International Conference on Operations Research 2023
Decision Support & Choice-Based Analytics for a Disruptive World

Generating alternative energy system design options that match real-world needs.

The human-trained SPORES algorithm

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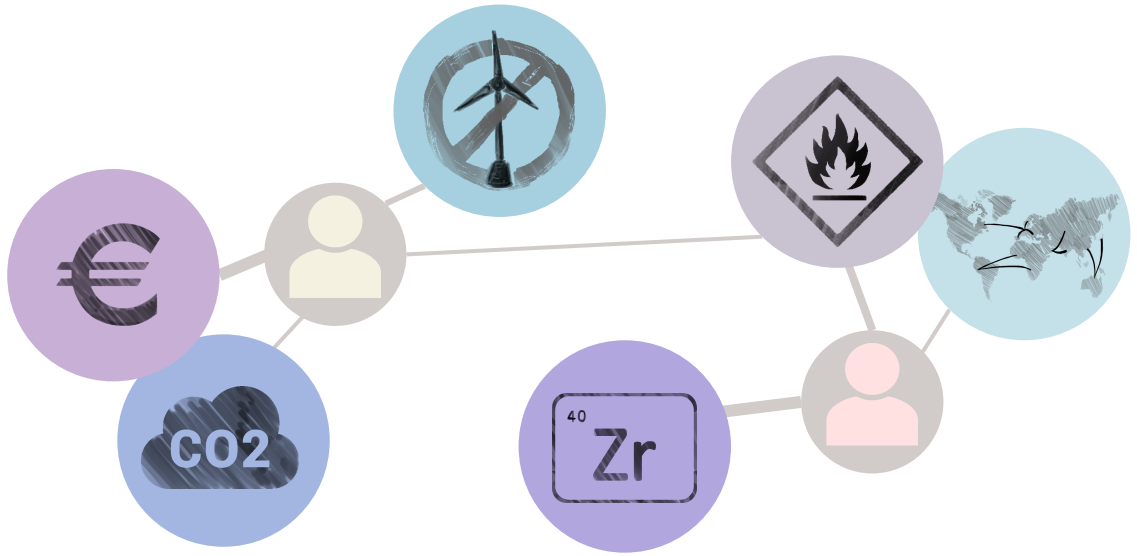
Part A.
Shortcomings of single-objective optimisation

Research gaps.
Is cost-optimal actually desirable?

Two generalisable shortcomings:

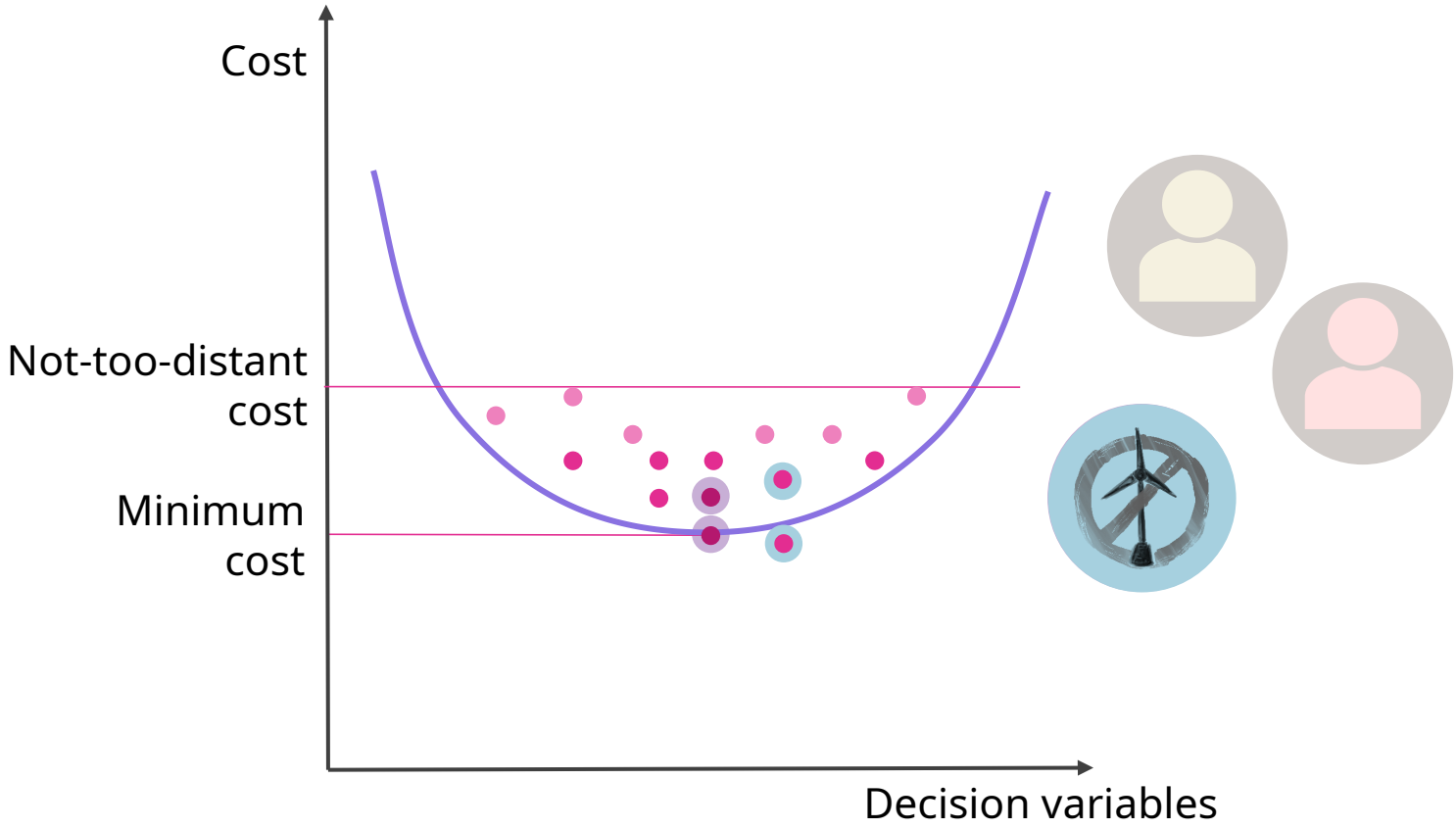
1. Real-world decisions involve much more than economic cost (social acceptance, environmental impact, ...)



Research gaps.
Is cost-optimal actually desirable?

Two generalisable shortcomings:

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

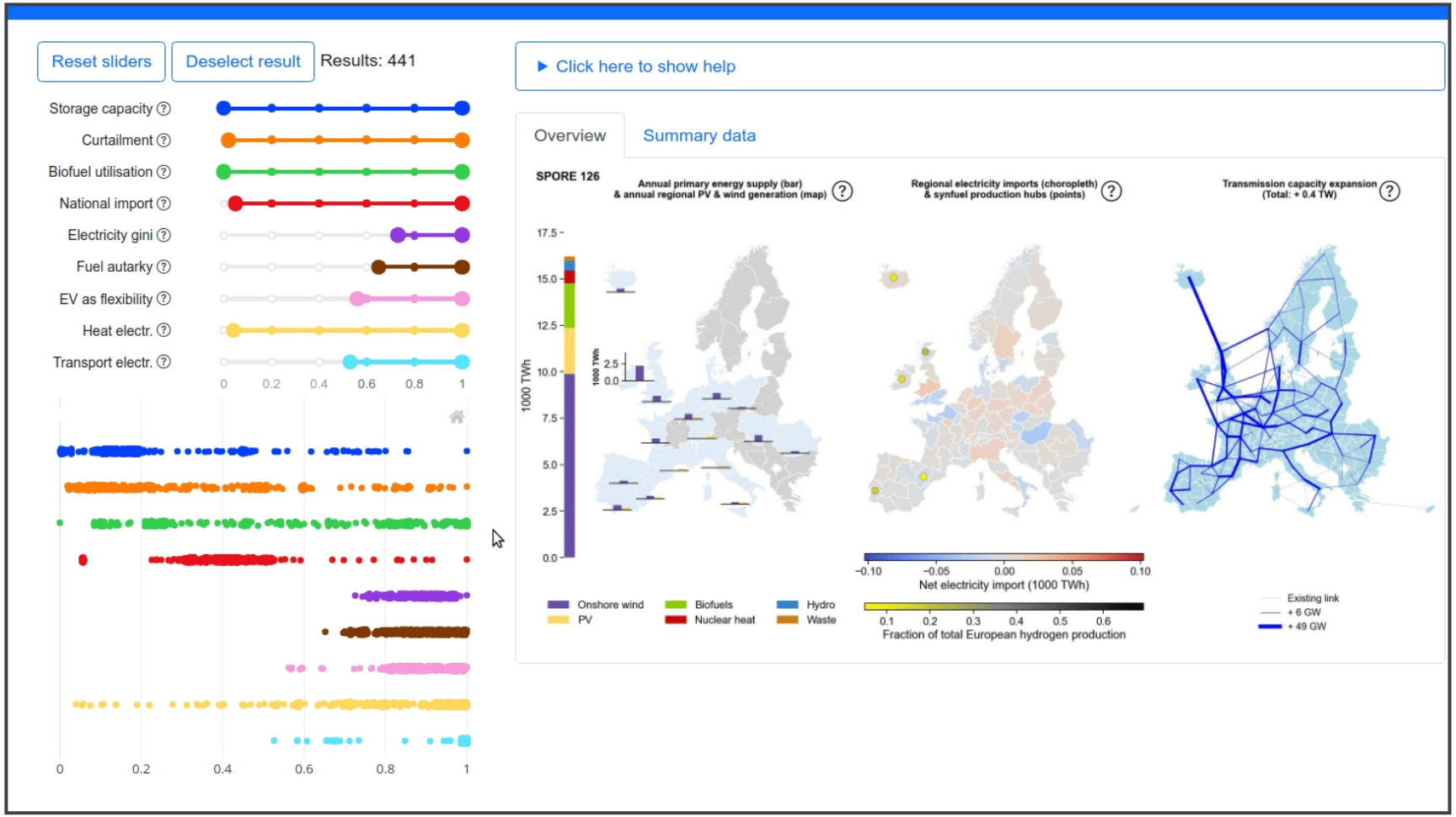


Part B.
Generating alternatives (MGA) and limitations therein

SPORES.

Spatially and technologically distinctive alternatives

An original development of “Modelling to Generate Alternatives” (MGA) designed for **spatial detail**, computational efficiency and **real-world relevance**



Explore the results yourself: explore.callio.pe/

SPORES.
Algorithmic workflow

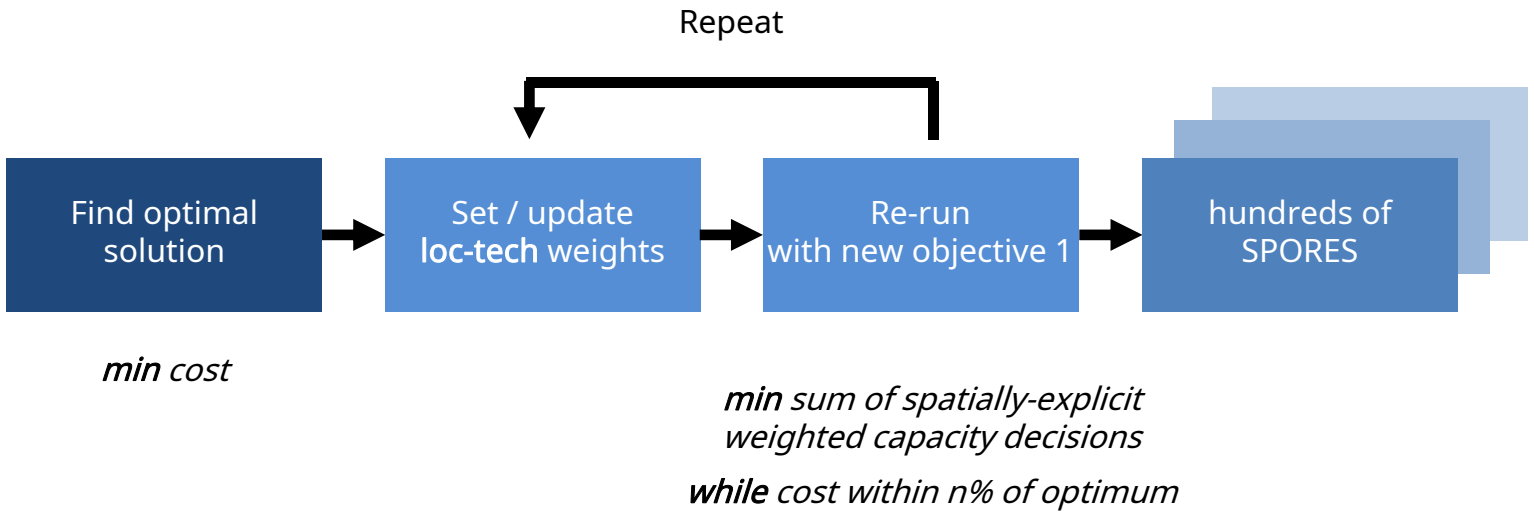
Unlike conventional MGA, **SPORES**:

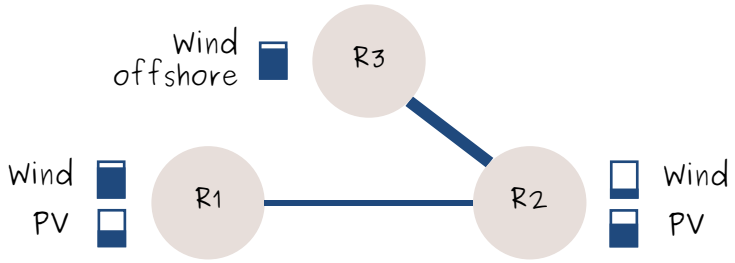
1. make explicit the search for spatially-distinctive solutions

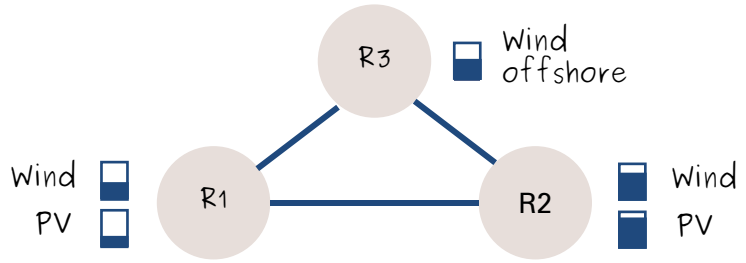
i: technologies

j: locations

$$min\ Y = \sum_j \sum_i w_{ij} x_{ij}^{cap}$$





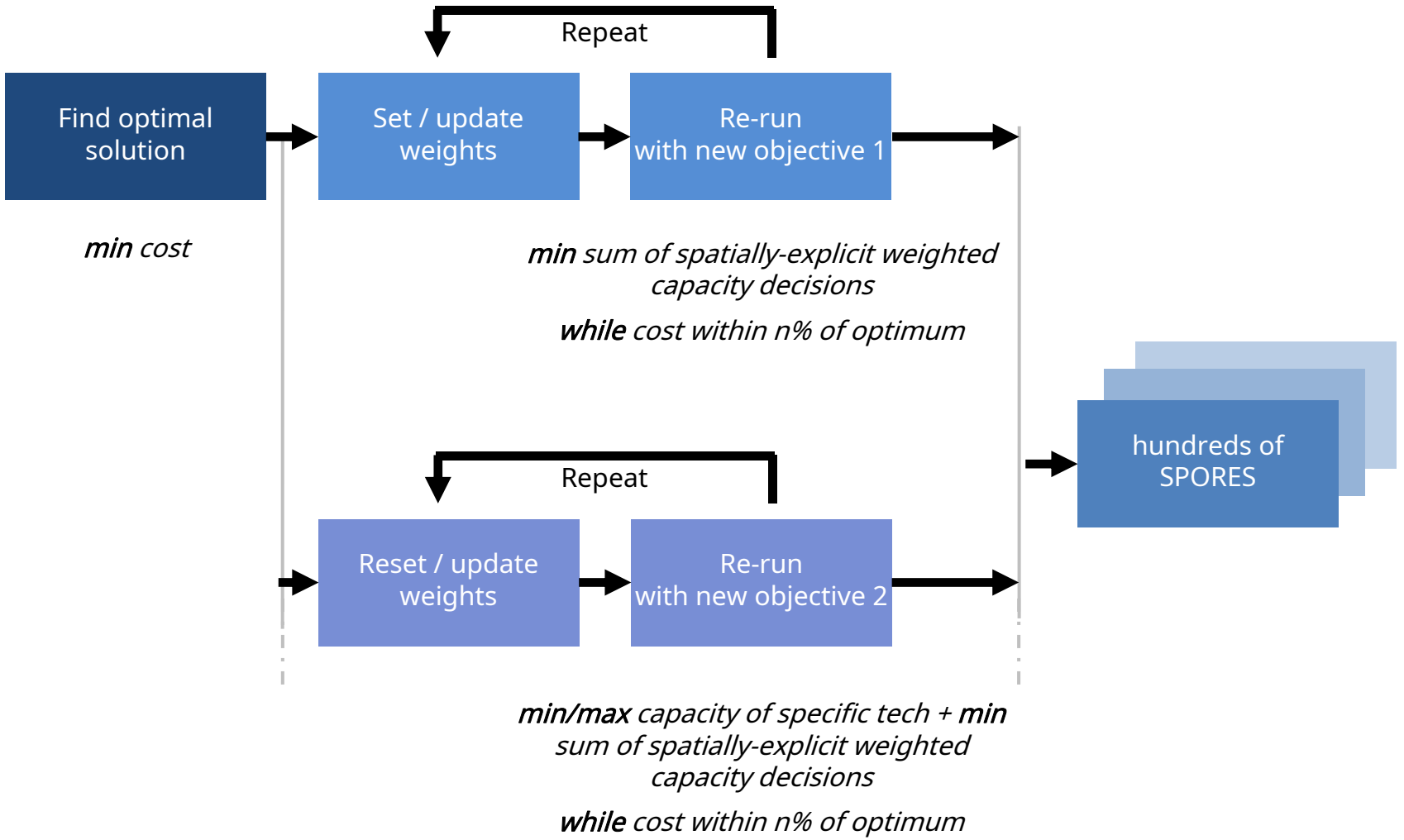


Lombardi, Pickering, Pfenninger. *Applied Energy.* 2023. doi.org/10.1016/j.apenergy.2023.121002

SPORES.
Algorithmic workflow

2. use multiple search directions in parallel

$$min\ Y_2 = a \sum_j \sum_i w_{ij} x_{ij}^{cap} \pm b \sum_j x_{ij}^{cap}$$



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

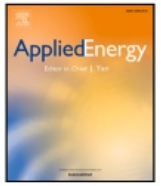
SPORES.
Where we left

Push spatially-explicit distinctiveness

Push technology to extremes

$$min\ Y_2 = a \sum_j \sum_i w_{ij} x_{ij}^{cap} \pm b \sum_j x_{\bar{i}j}^{cap}$$

Push either spatial or technology distinctiveness



What is redundant and what is not? Computational trade-offs in modelling to generate alternatives for energy infrastructure deployment

Francesco Lombardi [a,*], Bryn Pickering [b], Stefan Pfenninger [a]

"*Finding alternatives entails a **trade-off between spatial and technology dissimilarity***"

"*Focussing on finding all high-level technology alternatives may leave key **spatial configuration options unexplored***"

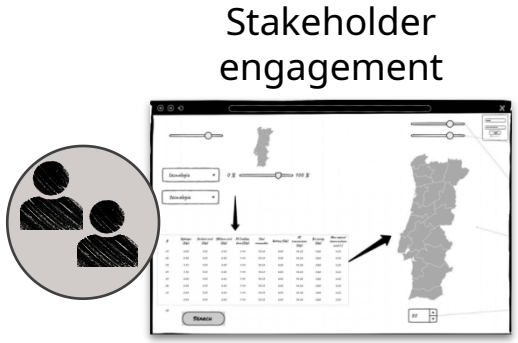
"*Ideal solution: iterating the decision space with stakeholders*"

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

Part C.
Integrating stakeholder preferences in an MGA loop

Humans in the loop.

Practical procedure



Stakeholder engagement

Most-liked options

- Low imports
- Citizen-led
- …

HIL-MGA

- MGA
- min H_2
- max PV
- …

New MGA-MOO formulation for each option

- PV: desired
- H_2: undesired
- …

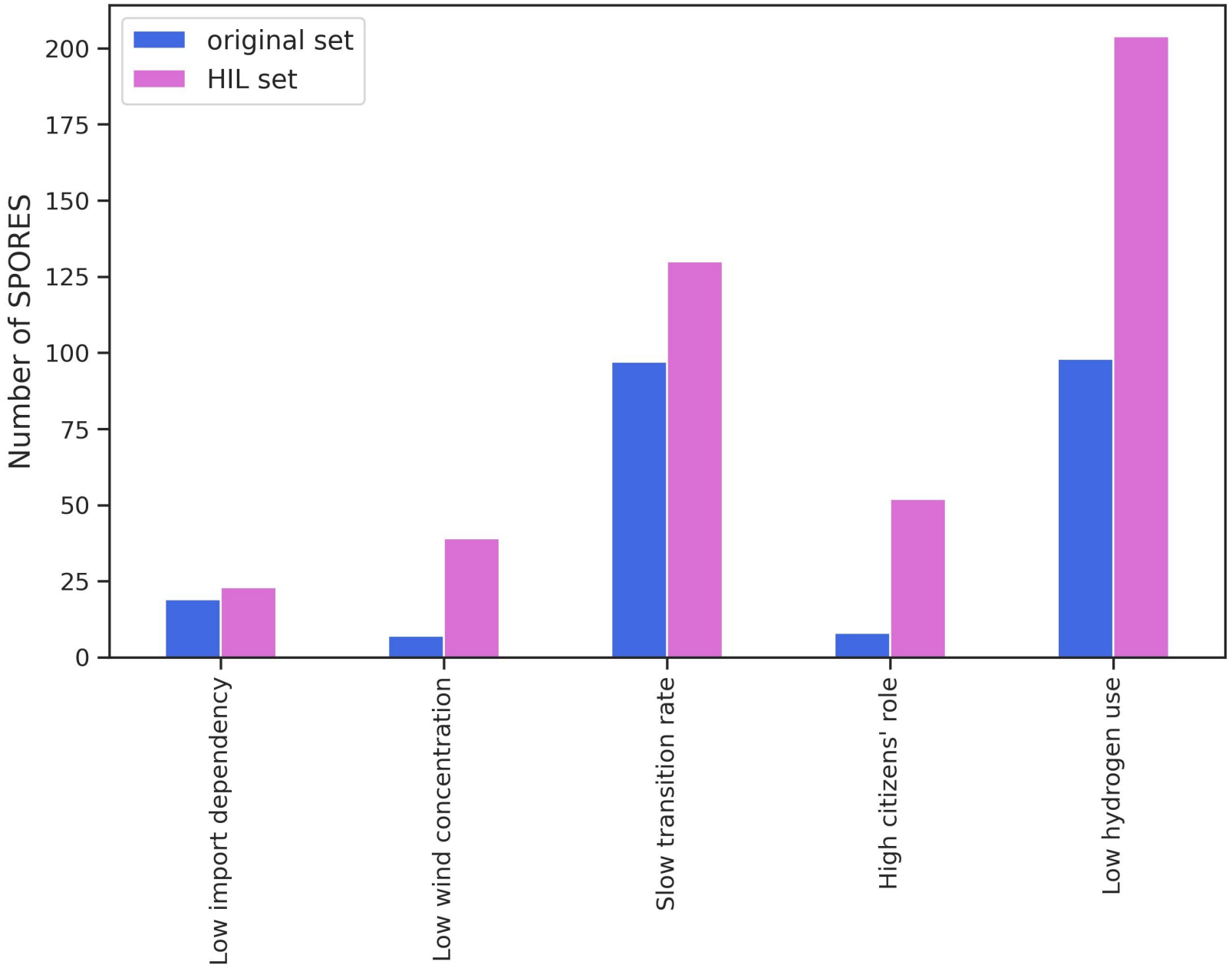
Automated feature detection for each option

$$min\ Y_3 = a \sum_j \sum_i w_{ij} x_{ij}^{cap} + \boldsymbol{b} \sum_j x_{\bar{i}j}^{cap} - \boldsymbol{c} \sum_j x_{\bar{i}j}^{cap}$$

Humans in the loop.

Impact on matching stakeholder needs

Example set of 260 SPORES from seeds-project.org in Portugal



Thank you.
Questions?

1. When applied to supporting decisions, MGA requires **stakeholder inputs to match real-world needs**
2. Cutting-edge **MGA-MOO (e.g. SPORES) lends itself to customisation** based on elicited stakeholder preferences
3. High-level or intangible **preferences can be mapped down to technical features** for use in an MGA-MOO formulation
4. The resulting human-in-the-loop **(HIL) MGA option space is richer** in design options that match stakeholder preferences

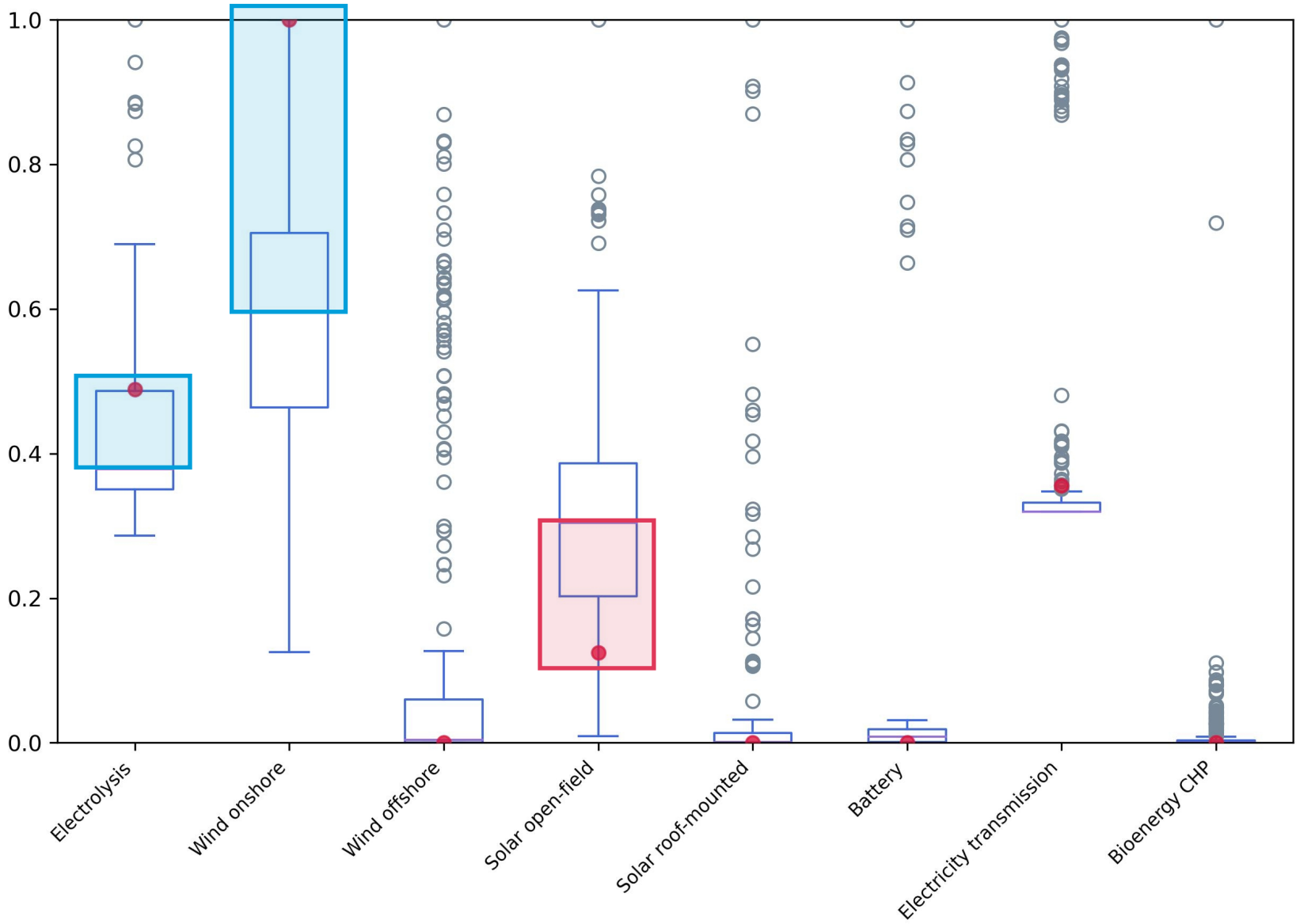
Additional material about SPORES and ongoing projects is available at www.flombardi.org

Supplemental Information.

Humans in the loop.

Automated mapping of features

Example: most-liked option due to very low import dependency



$$min\ Y_3 = a \sum_j \sum_i w_{ij} x_{ij}^{cap} + \boldsymbol{b} \sum_j x_{pv,j}^{cap} - \boldsymbol{c_1} \sum_j x_{wind,j}^{cap} - \boldsymbol{c_2} \sum_j x_{h_2,j}^{cap}$$