Humans in the loop. Challenges and way forward in the use of MGA to support real-world energy policy decisions

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Energy and Industry section

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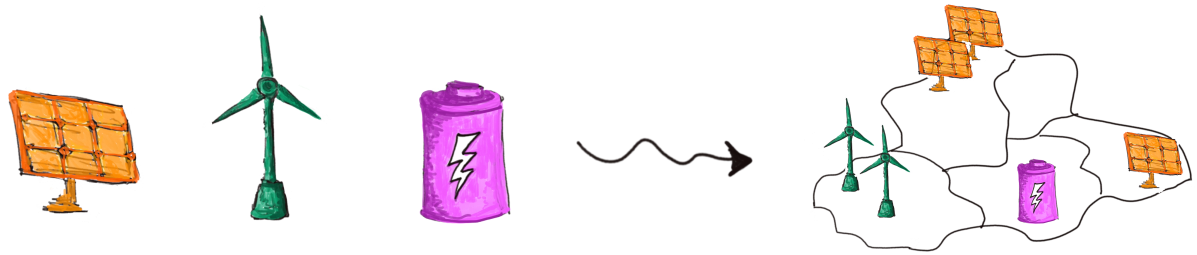
Part A.
Or why ’optimal’ does not equate ‘desirable’

The context.

Deep decarbonisation of energy systems

Need to deploy new renewable (mostly wind and solar), transmission and storage capacity

But **how much**? and **where**?

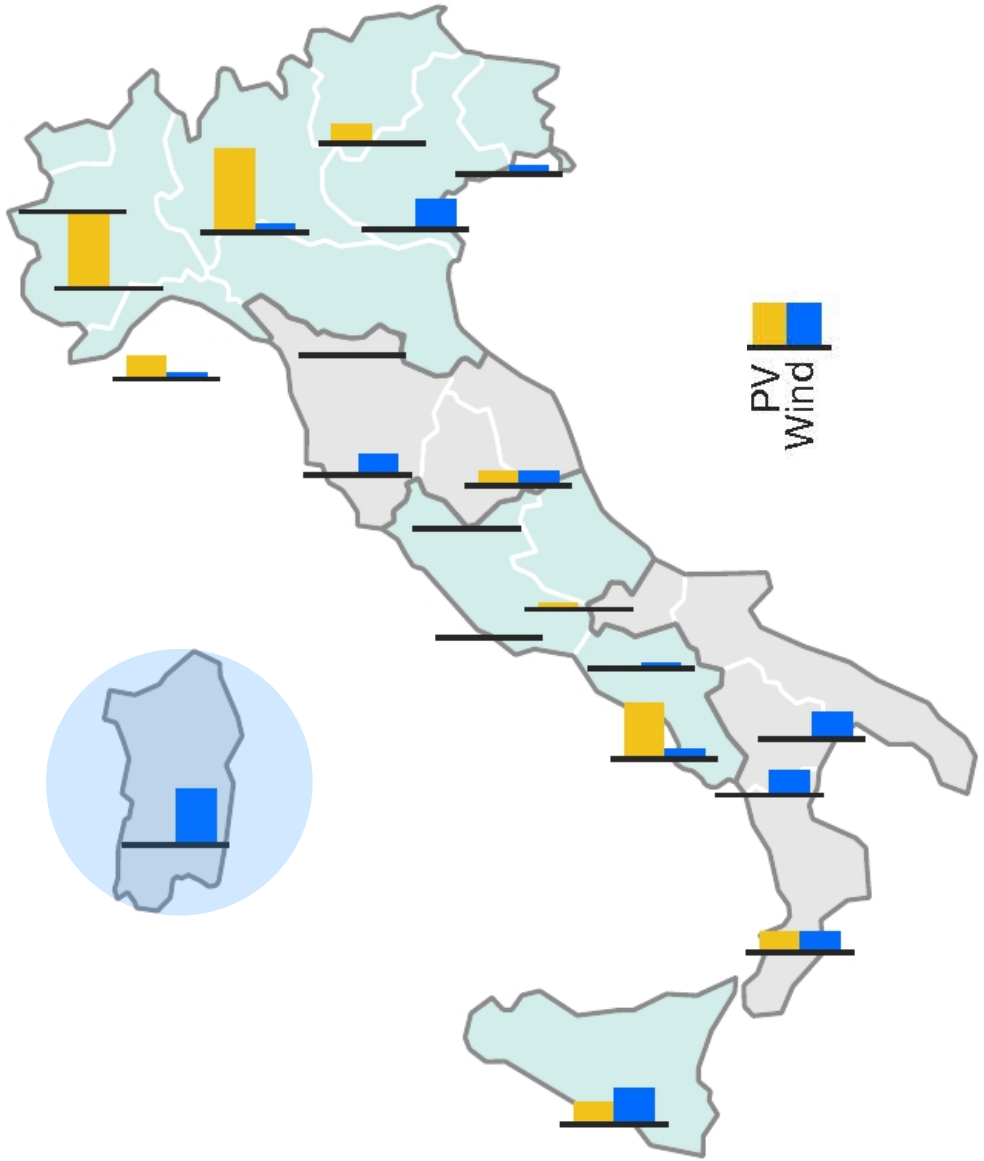


Energy system models try to provide quantitative insights around such questions

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

minimum cost

Cost optimality.
Is it actually desirable?

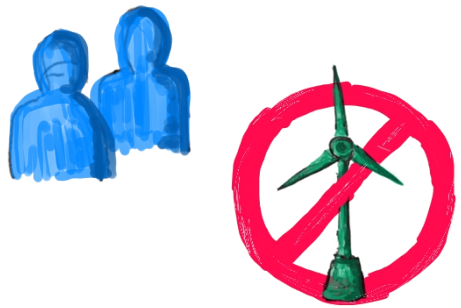


Source: Lombardi, Pickering, Colombo, Pfenninger. *Joule*, 2020. https://doi.org/gg8z6v

Cost optimality.
Is it actually desirable?

Two generalisable shortcomings:

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



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

Cost optimality. More than a computational flaw

What is more, the identification and communication of a single, cost-optimal solution leads to the **erroneous equation**:

cost-optimal = the only possible option

NO !

In turns, this gives rise to **deceptive claims***:

- «a configuration that avoids X is not possible»
- «decarbonisation requires Y (e.g., some bioenergy)»

The strive for cost-optimality is a leading source of **opacity** in energy modelling

*See, for instance: Brown et al.. *Ren. and Sust. Energy Reviews,* 2018. https://doi.org/gdwmvw

Part B.
Alternatives, and how to handle them

Modelling to Generate Alternatives.

In a nutshell

Methods to explore the near-optimal region have been formalised in the ‘80s

They are known under the name of **Modelling to Generate Alternatives**

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)

Brill. *Management Science*, 1979. https://doi.org/dbpd7r

Limits of conventional MGA.

1. Failure to unveil some obvious options

*"in many cases increasing the MGA slack value simply pushes the model further along the **same technology dimensions** rather than deploying different technologies.*

*[...]Other technologies, such as concentrating solar thermal or H_2 fuel cell vehicles **do not appear in any of the solutions**.*

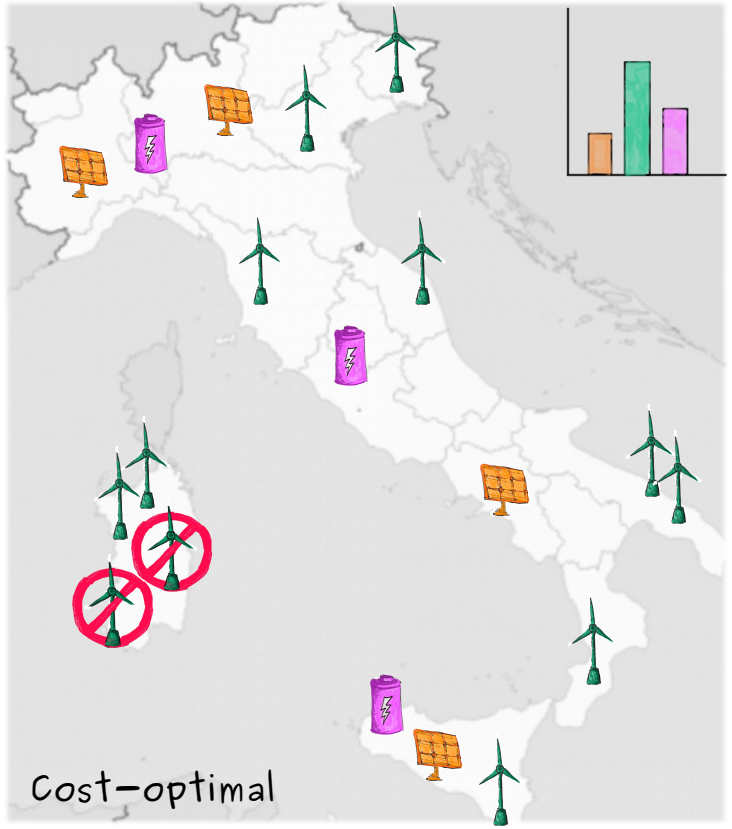
However, it is possible to modify the MGA algorithm to select certain technologies."

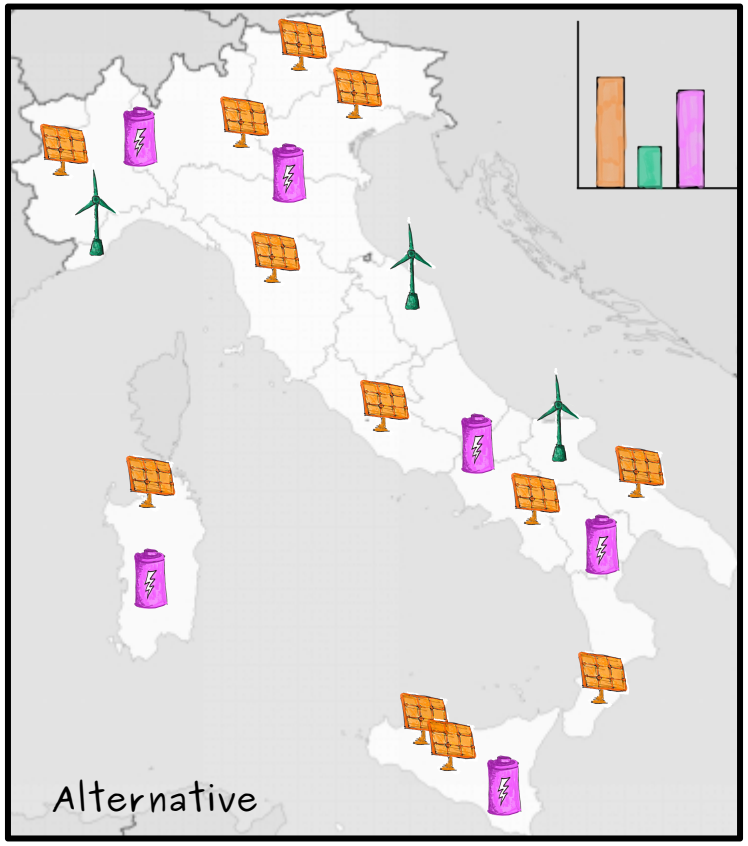
Source: DeCarolis, Babaee, Kanungo, *Env. Modelling & Software.* https://doi.org/f8n923

Limits of MGA.

2. Lack of spatial diversity

What **classic MGA** would provide:



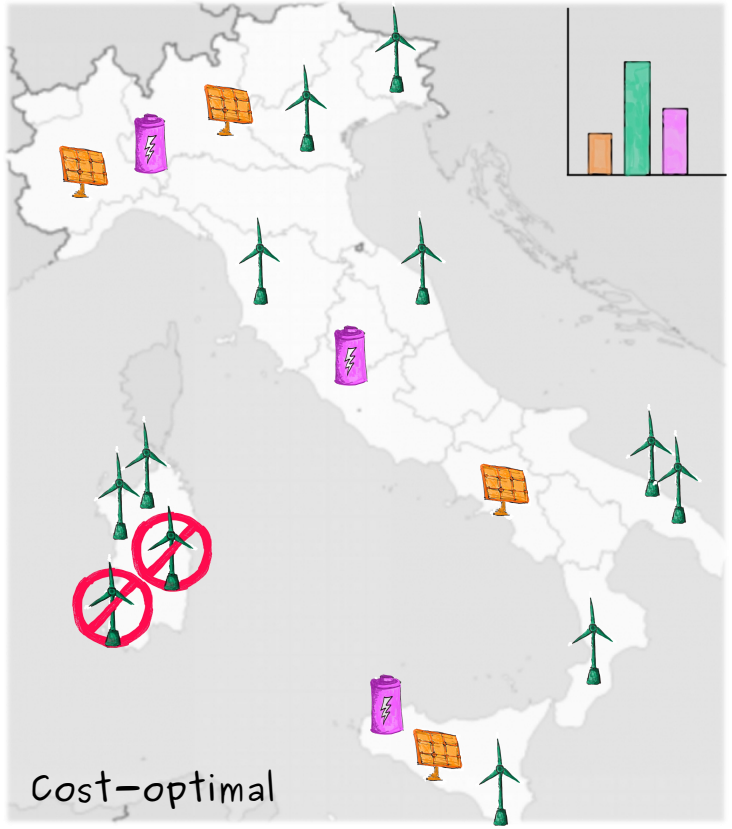


Diversity of **technology-mix**

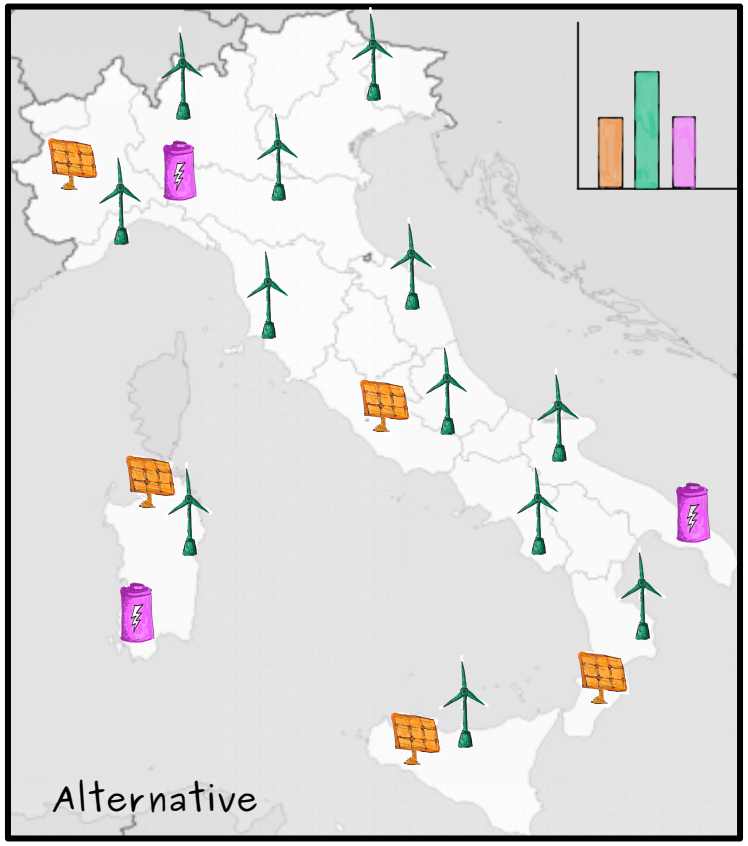
Limits of MGA.

2. Lack of spatial diversity

What we **additionally** want to know:



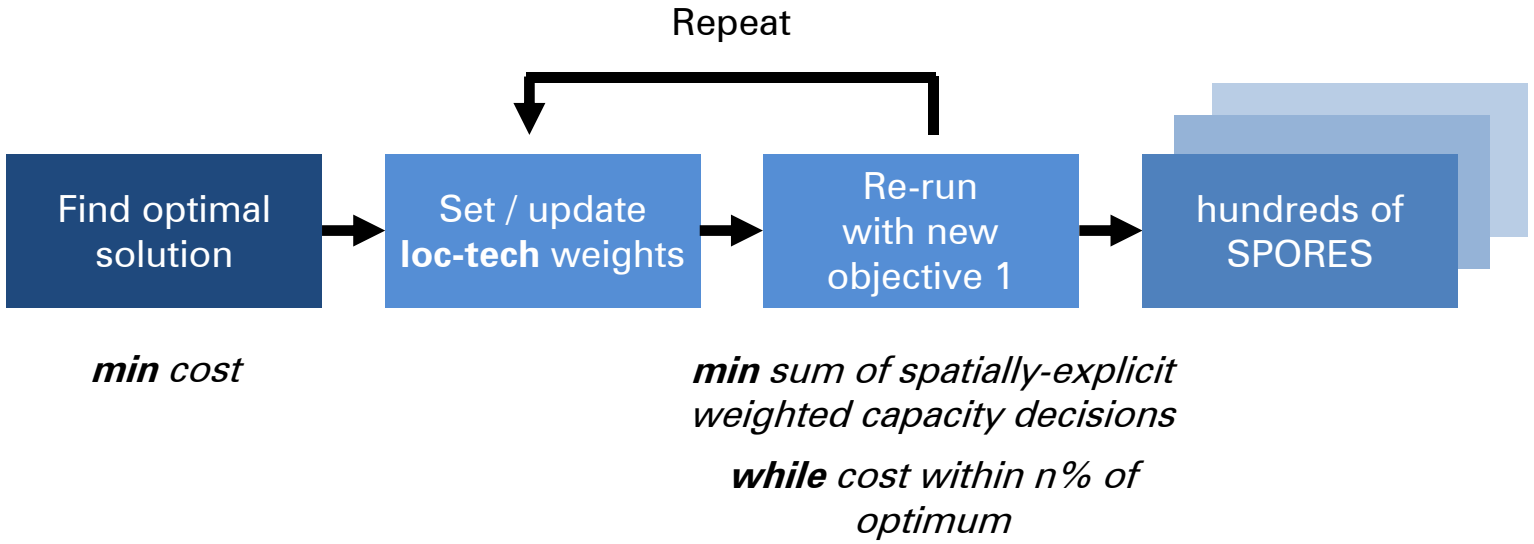
Diversity of **spatial-configuration**
(for roughly same tech mix)

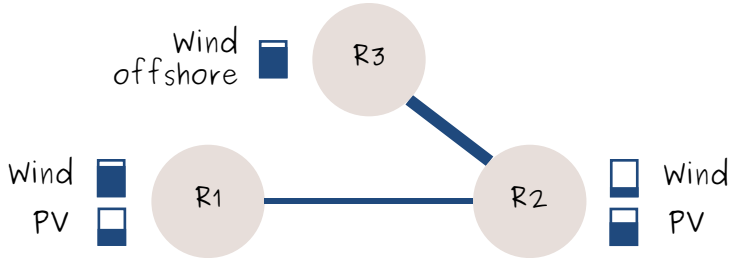


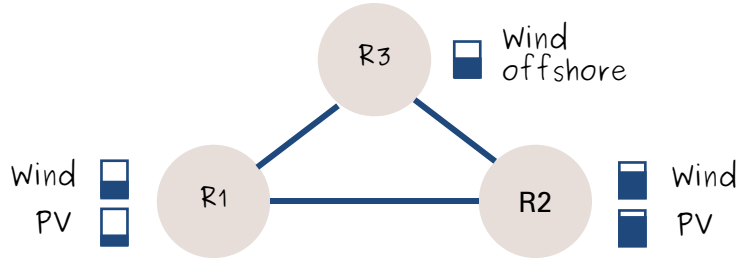
SPORES. Algorithmic workflow

Unlike conventional MGA, **SPORES**:

1. make explicit the search for spatially-distinctive solutions



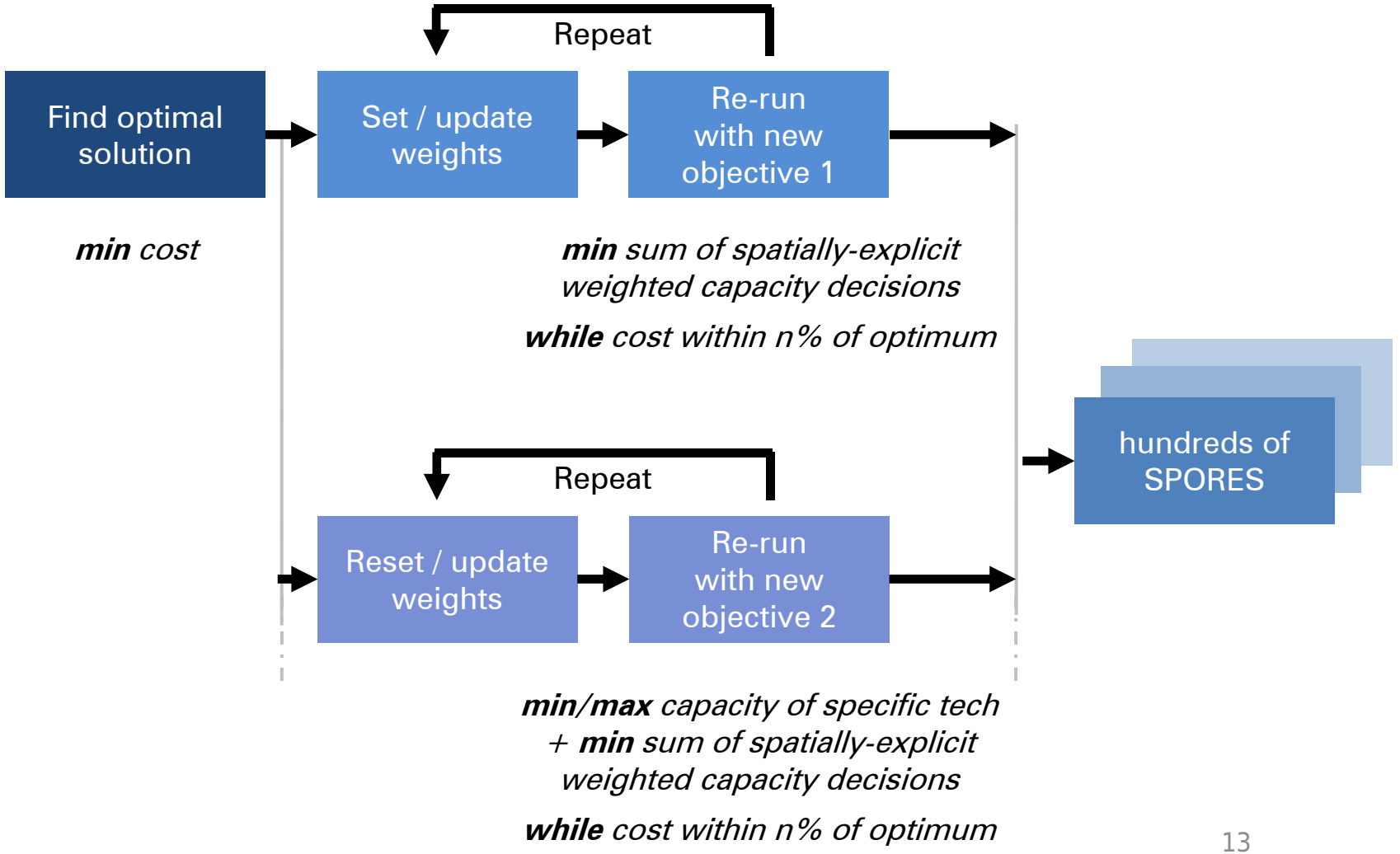




SPORES. Algorithmic workflow

Unlike conventional MGA, **SPORES**:

2. use multiple search directions in parallel



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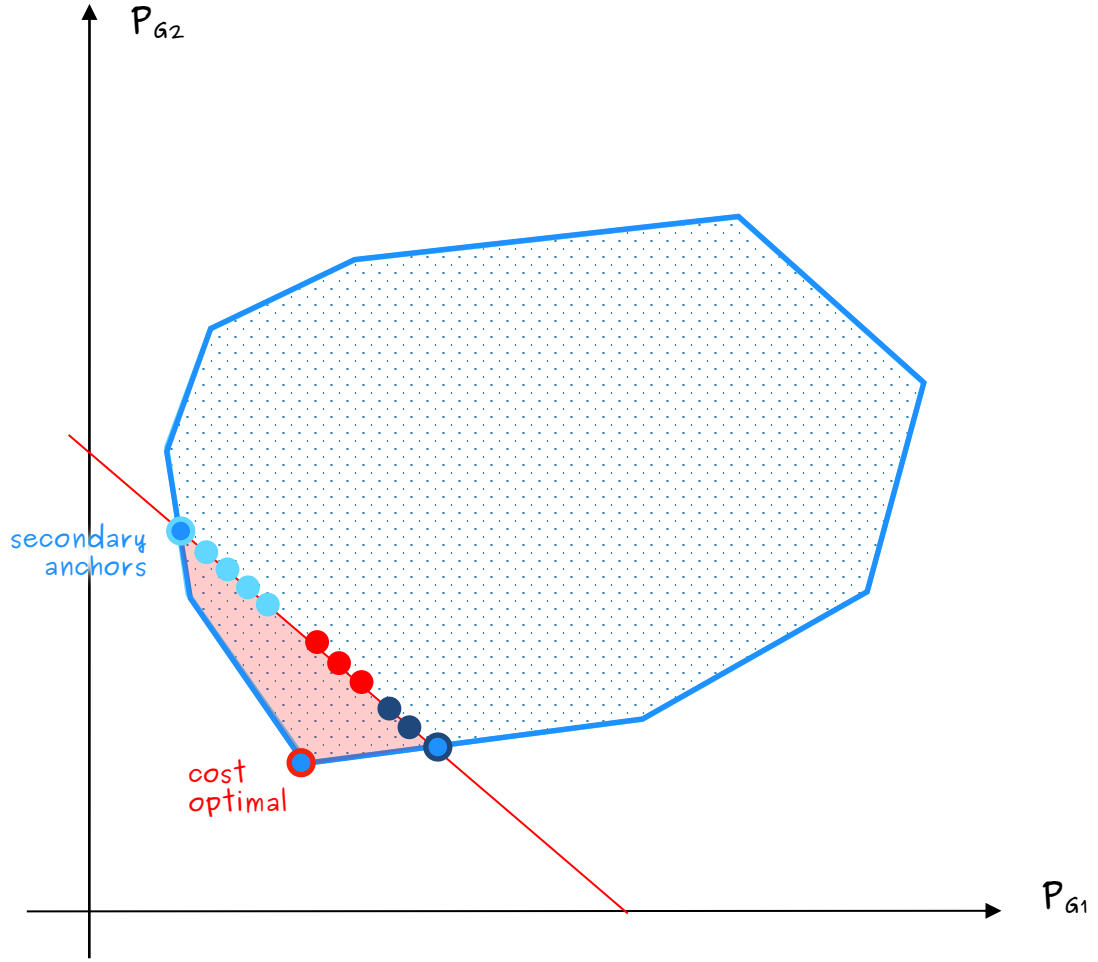
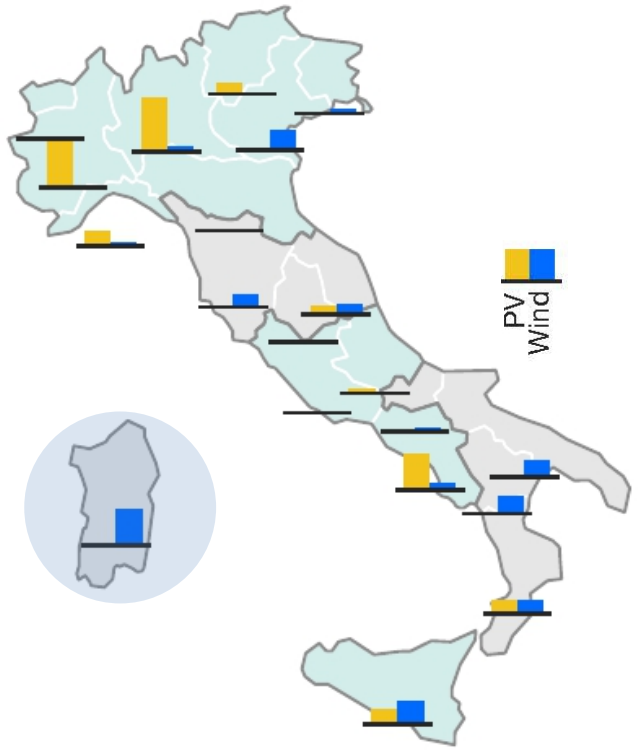
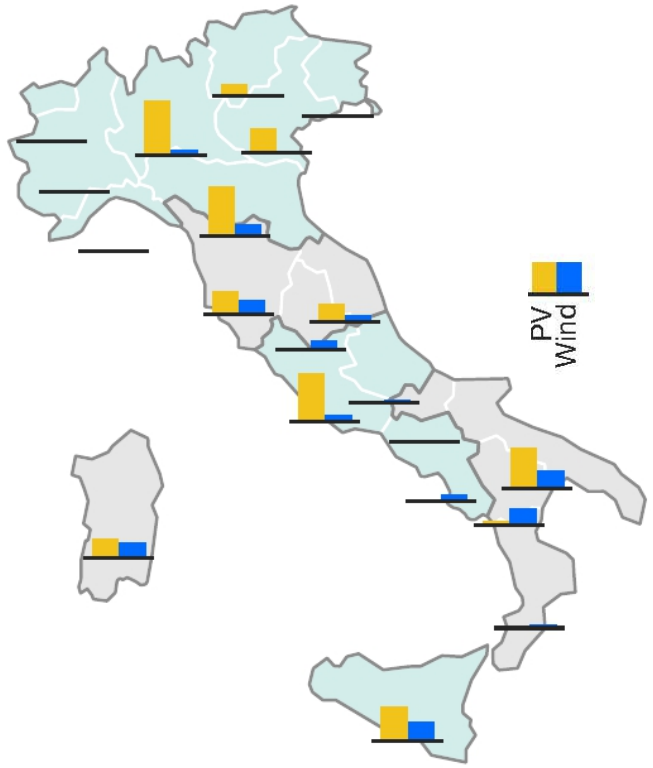


SPORES.

Explicit search for both technological and spatial diversity



Cost-optimal



Alternative

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

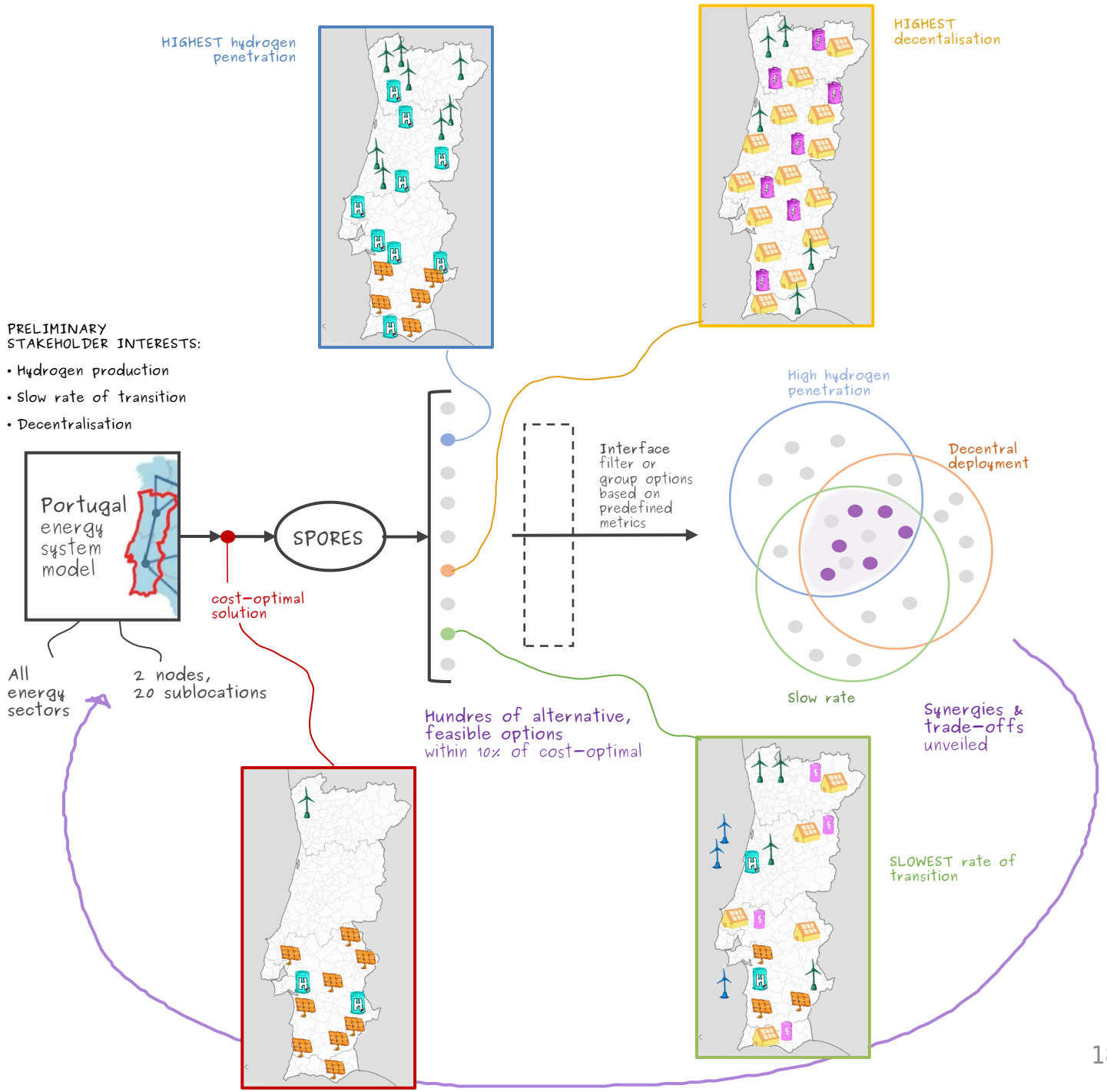
SPORES/ MGA. Open challenges

1. Virtually infinite alternatives exist, but **only a finite number** of those can be generated in practice. How many are enough?
   (and enough for whom?)

2. Enriching results with a wide range of feasible alternatives might **clash with users' call for simplicity** and understandability. How to deal with that?

Part C.
The SEEDS project: humans in the loop

SEEDS project. Human-led SPORES in Portugal



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   By means of user-friendly interfaces that allow to navigate the option space based on simple filters

Part D.
MGA research within SEEDS

More efficient computation.
Alternative weight-assignment methods

1. **Integer** (Brill et al., DeCarolis, ...)

   $w_{PV,R1}$: +1

2. **Relative deployment** (Italy study)

   $w_{PV,R1}$: +(deployed cap / max potential in region)

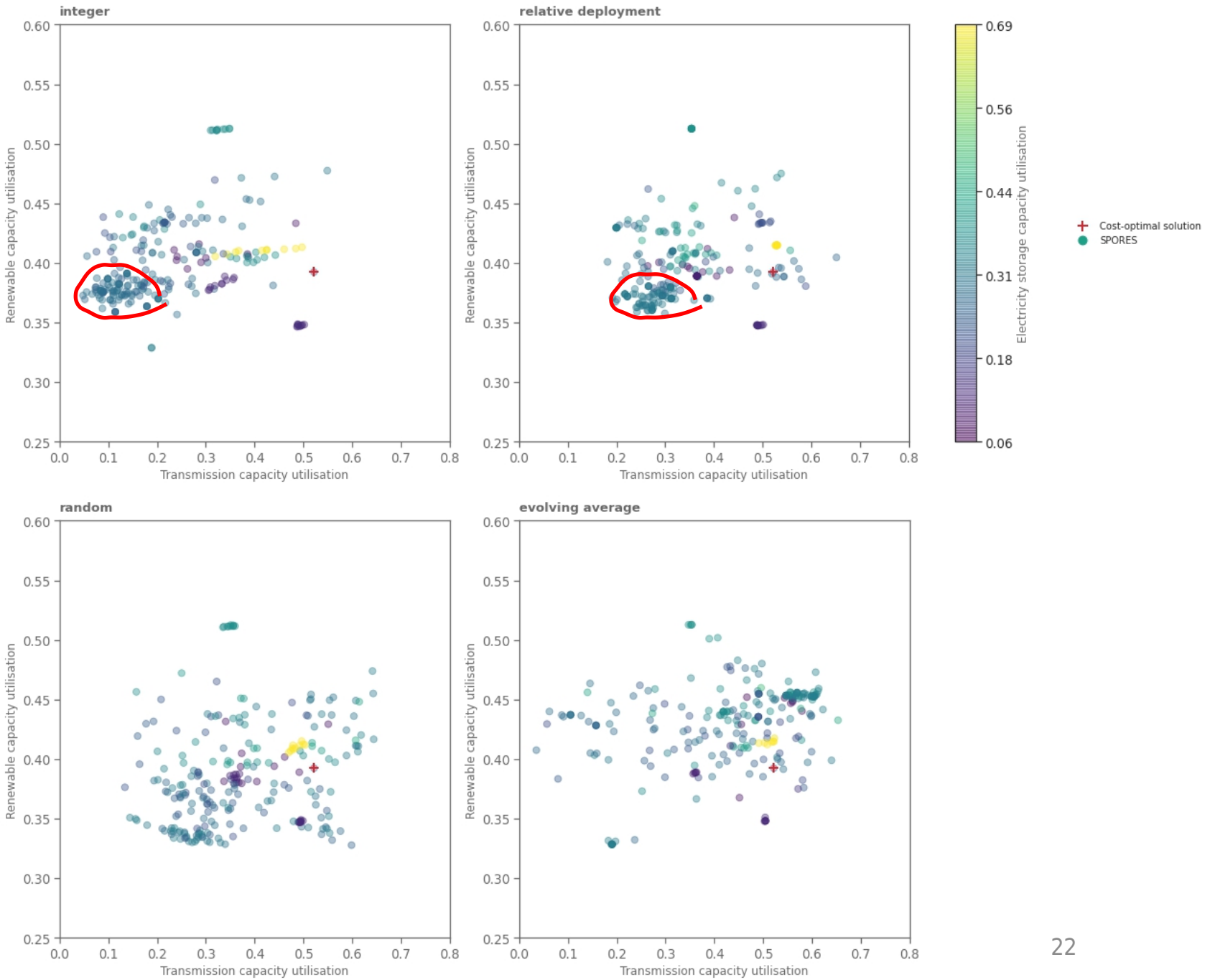
3. **Random** (Bernsten & Trutnevyte)

   $w_{PV,R1}$: +(random.uniform(0,1)

4. **Evolving average** (novel)

   $w_{PV,R1}$: +|relative dist. from average|$^{-1}$

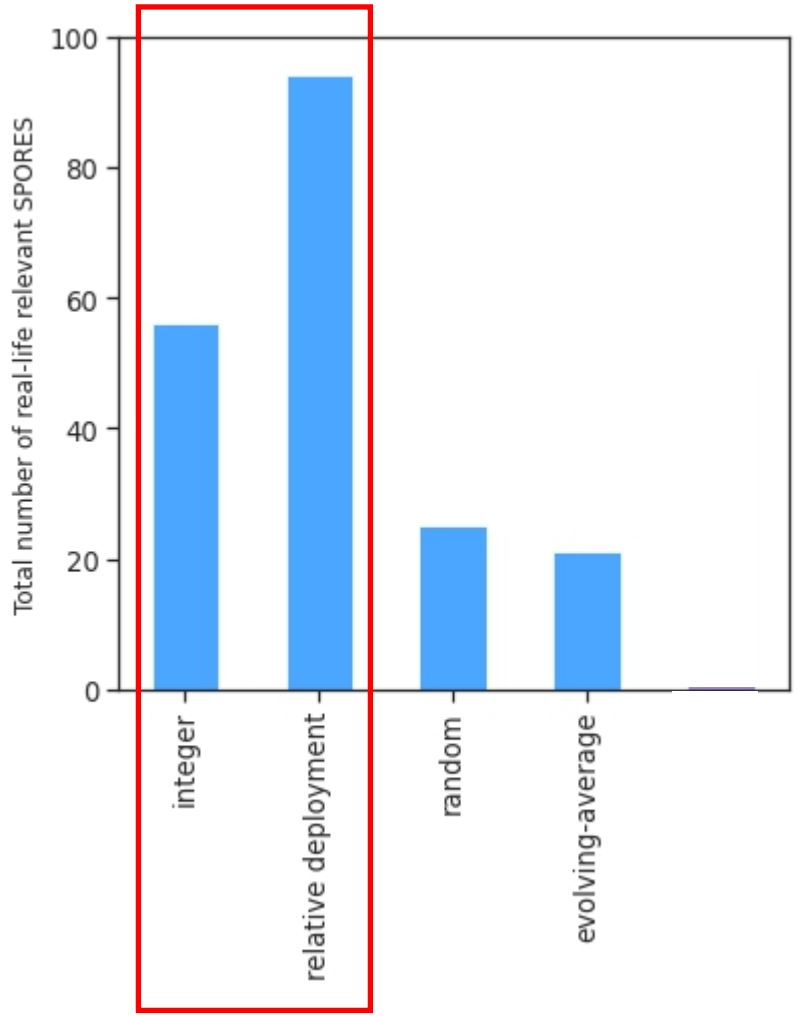
Solution space.
Across search strategies



Efficiency trade-off.

Technology-mix vs spatial diversity

The better a search strategy is at finding diverse **technology mixes**, the worse it is at generating **spatial diversity around a roughly fixed mix**

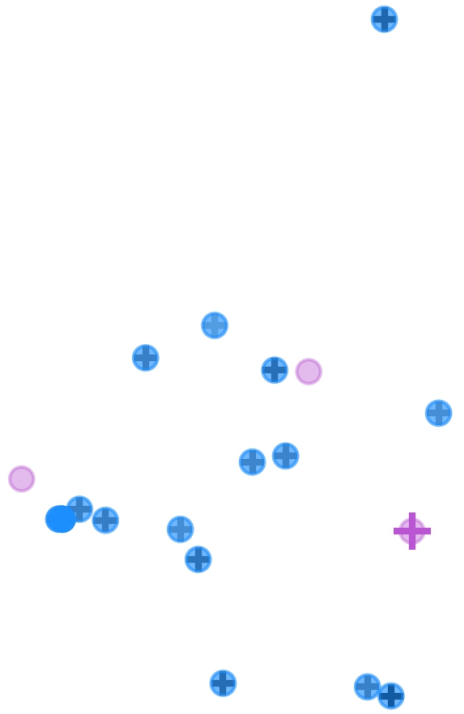


Hybrid workflow.

Evolving average

+

Integer



SPORES/ MGA. Open challenges

1. Virtually infinite alternatives exist, but **only a finite number** of those can be generated in practice. How many are enough?
   (and enough for whom?)

   It's complicated enough to deserve a whole slide...

2. Enriching results with a wide range of feasible alternatives might **clash with users' call for simplicity** and understandability. How to deal with that?

   By means of user-friendly interfaces that allow to navigate the option space based on simple filters

How many are enough?
Key takeaways

1. **Trade-off** between diversity of technology-mix and diversity of spatial configuration in exploring alternatives

2. **No alternative is redundant.** Even a brute-force exploration of technology mixes might miss key spatially-distinctive options

3. **Ideal solution**: initial as-exhaustive-as-possible exploration of the decision space, followed by **iteration with stakeholders**

4. **A hybrid workflow** is most suited for such as-exhaustive-as-possible exploration. **Evolving-average** alone is the best-available option when computational power is limted

Thank you!
Questions?

@FrLomb

1. Cost-optimality has little meaning in practice. Modellers should provide **alternatives**
2. Missing to do so **obfuscates what is possible** and leads to fallacious conclusions about the feasibility of the energy transition
3. Flexibility of choice - particularly about spatial deployment - is **very likely** in any scenario, leaving **room for stakeholder discussion**
4. Yet, only a finite number of alternatives can be generated, which calls for **stakeholder integration in the computational workflow**
5. User-friendly **interfaces** might help balancing a wider decision space with calls for **understandability**

Thanks to:
Collaborators including Stefan Pfenninger, Bryn Pickering
Partners of the SEEDS project as listed in seeds-project.org/about/

Coming soon.

1. Feasible options for a fully sector-coupled, carbon-neutral energy system in Europe
   [submitted, lead: B. Pickering]

2. Methodological paper about how many alternatives are enough, with results for European power sector
   [in progress]

3. Position paper about the need to consider alternatives (or to make claims consistent with their existence) when using energy system optimisation models
   *[in progress, with **plan to invite all MGA teams to join** next year]*