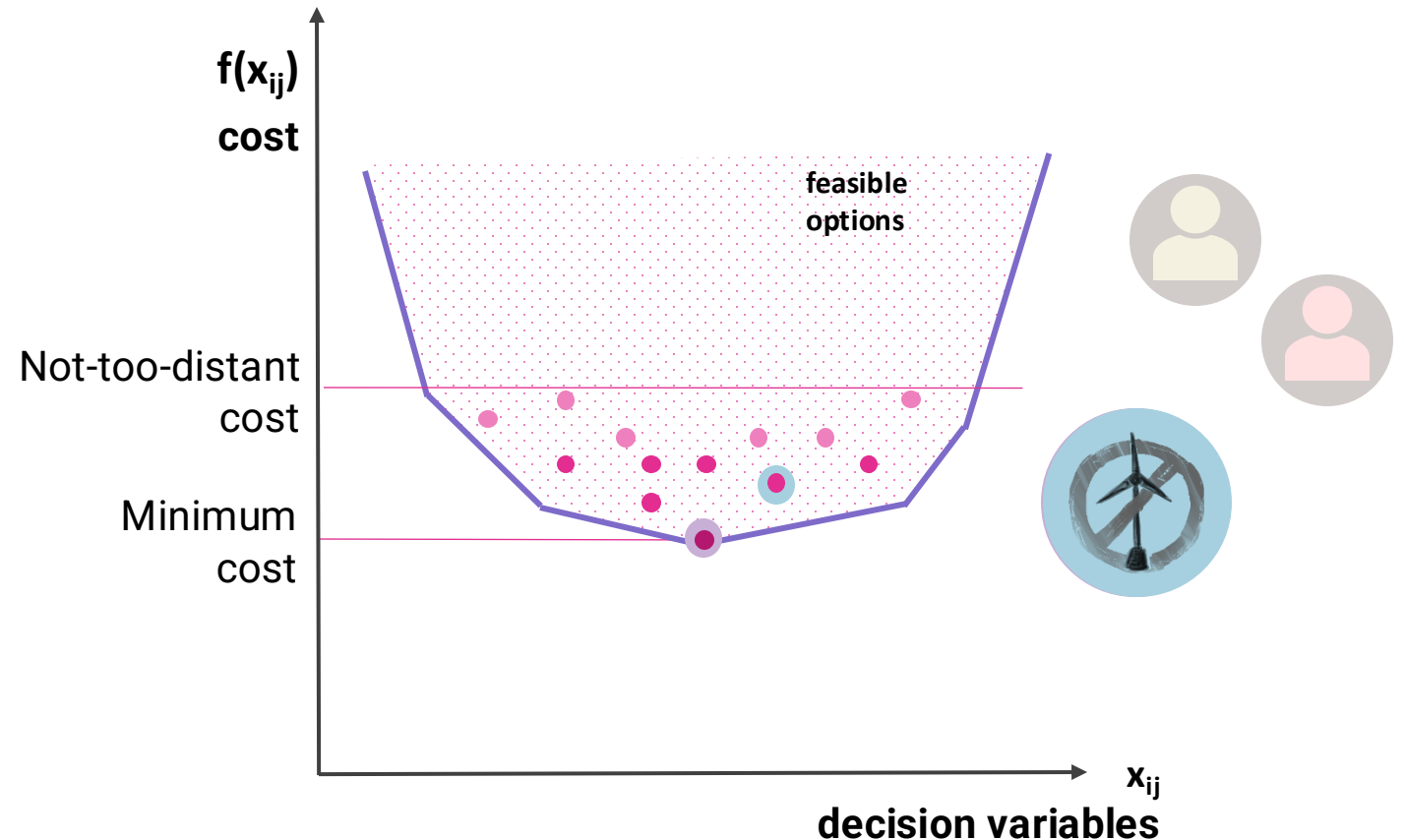


Cost-optimality.

Generalisable shortcomings

Two issues when applied to energy transition planning:

2. It is pointless to fixate on the minimum cost considering the uncertainty surrounding all cost assumptions

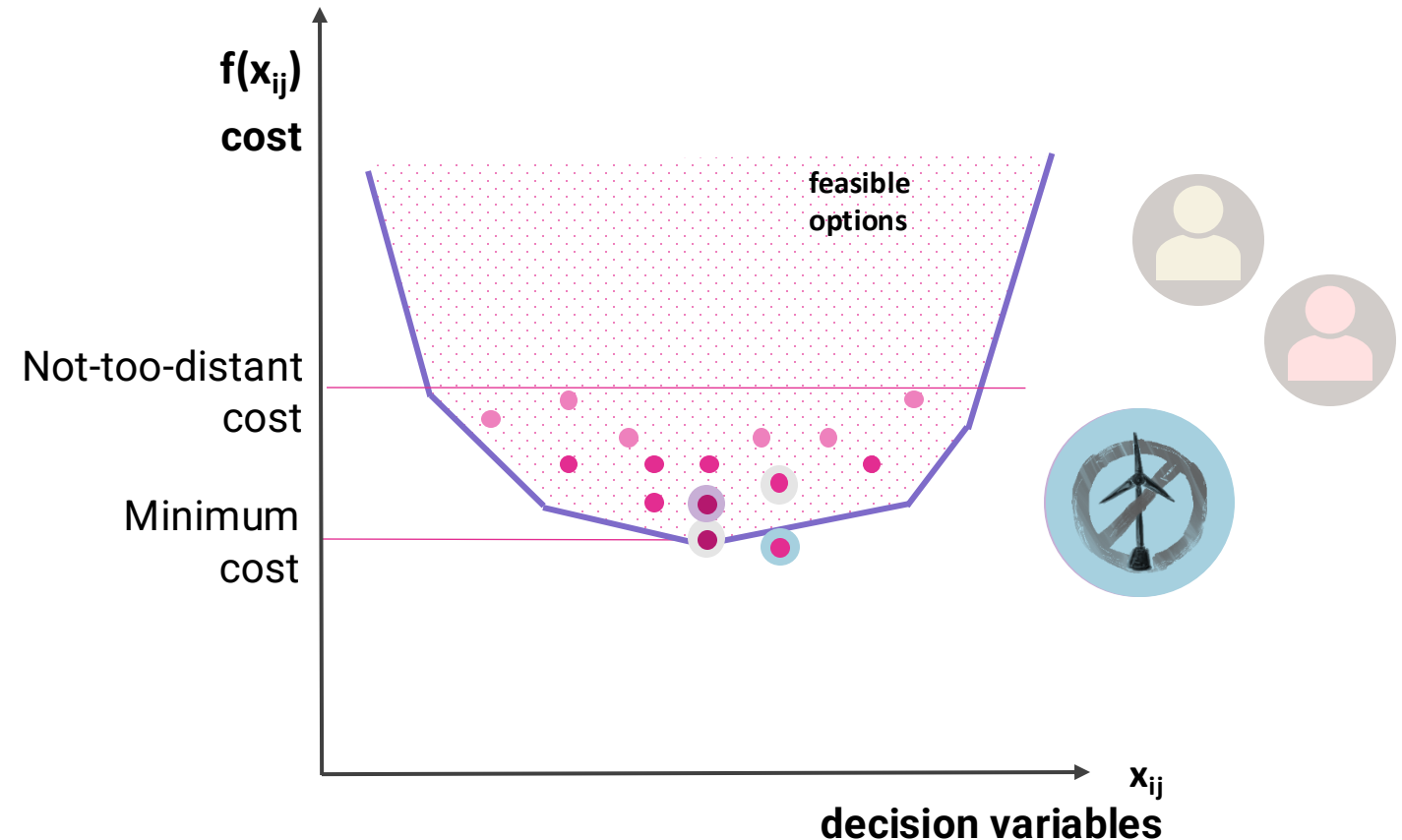


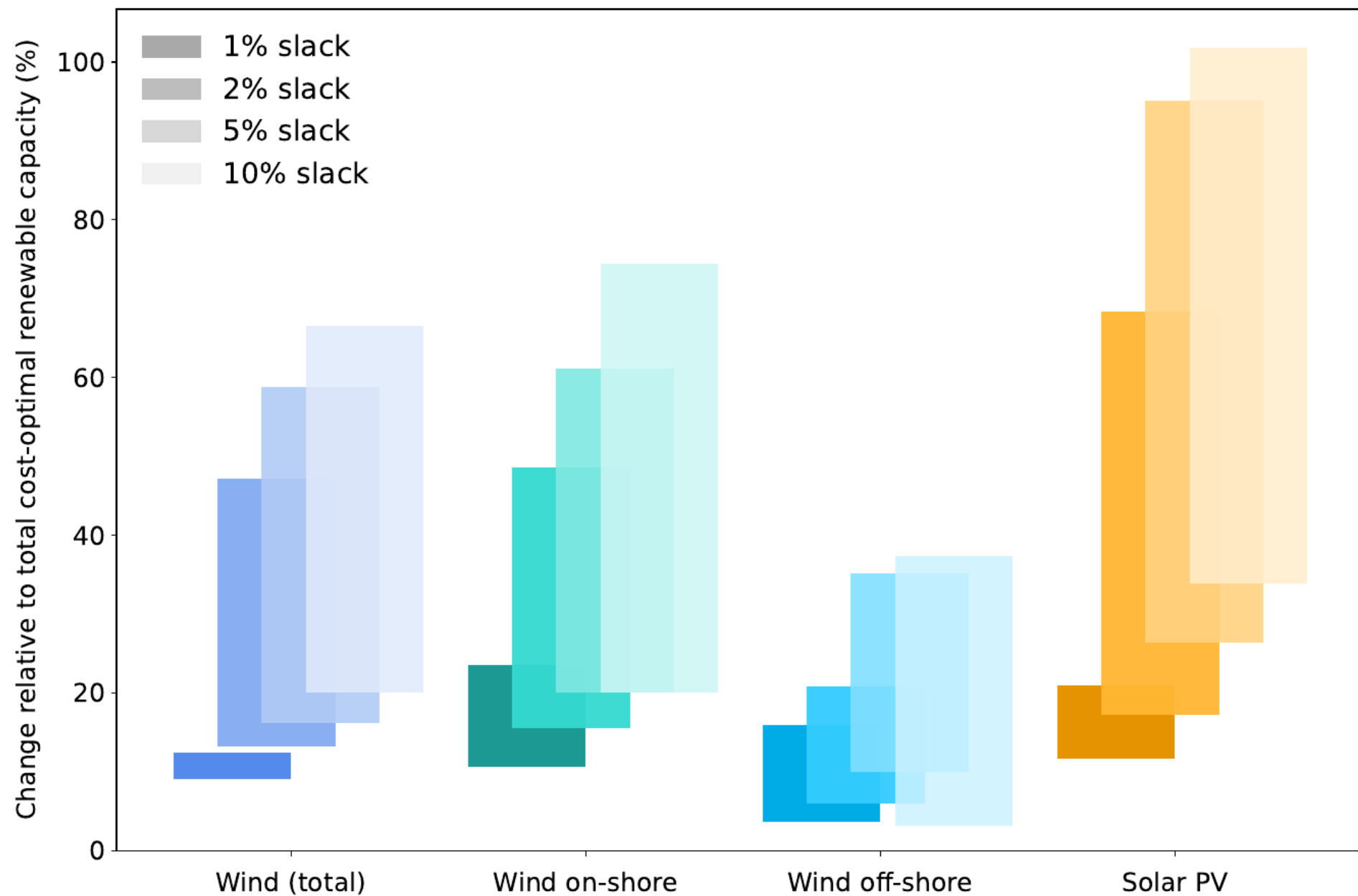
Cost-optimality.

Generalisable shortcomings

Two issues when applied to energy transition planning:

2. It is pointless to fixate on the minimum cost considering the uncertainty surrounding all cost assumptions

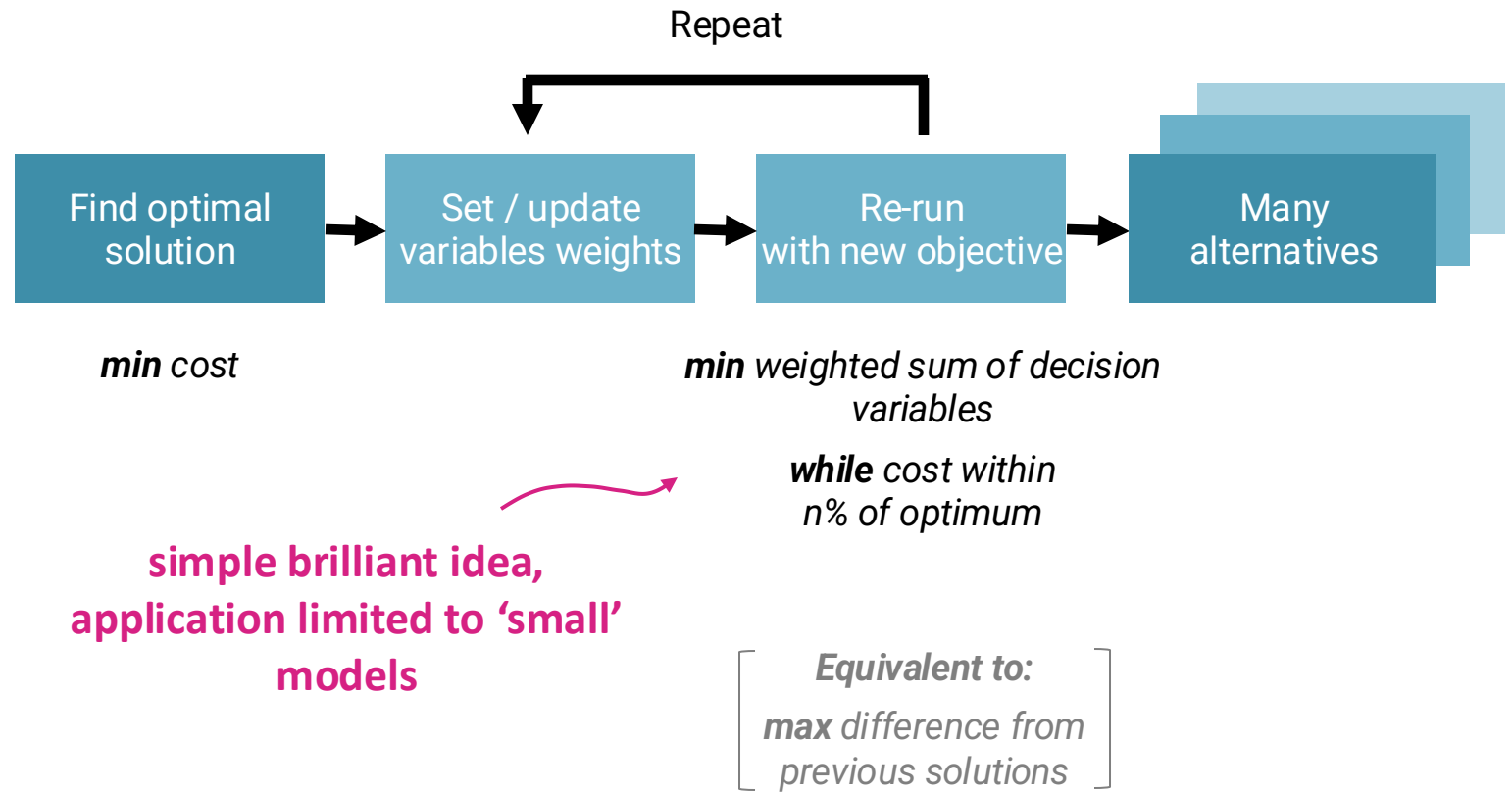




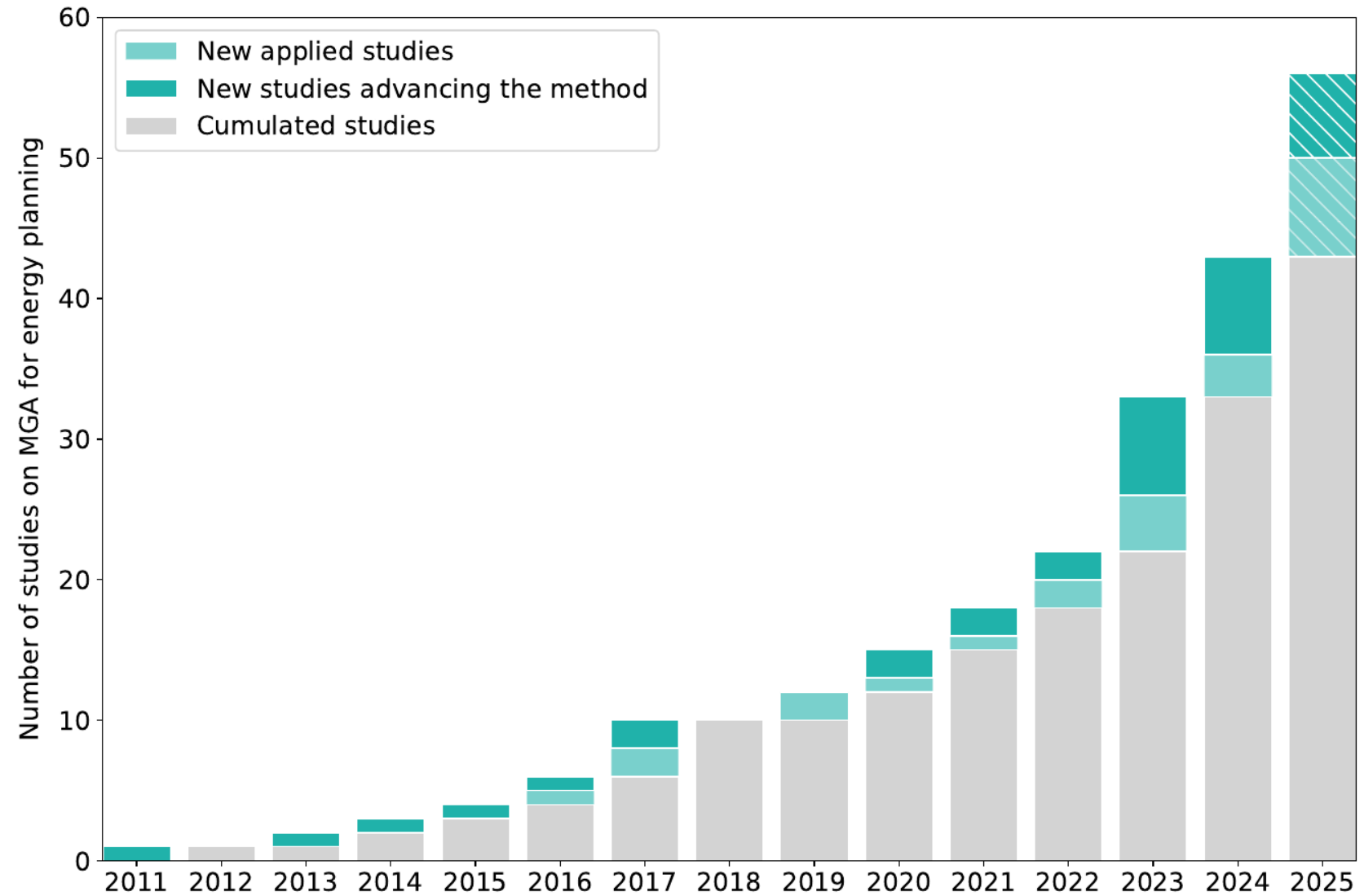
Part B.

(Next-generation) Modelling to Generate Alternatives

Modelling to Generate Alternatives.



Modelling to Generate Alternatives.

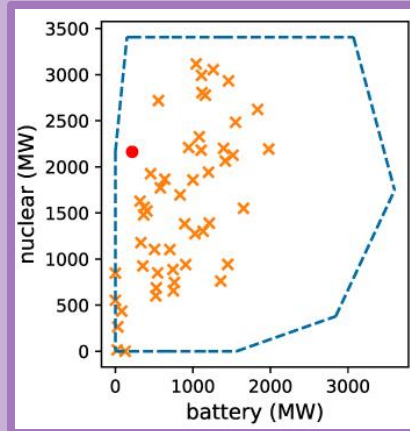


Next-gen MGA.

(selected illustrative examples)

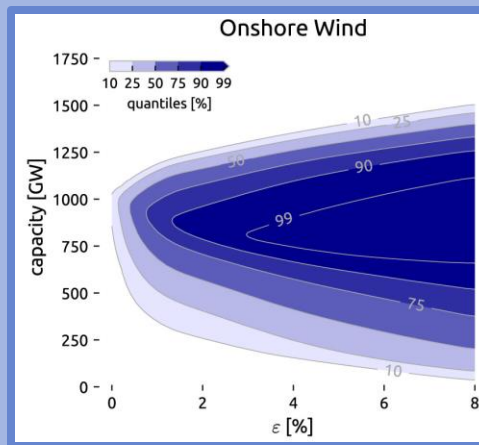
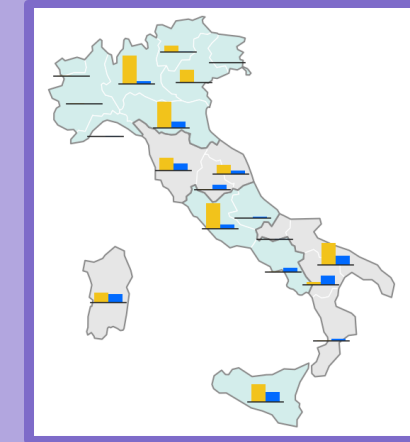
Lau, Patankar, Jenkins. *Env. Res.: Energy*, 2025. doi.org/p8nk

More efficient and robust computation



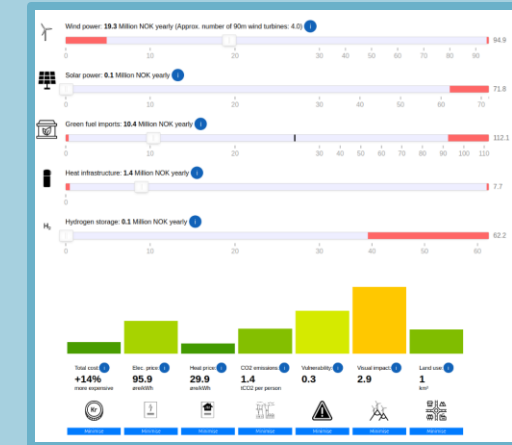
Lombardi, Pickering, Pfenninger. *App. En.*, 2023. doi.org/j457

Tailored search for spatial aspects



Integration with parametric uncertainty

Neumann, Brown. *iScience*, 2023. doi.org/g27qjq



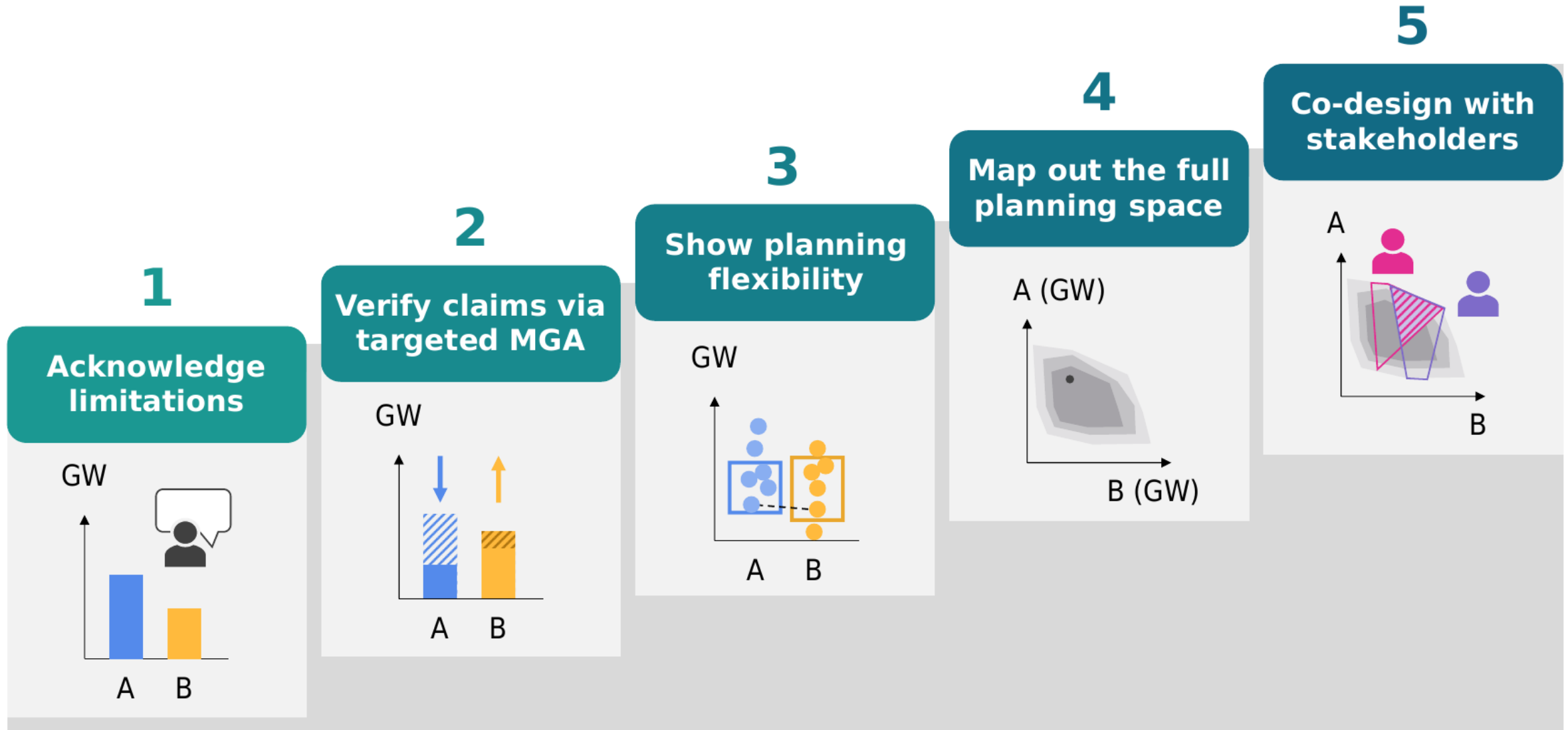
Intuitive and practically applicable outputs

Vågerö, van Greevenbroek, Grochowicz, Roithner. *arXiv*, 2025. doi.org/p8nm

Part C.

Integrate MGA in your analysis in five flexible levels

An MGA integration ladder.



Cost-optimal planning provides a false sense of exactness

Next-gen MGA enables technically-robust and socially-viable plans

Tailored MGA checks on key insights are simple but very helpful