’Lessons learnt’ seminar series at VITO - 19th May 2025

The ‘optimum’ doesn’t work in practice.

How to generate practically viable decision alternatives

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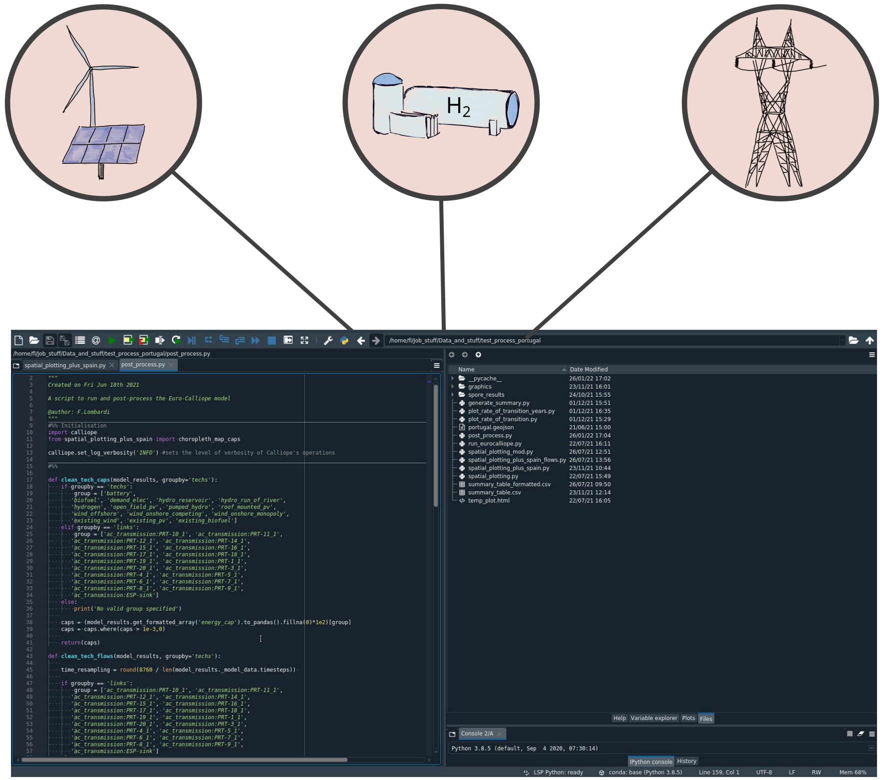
Part A.
What’s wrong with conventional optimisation

The standard.

Optimising the system re-design

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



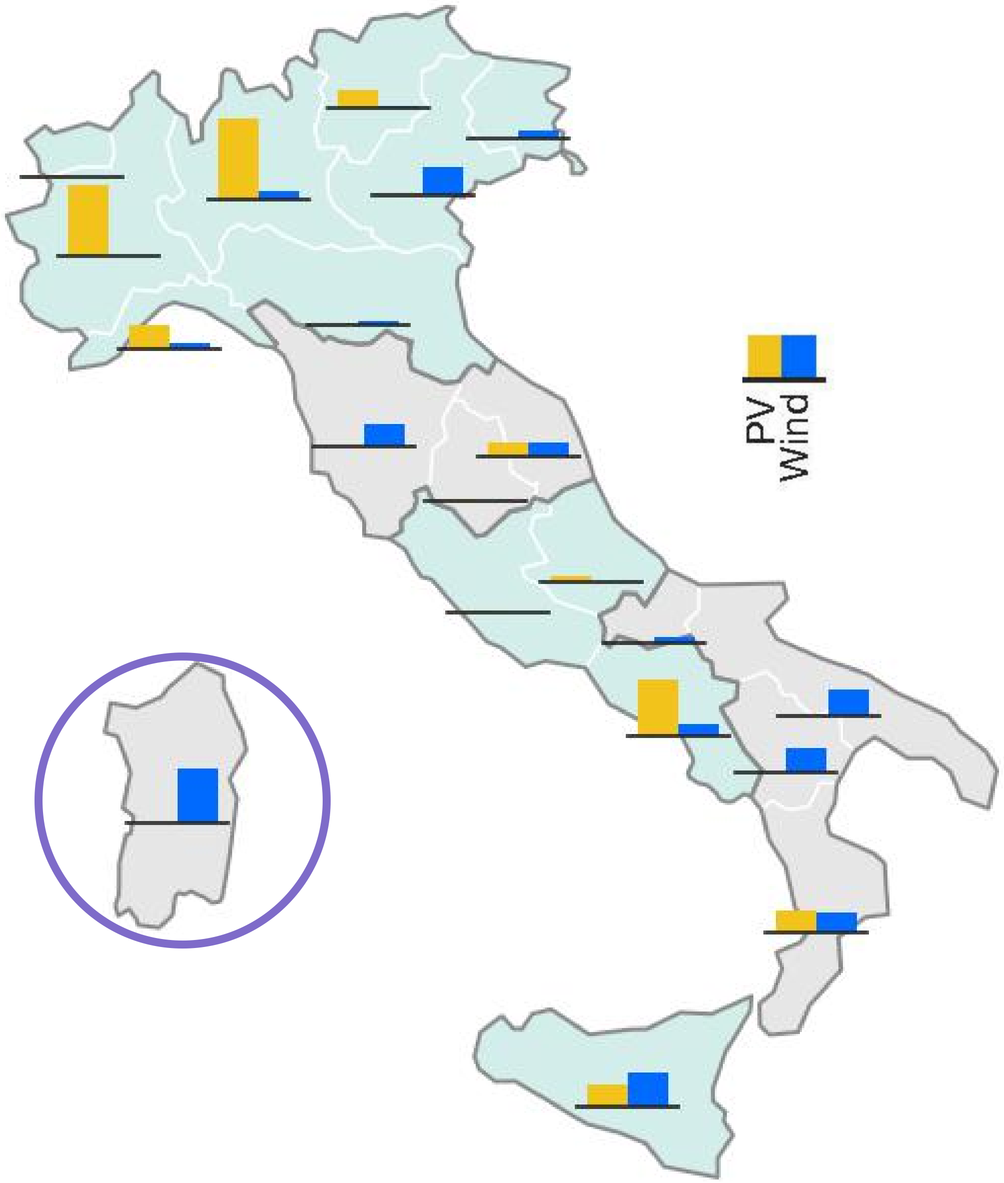
Energy system models provide quantitative insights on such questions.

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

minimum cost

Cost-optimality.

Is it desirable?

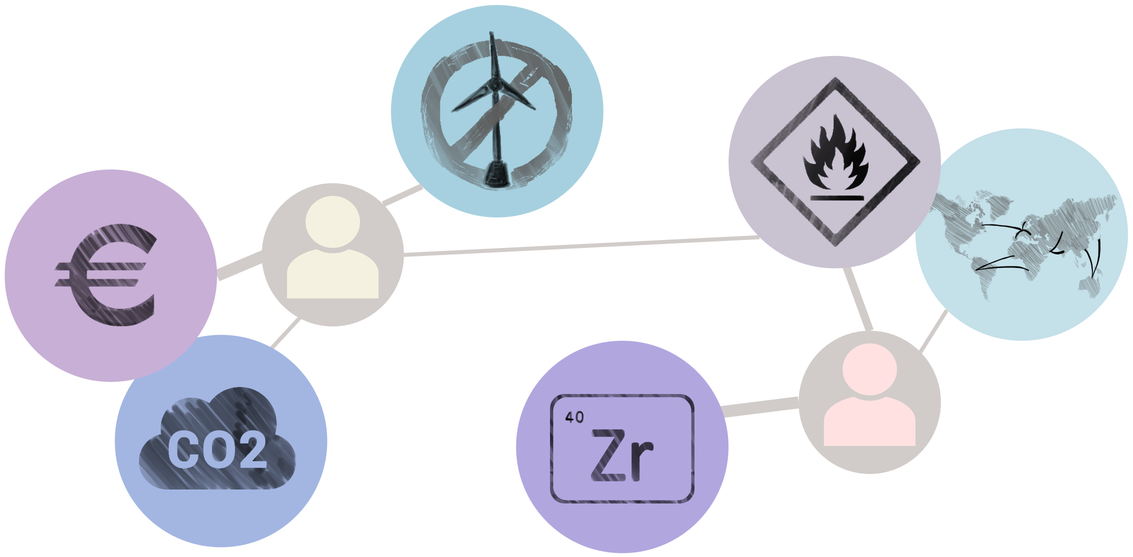


Lombardi, Pickering, Colombo, Pfenninger. *Joule*, 2020. doi.org/gg8z6v

Two issues when applied to socio-technical systems:

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

Cost-optimality.
Generalisable shortcomings

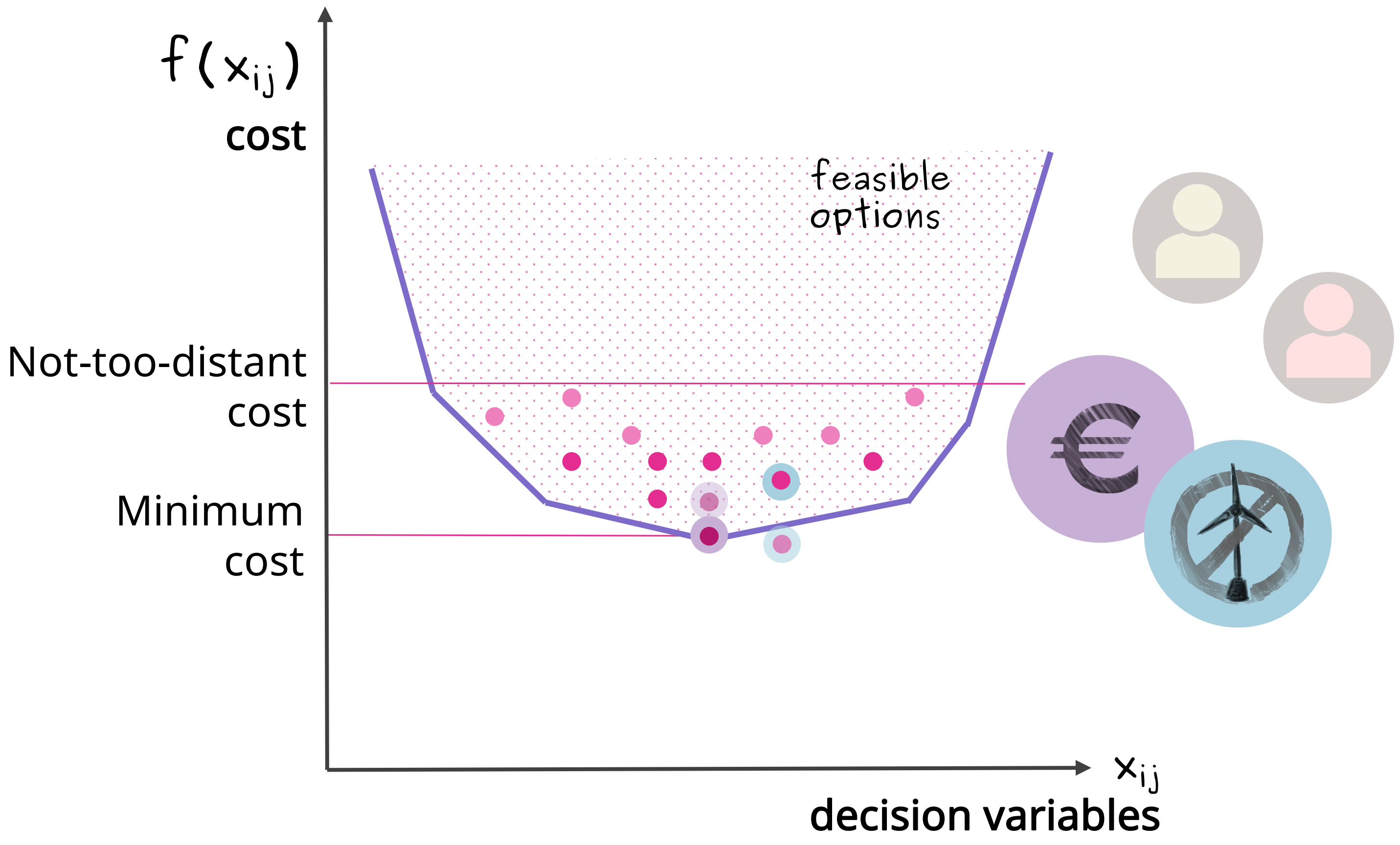


And multi-objective optimisation won’t help! We cannot parametrise all that matters for real-world decisions

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



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)**

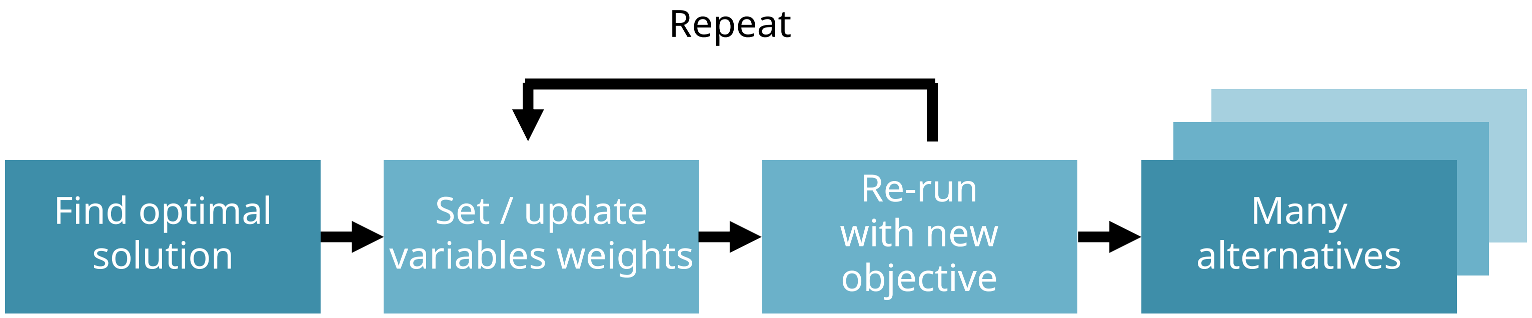
MANAGEMENT SCIENCE
Vol. 25, No. 5, May 1979
Printed in U.S.A.

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.



min cost

min weighted sum of decision variables

***while** cost within n% of optimum*

simple brilliant idea, application limited to 'small' models

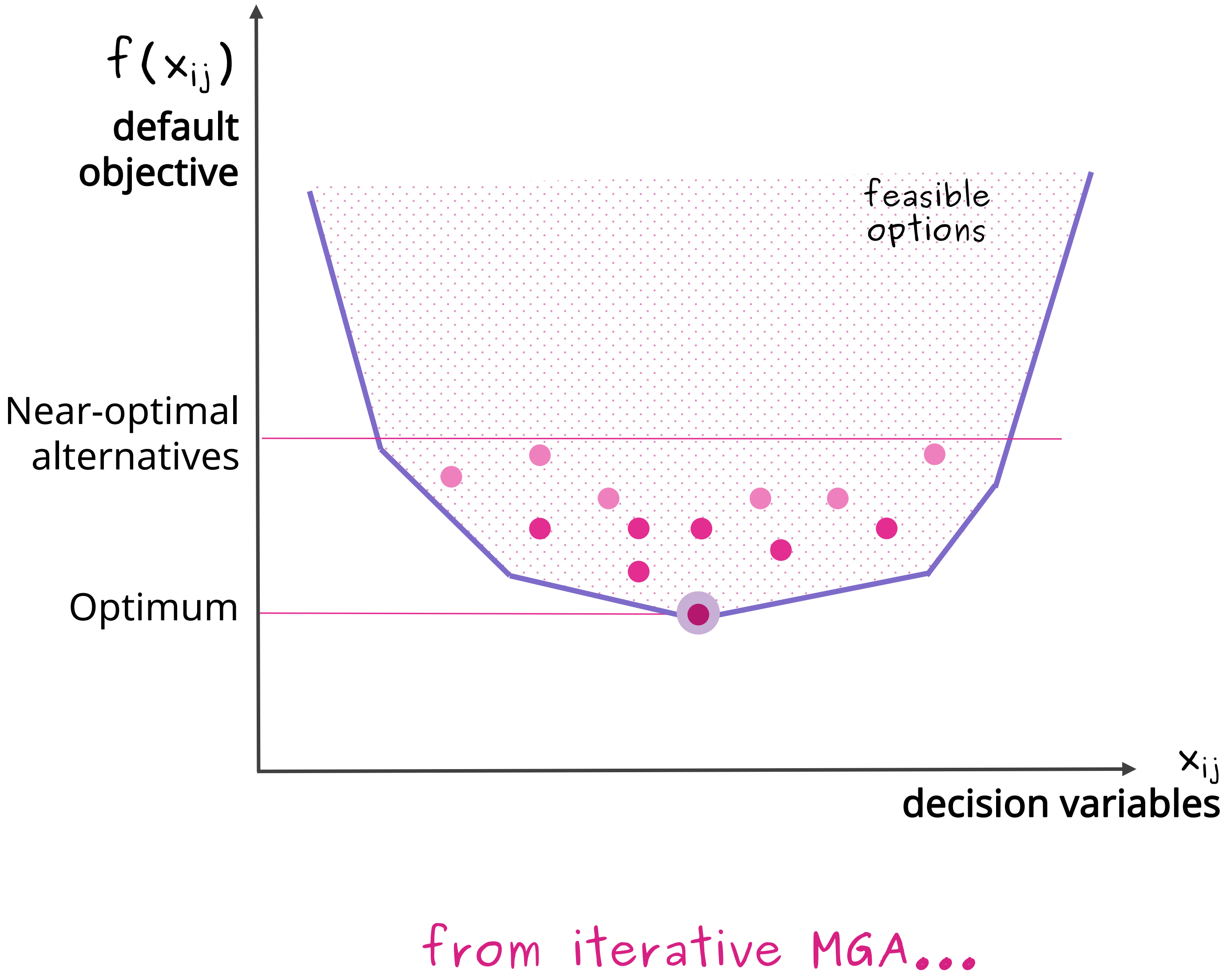
Equivalent to:

***max** difference from previous solutions*

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

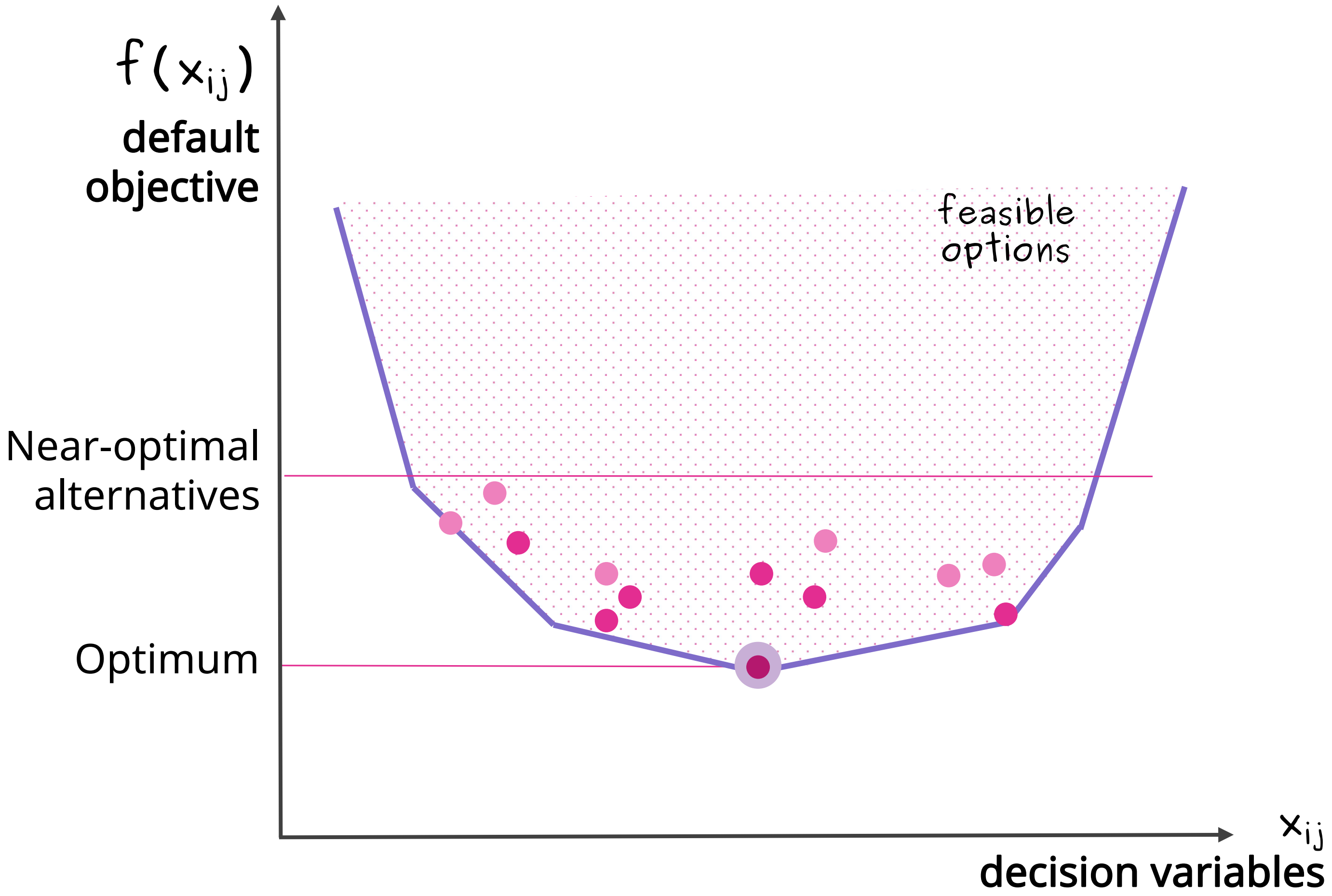
Modelling to Generate Alternatives.

Conventional



Modelling to Generate Alternatives.

Next-generation

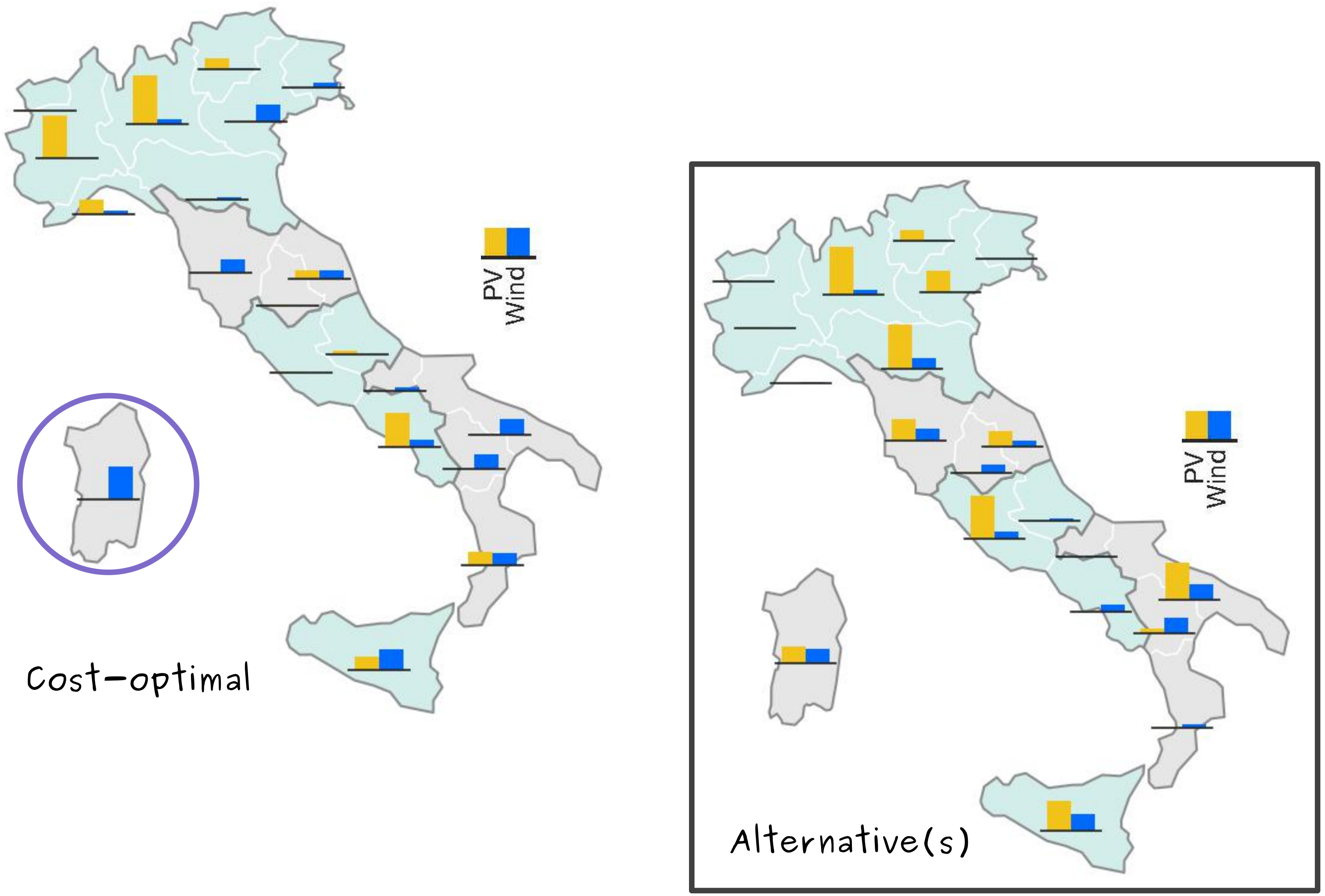


...to parallelised MGA (SPORES)

An original development of MGA designed for **spatial detail, computational efficiency** and **real-world relevance**

SPORES.

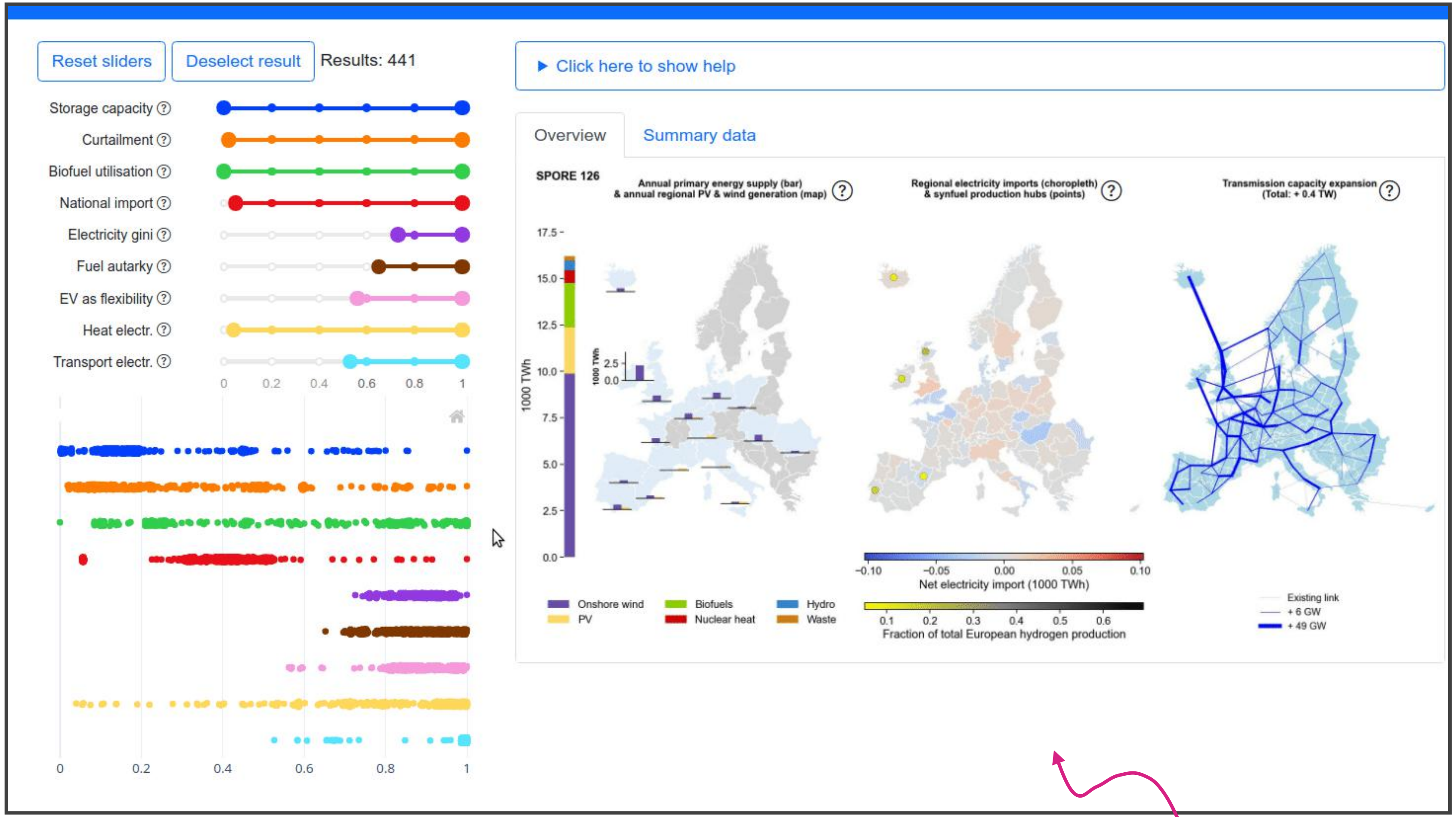
Spatially and technologically distinctive alternatives



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

Explore the results yourself: explore.callio.pe/

SPORES.
Europe-wide application



In the last three years, exponential growth of the topic

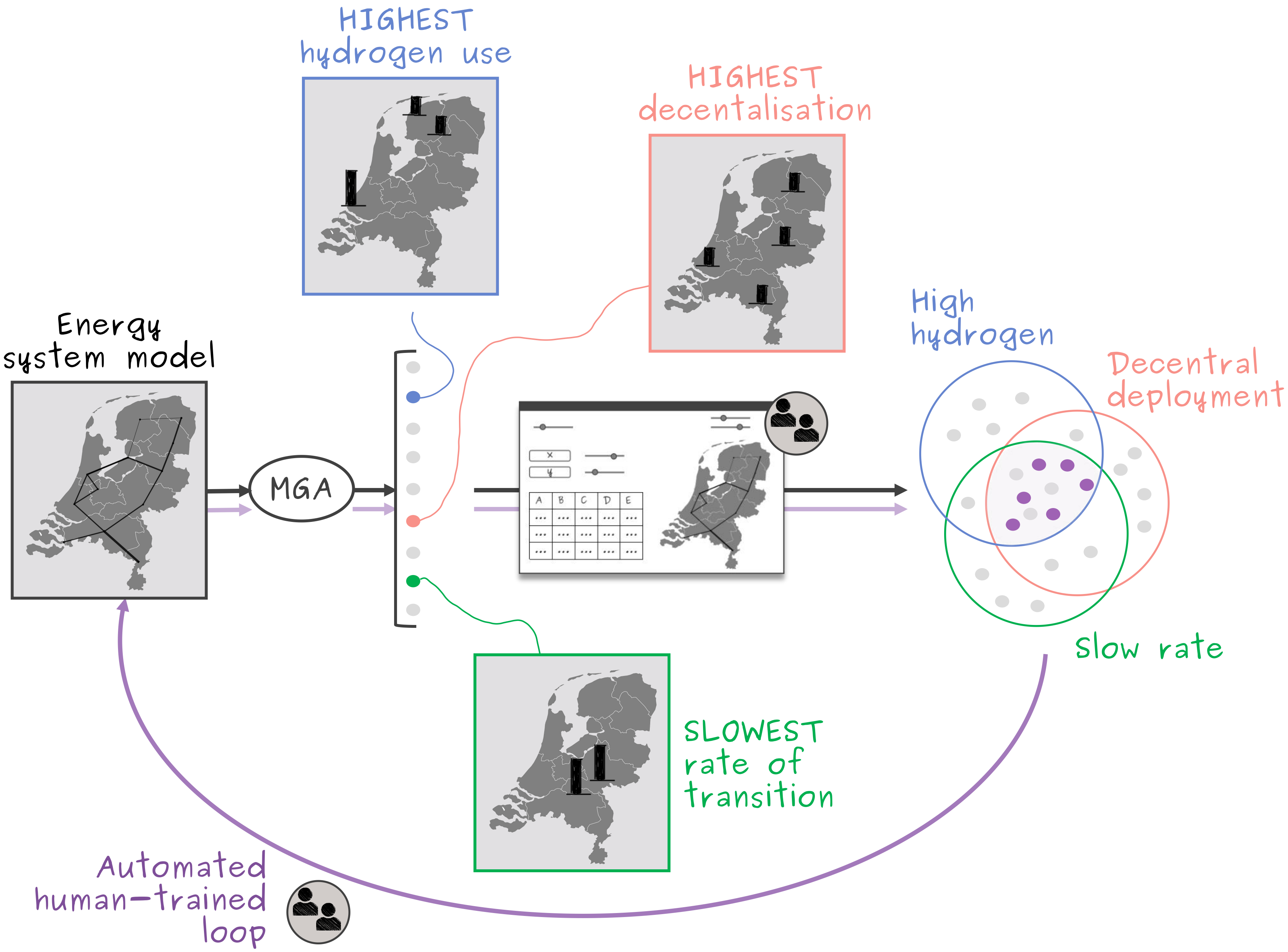
Pickering, Lombardi, Pfenninger. *Joule*. 2022. [doi.org/jbd7](doi.org/jbd7)

Part C.
Latest trends and developments

Co-evolutionary
meta-heuristics

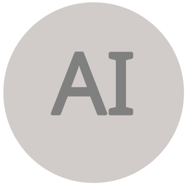
AI

Humans in the loop.

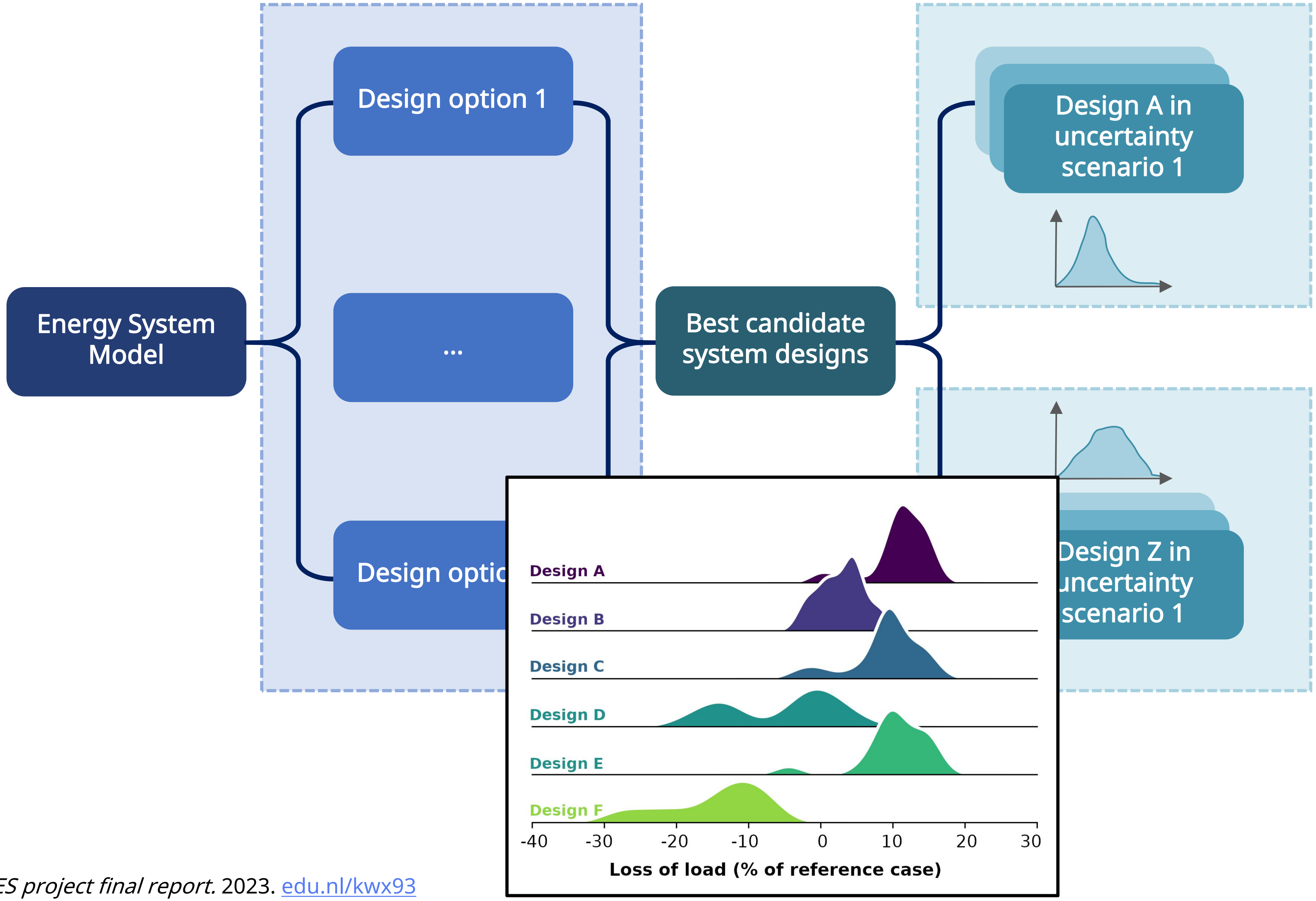


Lombardi, Pfenninger. *PLOS Climate.* 2025. doi.org/nprk

Machine-learning
surrogate models



Technical resilience.



Lombardi, Pickering, Pfenninger. *WindSPORES project final report.* 2023. [edu.nl/kwx93](edu.nl/kwx93)
Originally piloted in: Van Til (*supervisor*: Lombardi), *TU Delft MSc Thesis*. 2021

What can you do for a **time- and resource-constrained analysis**?

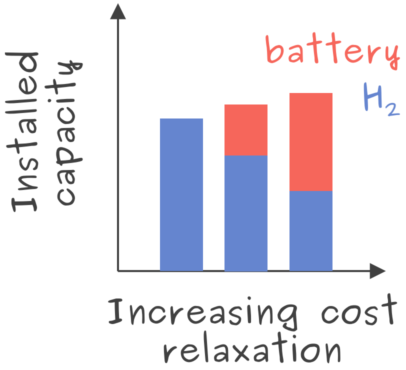
MGA as sensitivity.

Model → Results and key claims → Change objective to test claim *Z* → Single MGA test run → Insight on robustness to claim *Z* → More solid claims

e.g. 'batteries are less cost-effective than H_2 storage'

e.g. maximise battery while cost is relaxed by 5%

e.g. 'batteries are less cost-effective than H_2 storage but can still replace it for marginally higher costs'



You don't get a complete picture of all the options, but you can at least **test** whether your **key claims** are solid

First proposed in: Lombardi, Pickering, Pfenninger. *Applied Energy*, 2023. https://doi.org/j457
Prominently featured in: Lombardi, van Greevenbroek, Grochowicz, Lau, Neumann, Patankar, Vågerö, [forthcoming]

Cost-optimisation provides a false sense of certainty

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

Computational cost can be tailored to needs and keeps improving

Largely overlapping with the conclusions in: Lombardi, van Greevenbroek, Grochowicz, Lau, Neumann, Patankar, Vågerö, [forthcoming]