Beyond cost-effectiveness.

Designing socially viable and technically resilient energy systems

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Some of the slides in this presentation are reused from a presentation on a similar topic held together with F. Neumann as part of the ECEMP 2025 conference.
See: www.flombardi.org/lectures/

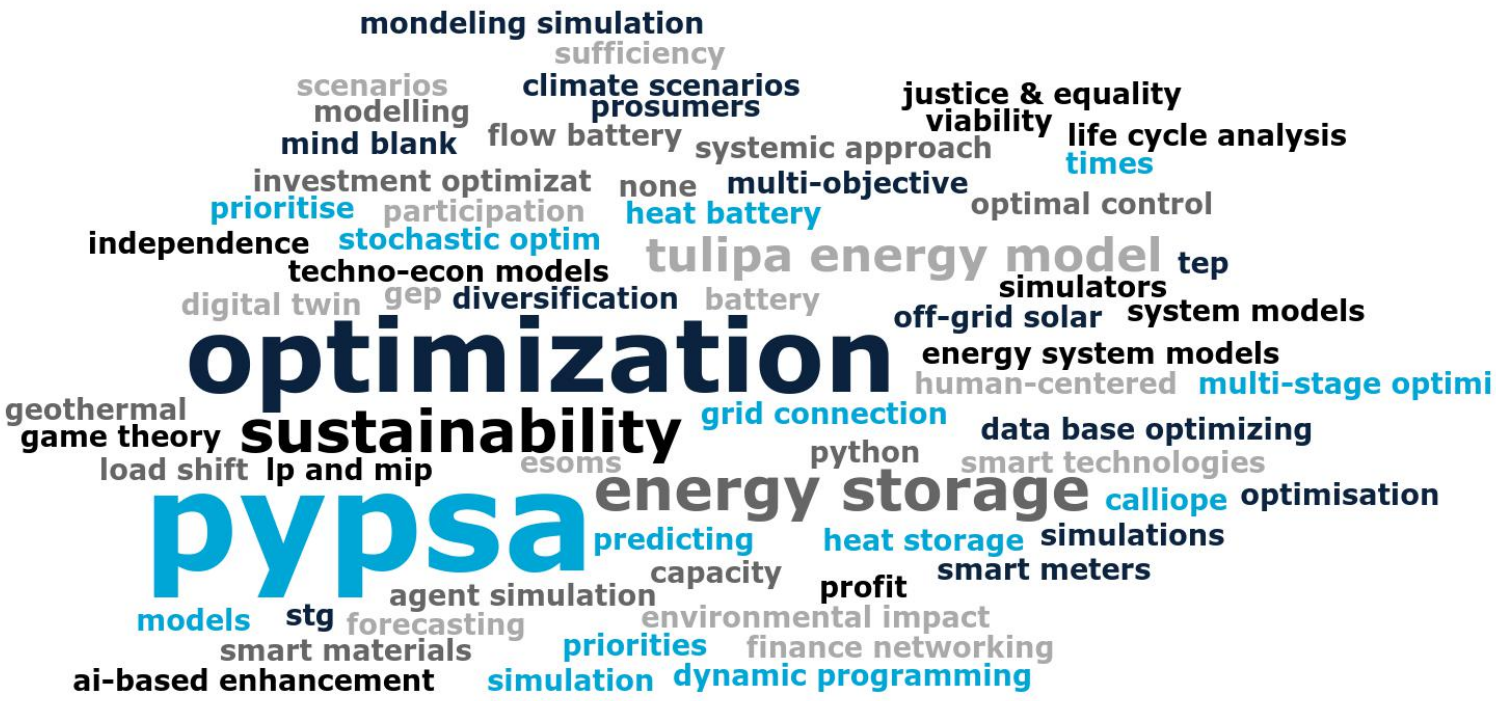
Prelude.

What do you know about energy system design?

What **methods, approaches or tools** come to mind to support the (re)design of new energy systems?

Designing energy system.

How?



Learning objectives.

By the end of today's session, you will be able to:

A. Discuss **the shortcomings** of conventional energy system design

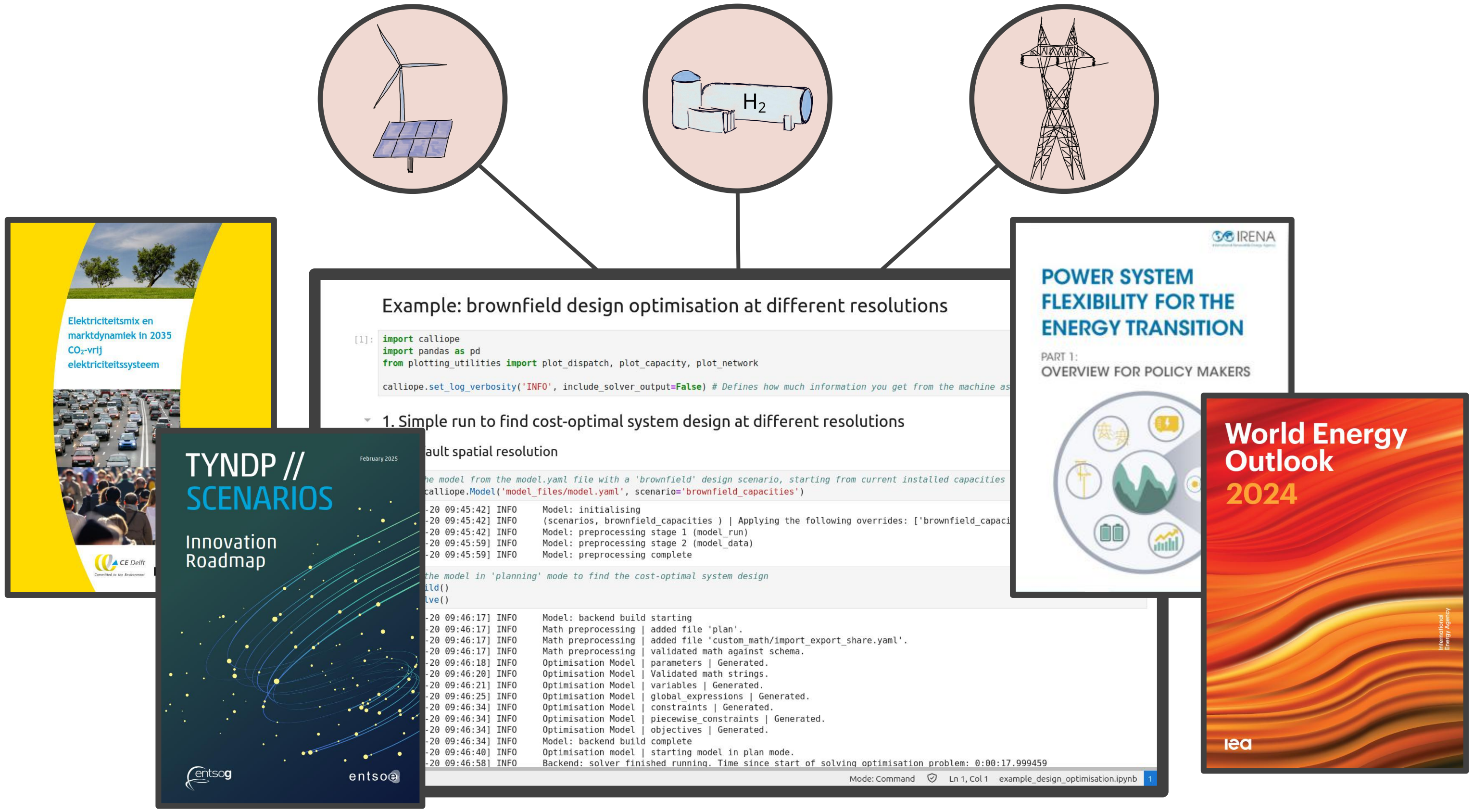
B. Select suitable **methods to deal with such shortcomings**

Part A.

Conventional system design. What’s wrong with it?

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

The standard.
Optimising the system re-design



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

Why would a cost-optimal energy system design be potentially undesirable in practice?

Cost-optimality.

Is it desirable?

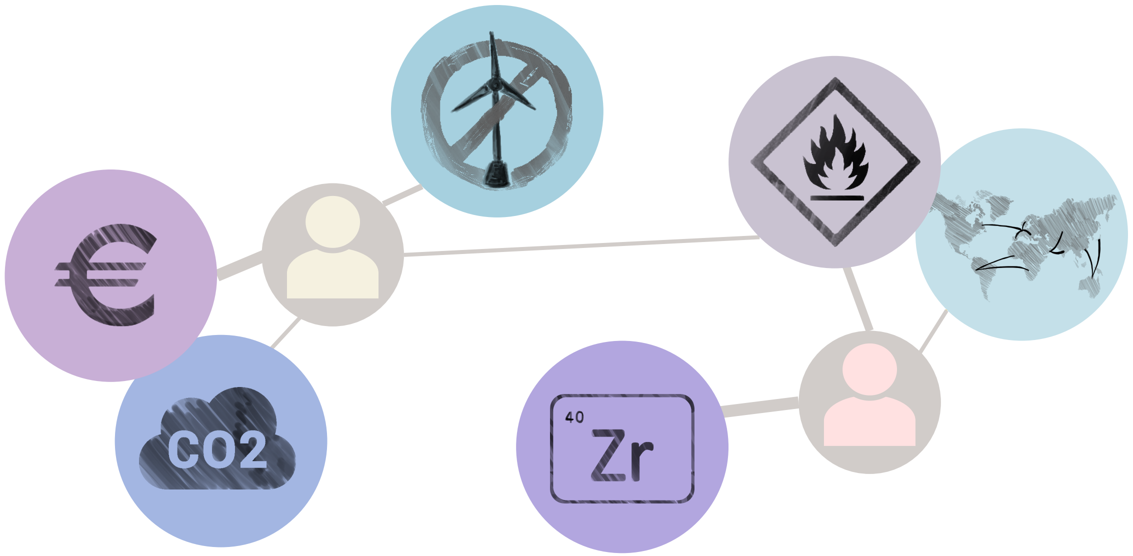
Cost-optimality.
Is it desirable?

Lombardi, Pickering, Colombo, Pfenninger. *Joule*, 2020. doi.org/gg8z6v

Cost-optimality.
Generalisable shortcomings

Two issues when applied to socio-technical systems:

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



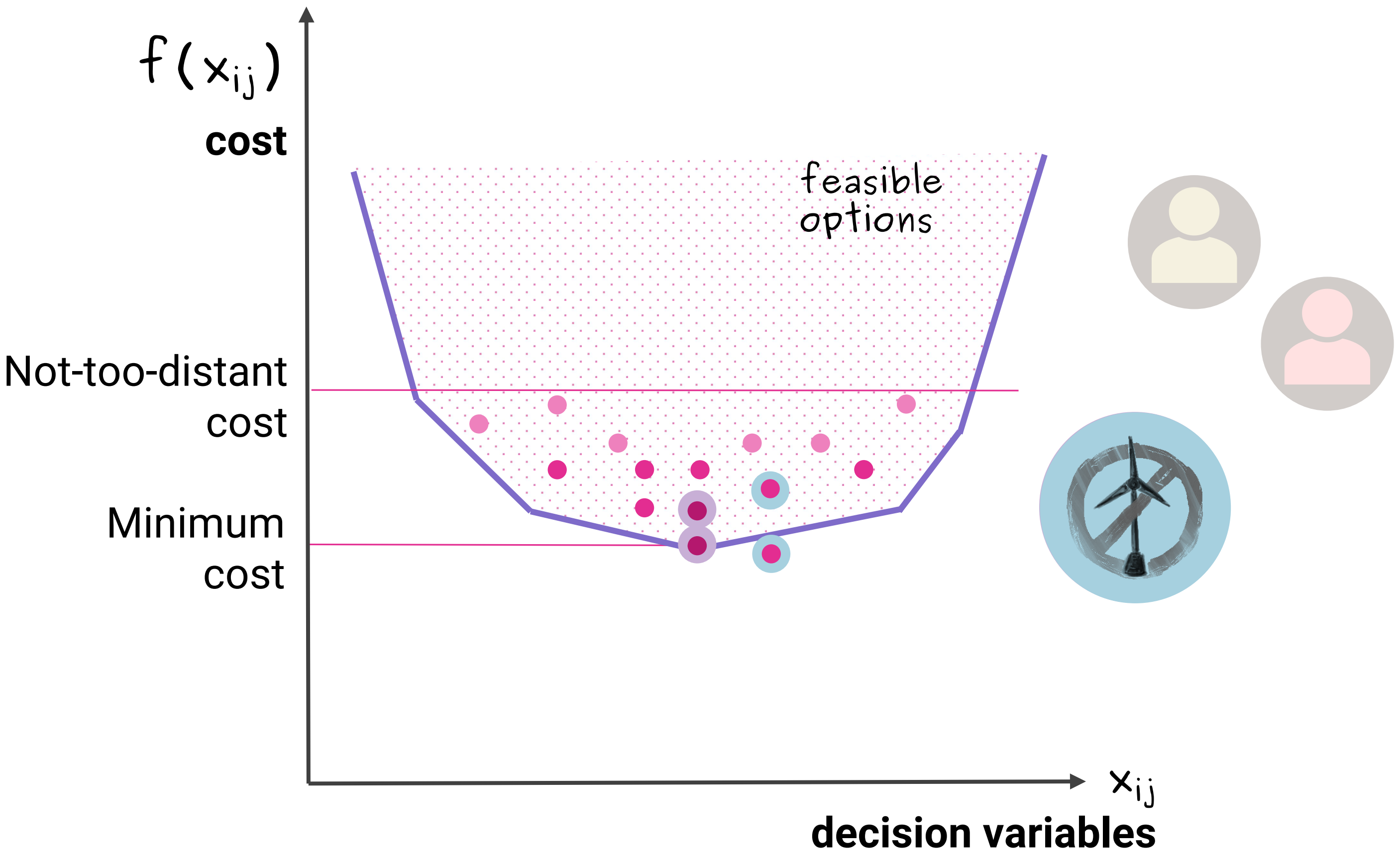
And multi-objective optimisation won't help! We cannot parametrise all that matters for real-world decisions

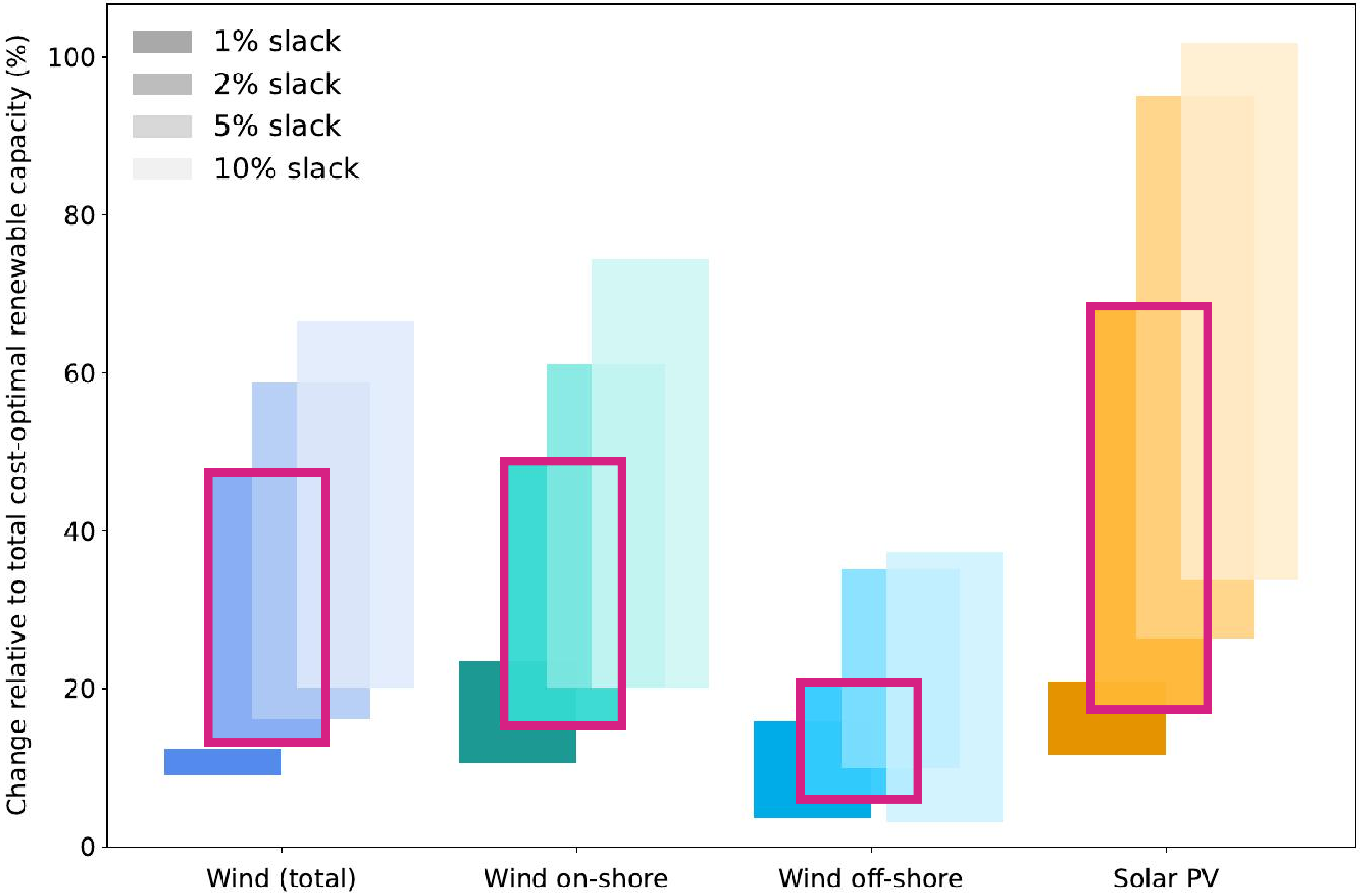
Cost-optimality.

Generalisable shortcomings

Two issues when applied to socio-technical systems:

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





Lombardi, van Greevenbroek, Grochowicz, Lau, Neumann, Patankar, Vågerö. *Joule,* 2025. doi.org/p8b5

Part B.
(Next-generation) Modelling to Generate Alternatives

Modelling to Generate Alternatives.

Methods to explore the near-optimal region have been proposed in 1979 and then developed throughout the ‘80s

They are known as **Modelling to Generate Alternatives (MGA)**

MANAGEMENT SCIENCE
Vol. 25, No. 5, May 1979
Printed in U.S.A.

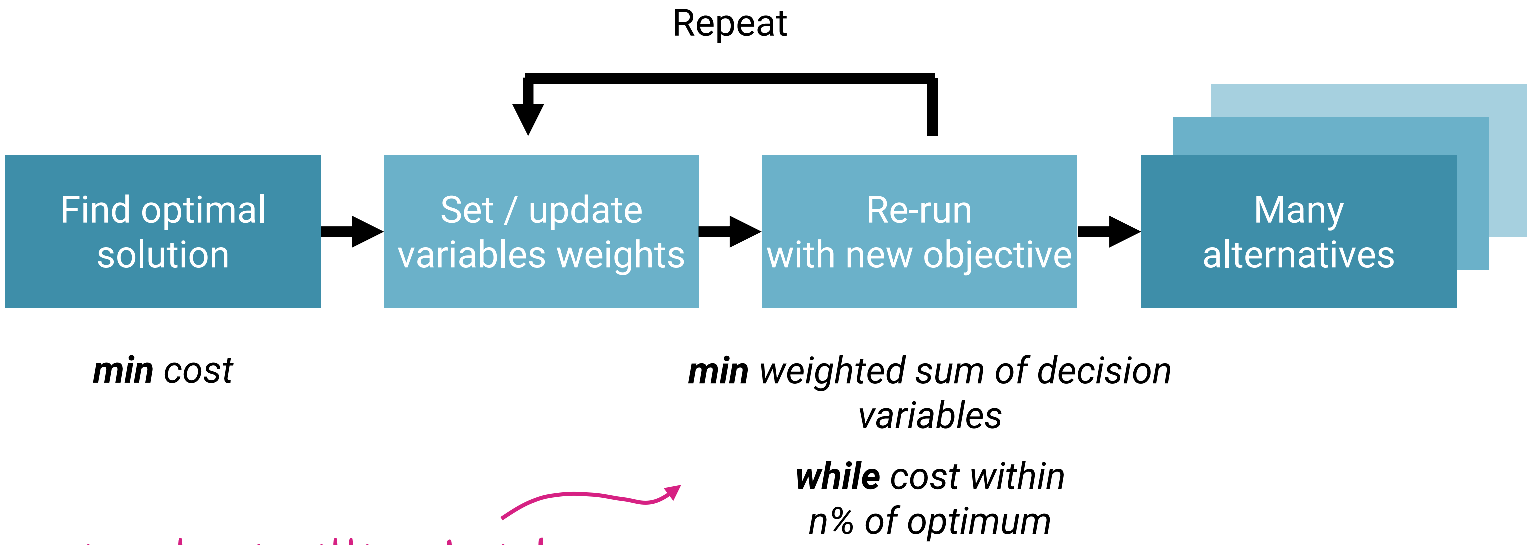
THE USE OF OPTIMIZATION MODELS IN PUBLIC-SECTOR PLANNING*

E. DOWNEY BRILL, JR.†

When applied to public-sector planning, traditional least-cost optimization models and their offspring, contemporary multiobjective models, have often been developed under the optimistic philosophy of obtaining “the answer.” Frequently, such models are not very useful because there is a multitude of local optima, which result from wavy indifference functions, and because important planning elements are not captured in the formulations. Omitted elements, in fact, may imply that an optimal planning solution lies within the inferior region of a multiobjective analysis instead of along the noninferior frontier. The role of optimization methods should be re-thought in full recognition of these limitations and of the relevant planning process. They should be used to generate planning alternatives and to facilitate their evaluation and elaboration; they should also be used to provide insights and serve as catalysts for human creativity. As illustrated by recent examples, these roles may require the use of several models as well as new types of optimization formulations and modified algorithms and computer codes.

(GOVERNMENT; OPTIMIZATION MODELS; PLANNING; POLICY ANALYSIS)

Modelling to Generate Alternatives.



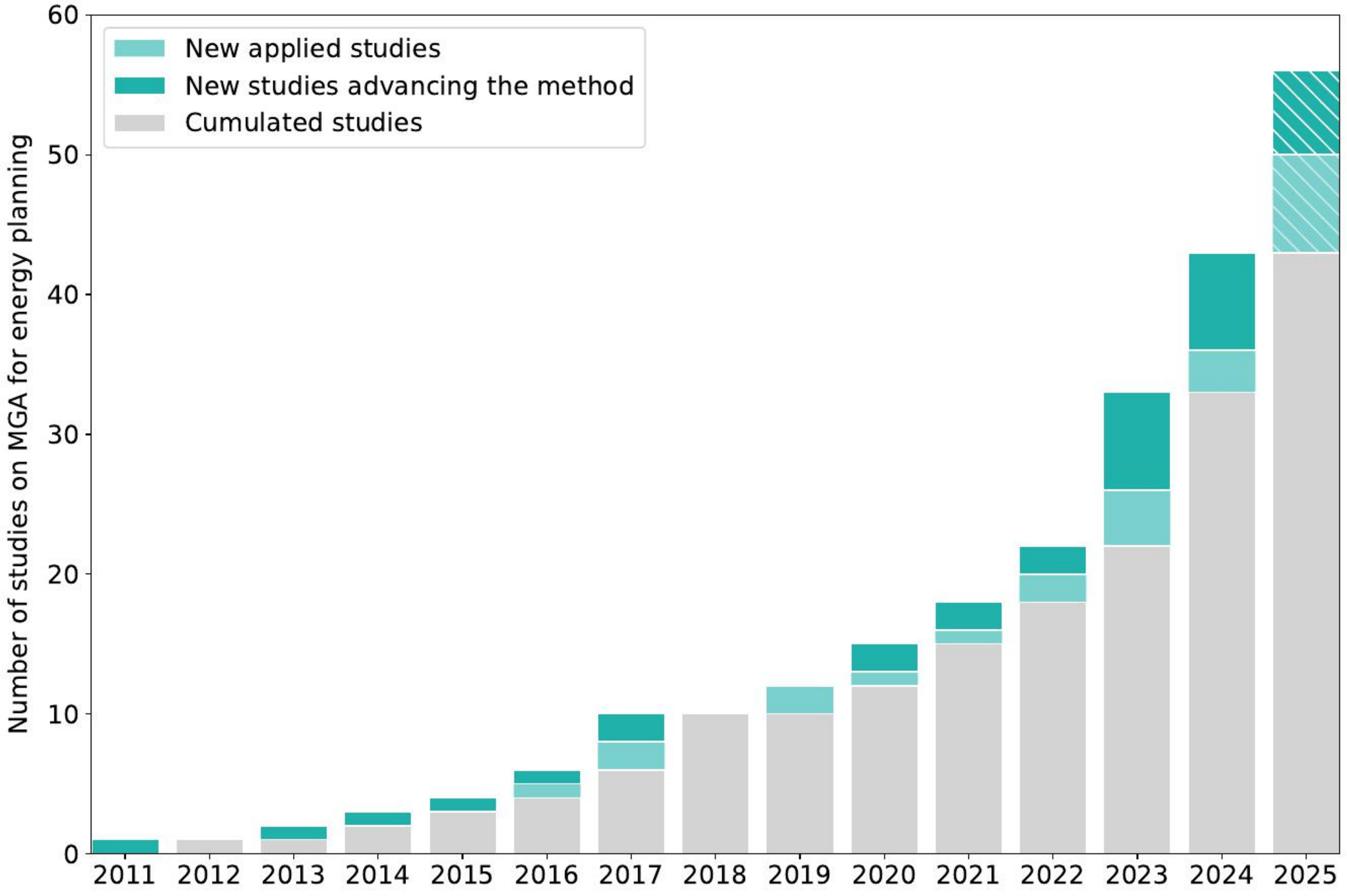
simple brilliant idea, application limited to 'small' models

Equivalent to:

max *difference from previous solutions*

Adapted from: Lombardi, Pickering, Pfenninger. *Applied Energy*. 2023. doi.org/10.1016/j.apenergy.2023.121002

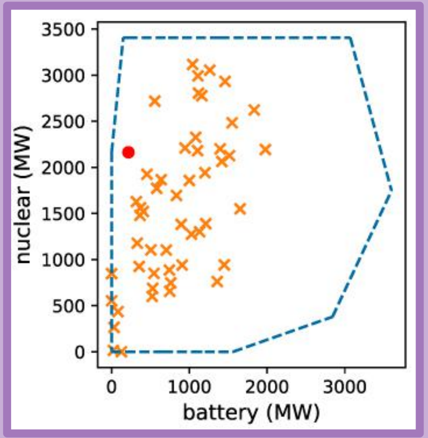
Modelling to Generate Alternatives.



Lombardi, van Greevenbroek, Grochowicz, Lau, Neumann, Patankar, Vågerö. *Joule,* 2025. [doi.org/p8b5](doi.org/p8b5)

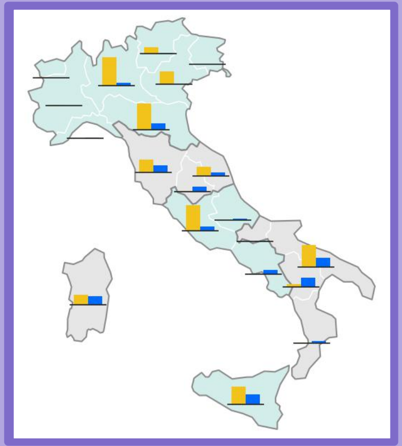
Lau, Patankar, Jenkins. *Env. Res.: Energy,* 2025. doi.org/p8nk

More efficient and robust computation



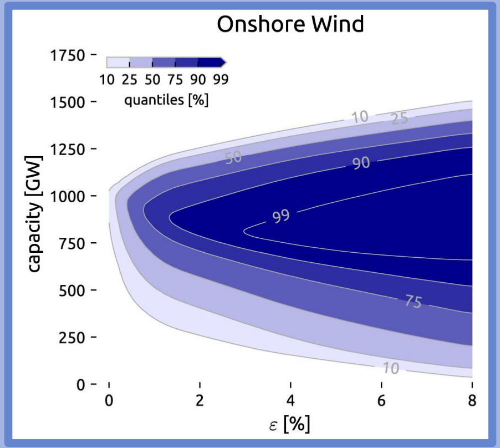
Lombardi, Pickering, Pfenninger. *App. En.,* 2023. doi.org/j457

Tailored search for spatial aspects



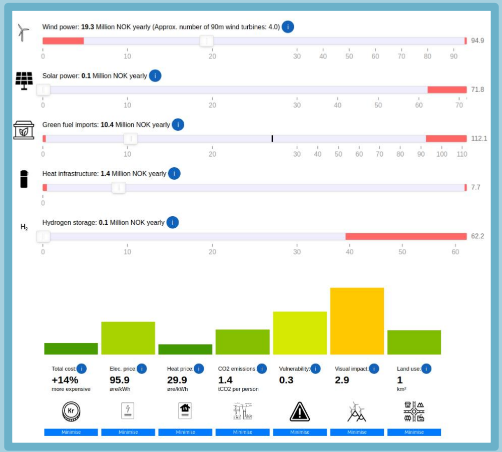
Next-gen MGA.

(selected illustrative examples)



Integration with parametric uncertainty

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

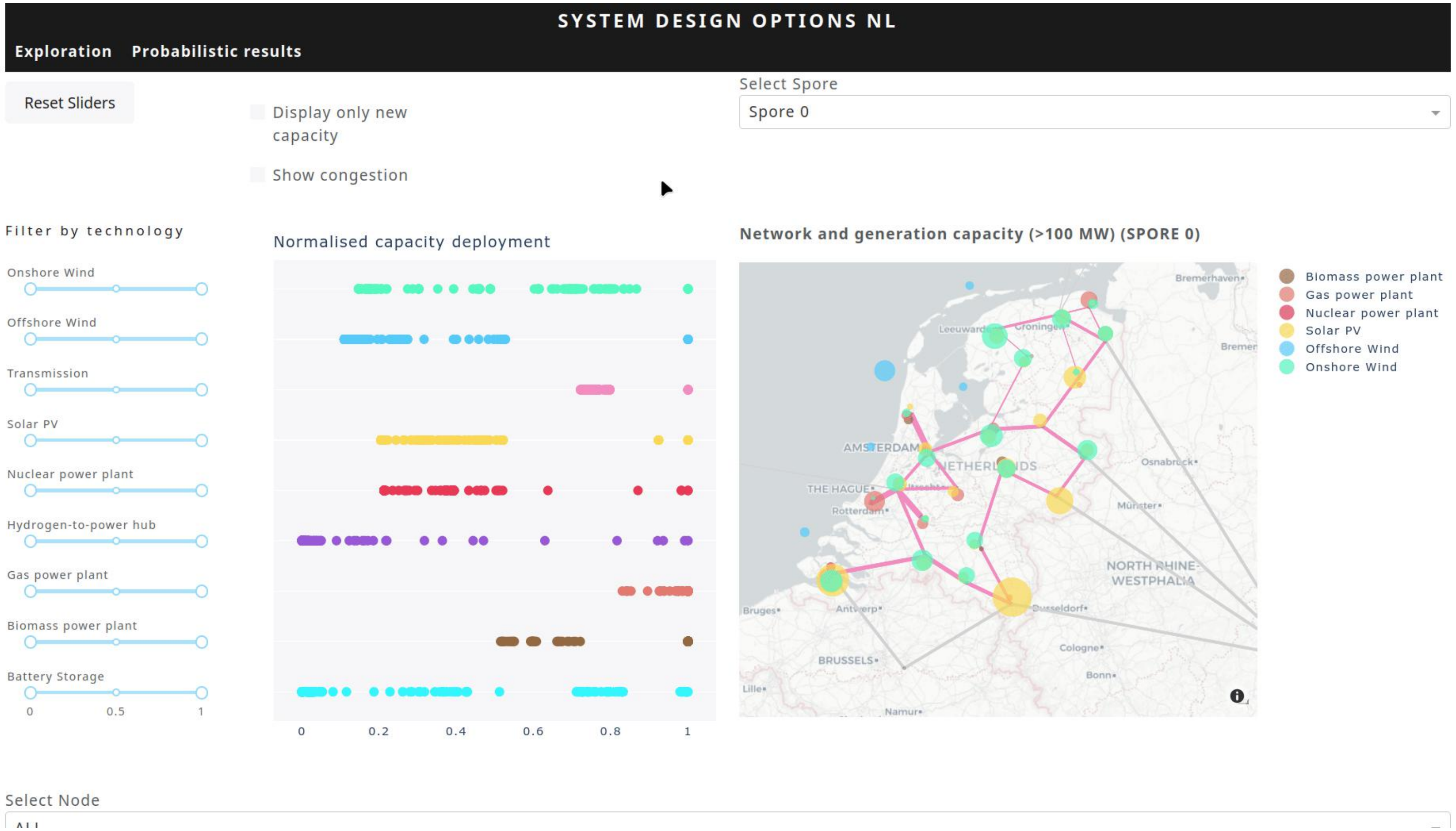


Intuitive and practically applicable outputs

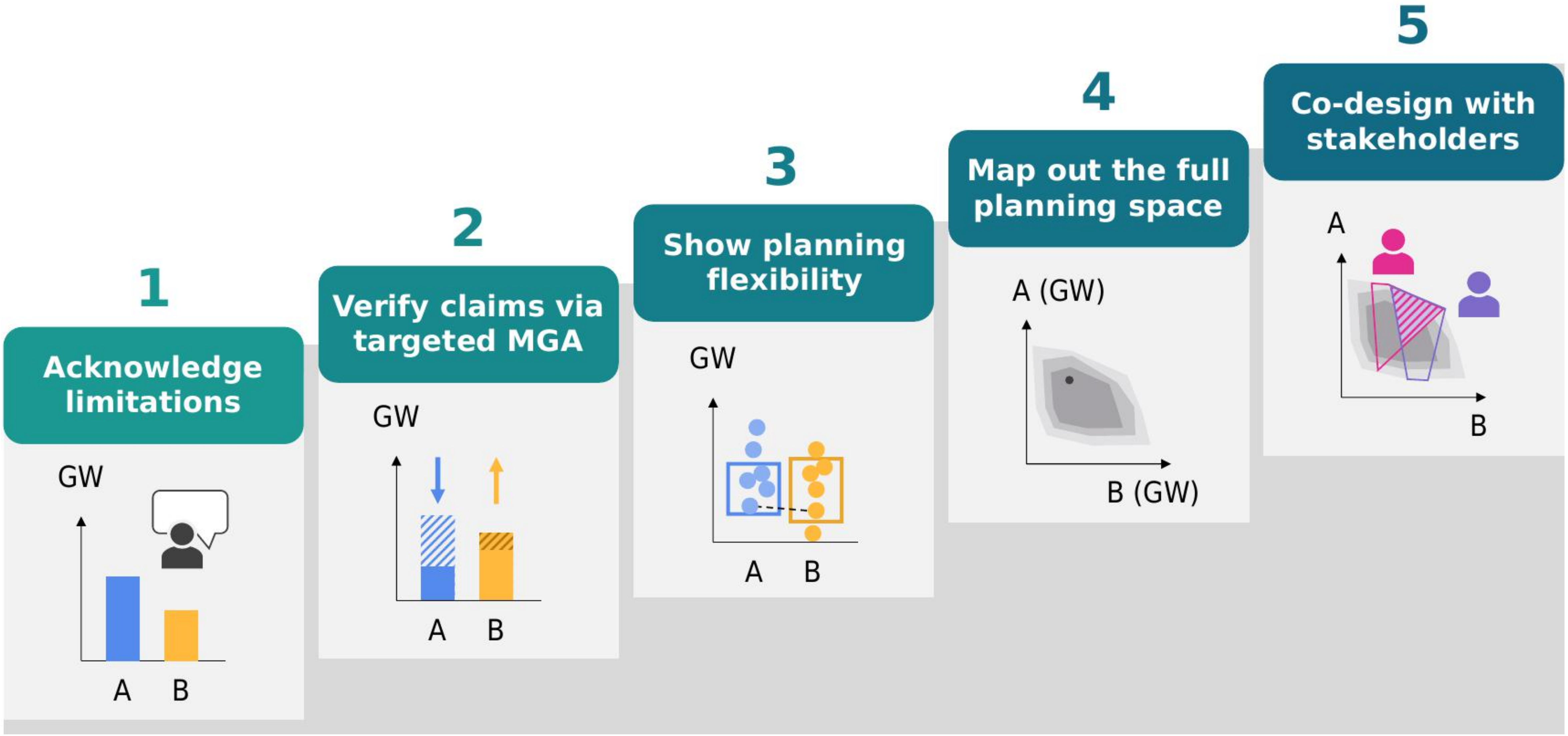
Vågerö, van Greevenbroek, Grochowicz, Roithner. *arXiv*, 2025. doi.org/p8nm

Next-gen MGA.

Interfaces



An MGA integration ladder.



Lombardi, van Greevenbroek, Grochowicz, Lau, Neumann, Patankar, Vågerö. *Joule,* 2025. doi.org/p8b5

Discuss with who's sitting next to you (groups of 2-4 people)

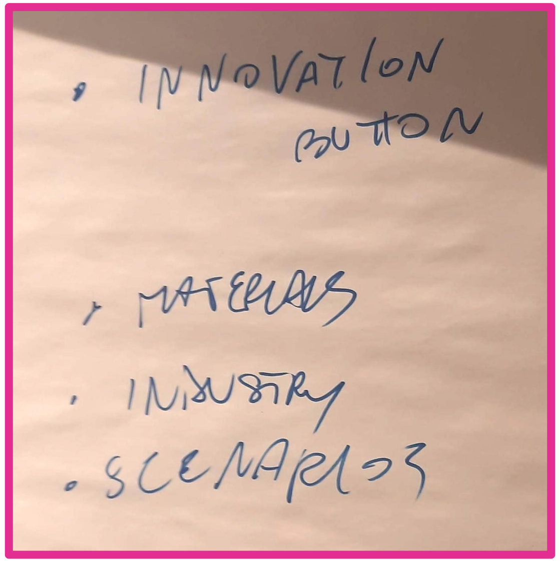
5 minutes!

Modelling to Generate Alternatives.

What are we still **missing**?

What is **not convincing** enough?

What is **problematic**?



Next-gen MGA.
Future work

Long-term pathways (multi-horizon optimisaton)

More efficient parametric uncertainty integration

Dealing with non-convex problem formulations

More real-world demos and human interface developmentts

Conventional optimisation provides a false sense of certainty

Near-optimality enables technically-robust and socially-viable designs

Computational cost can be tailored to needs and keeps improving