

Seeing the Forest for the Scenarios: Using Decision Trees to Draw Conclusions from Large Energy Scenario Sets

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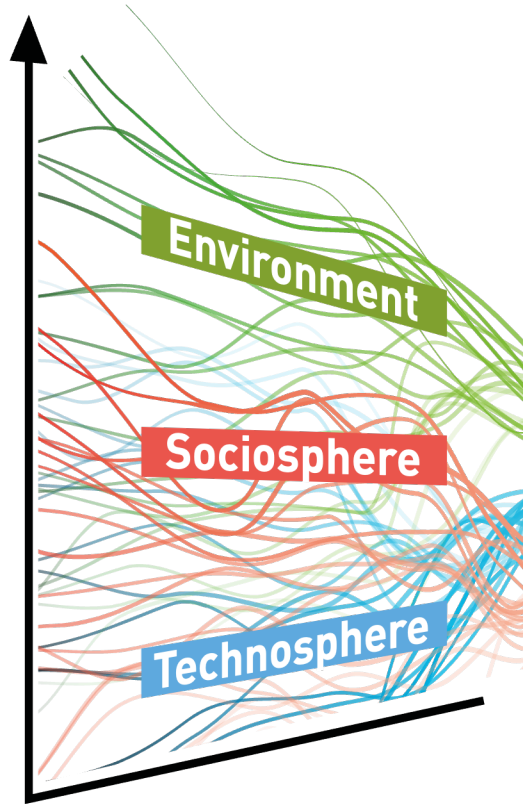
PRISMA summer school on uncertainty in energy and integrated assessment models of climate change
Geneva, June 15-19 2026

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Uncertainty: a major unsolved problem in the energy transition



Research Vision: The Uncertainty Funnel



European Research Council

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Research Vision: The Uncertainty Funnel

Sources:

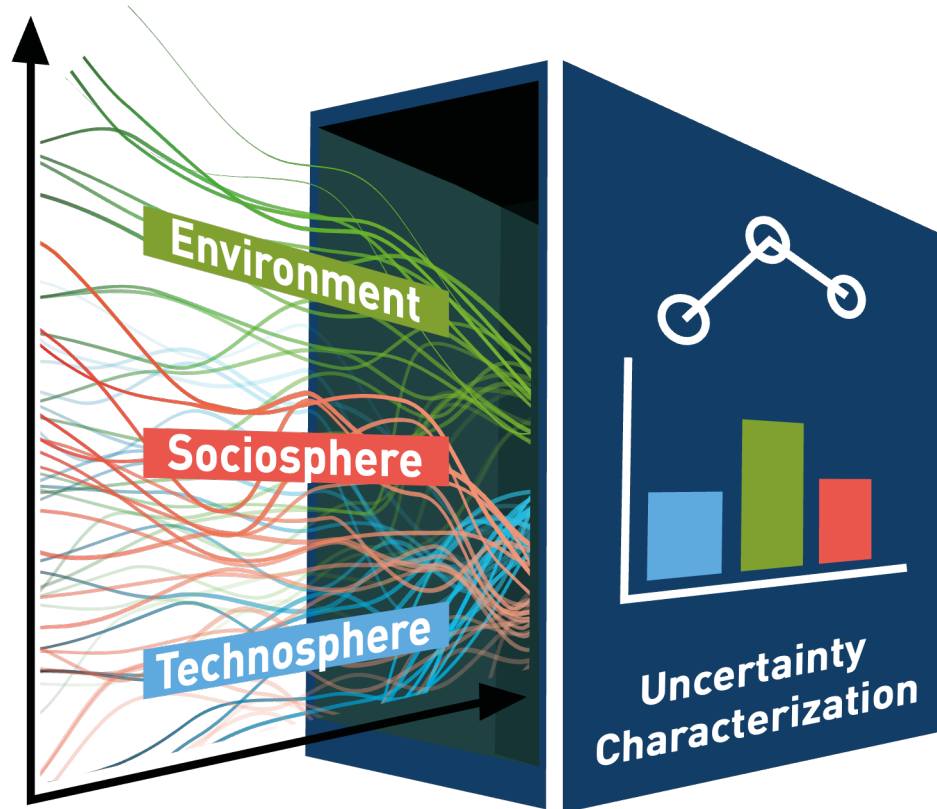
[1] Grossmann et al, *Computers and Chemical Engineering*, 2016

[2] Moret et al, *Applied Energy*, 2017



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Barriers in State of the Art



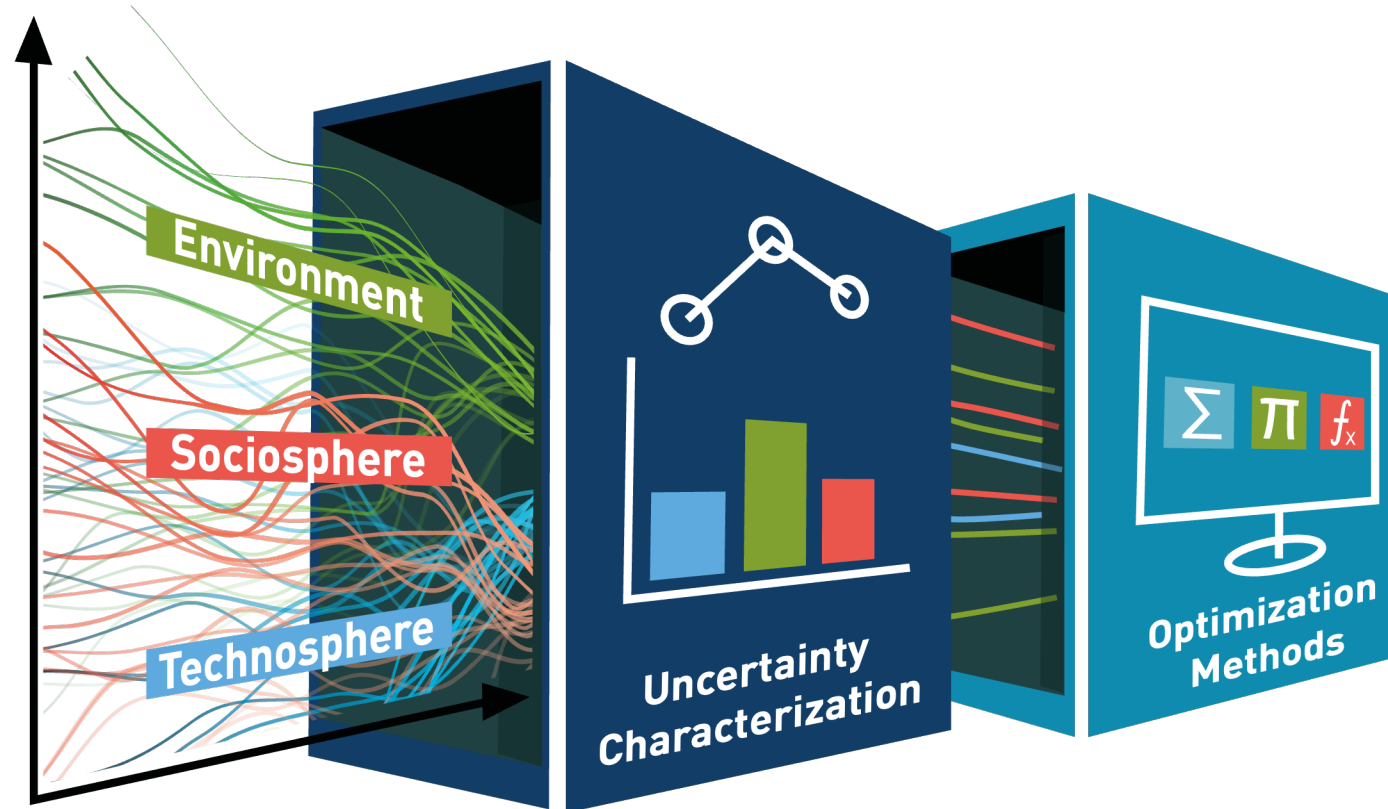
- Data quality and availability^[1]
- Some uncertainties are completely ignored^[2]

Research Vision: The Uncertainty Funnel

Sources:

[1] Moret et al, *European Journal of Operational Research*, 2020

[2] Gao et al, *Operations Research*, 2022



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Barriers in
State of the Art



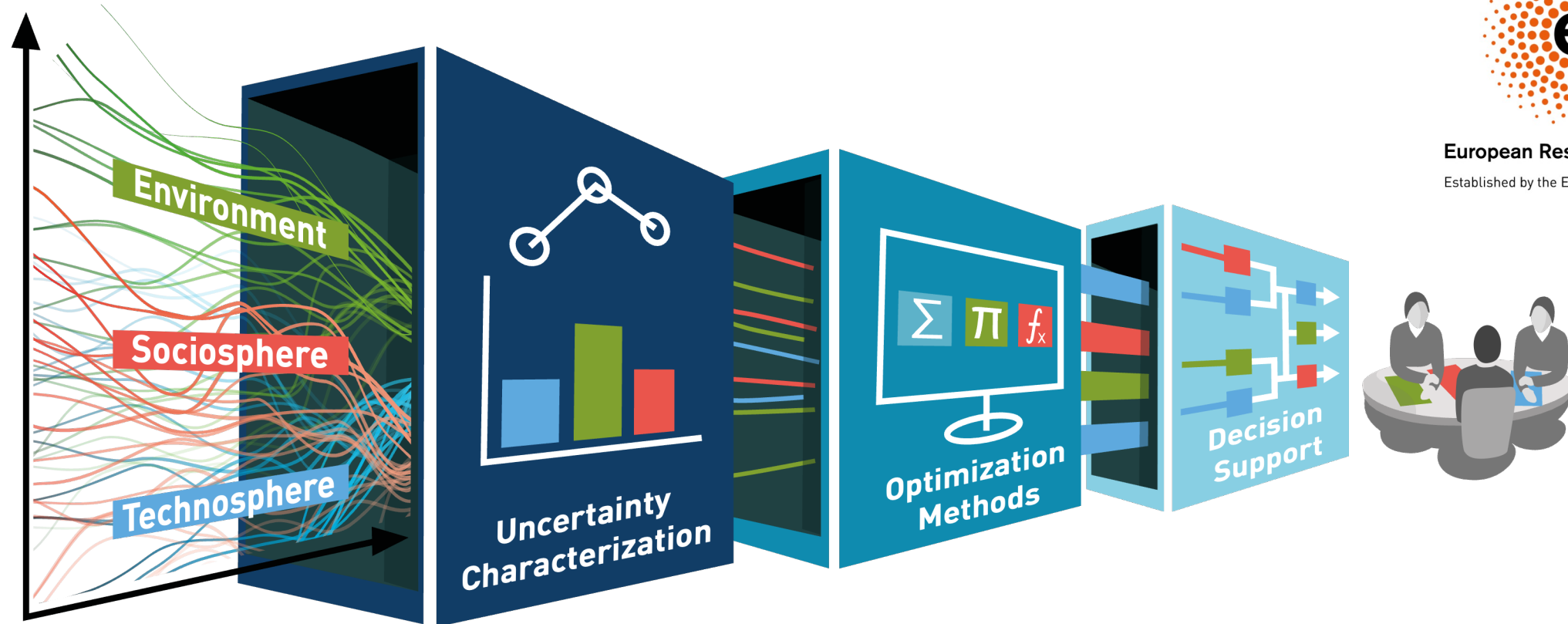
- Complex Formulations^[1]
- Computational Deadlock^[2]

Research Vision: The Uncertainty Funnel

Sources:
[1] Pickering et al, *Joule*, 2022



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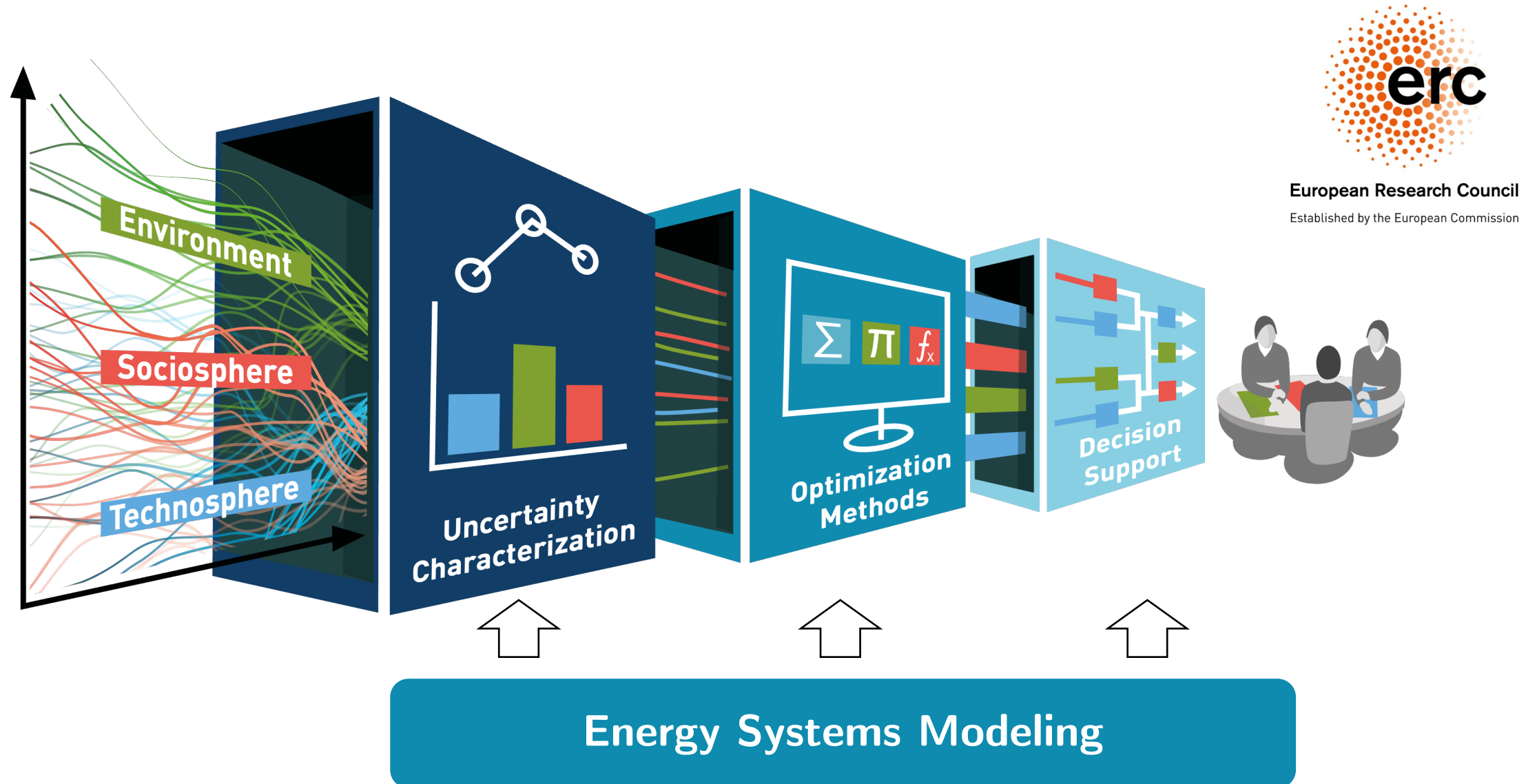


Barriers in
State of the Art



Complexity of
Outputs^[1]

Research Vision: The Uncertainty Funnel



Gabriel Wiest, ETH Zurich
PhD student

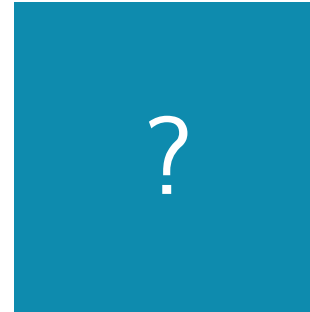
“Low-regrets” and “must-avoids”
for the energy transition



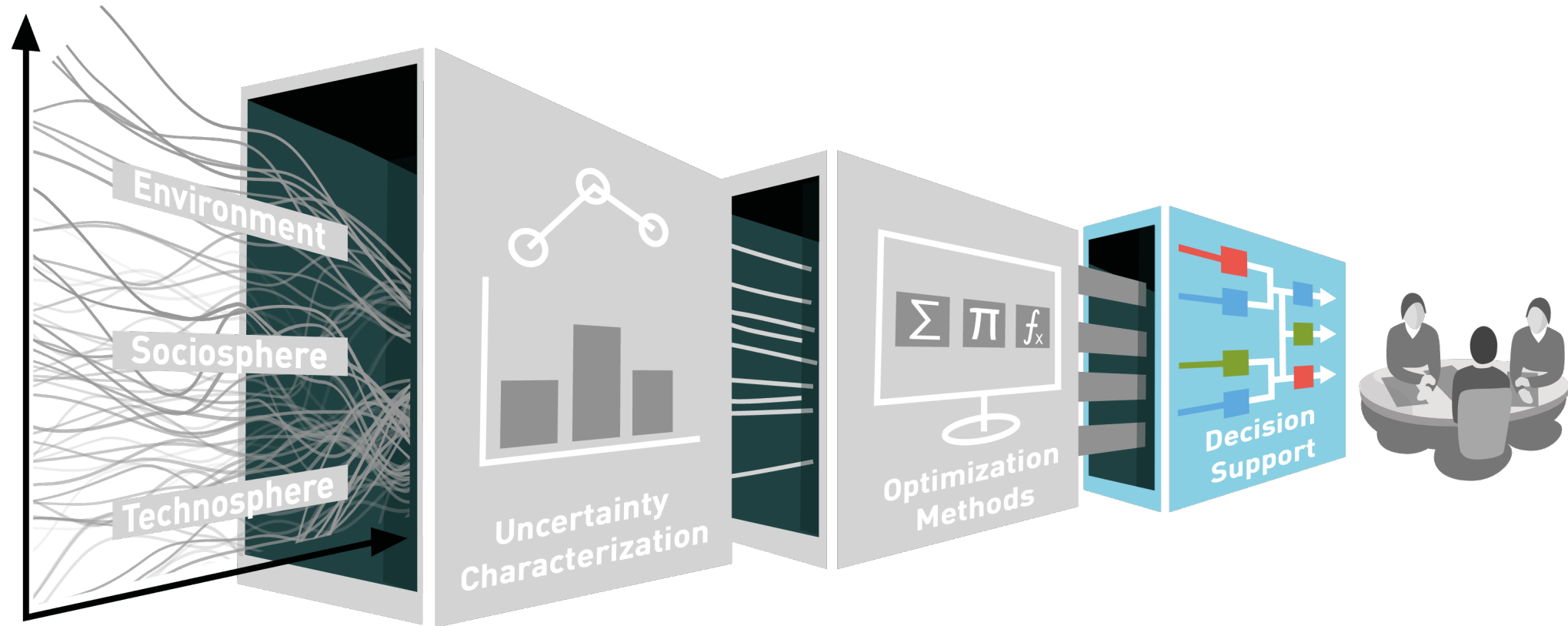
Lucia Clara Cairella, Polimi
PhD student
Uncertainty in social acceptance

Giorgia Gossi, Polimi
Research Assistant

Uncertainty Characterization



Research Vision: The Uncertainty Funnel



**Barriers in
State of the Art**

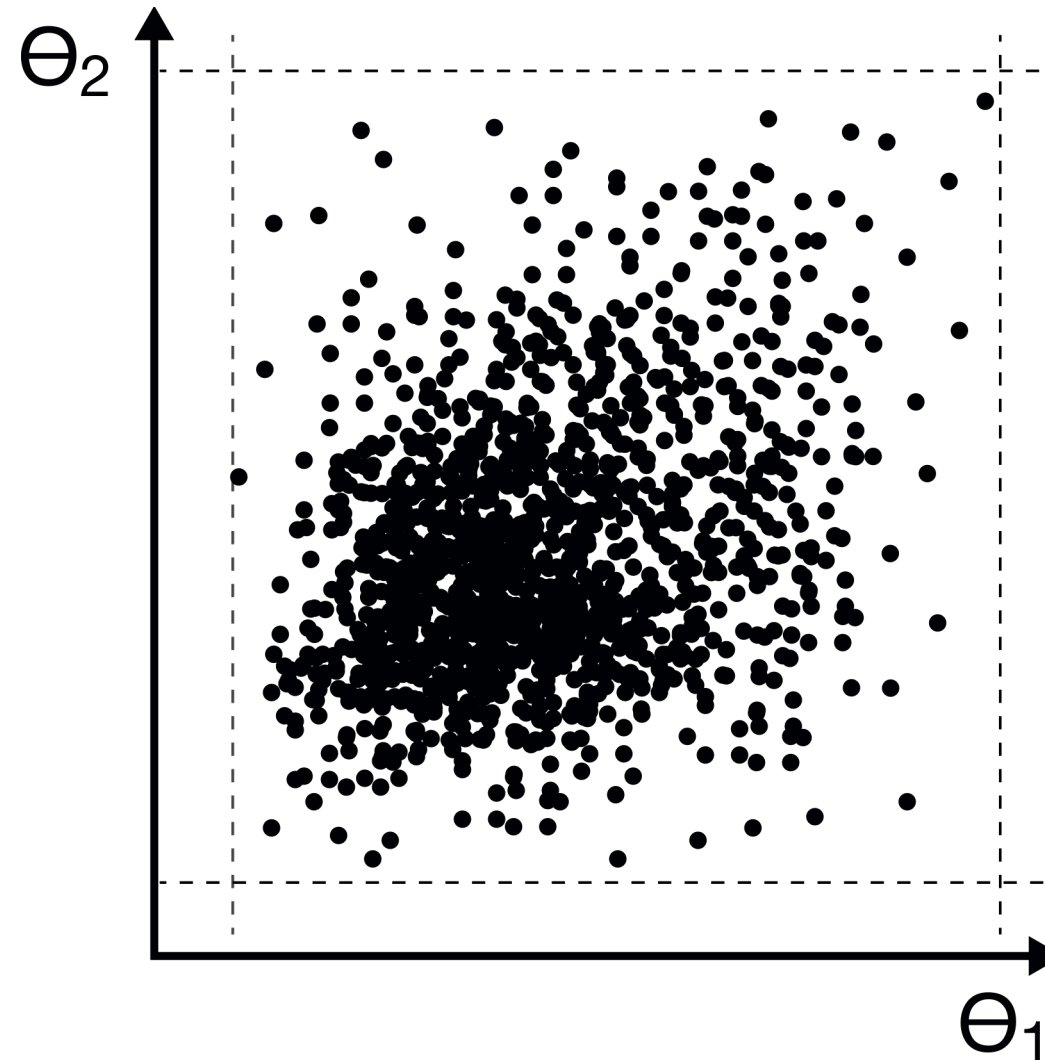


**Complexity of
Outputs**



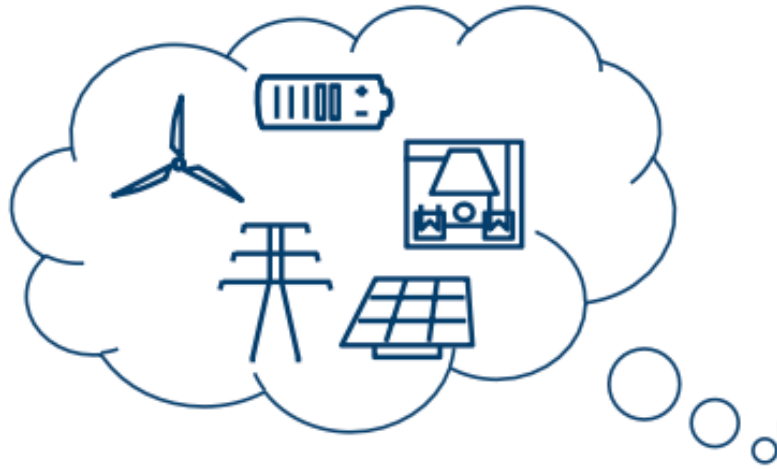
How can we streamline hundreds of scenarios into interpretable options?

Energy system scenarios have many **uncertainties!**





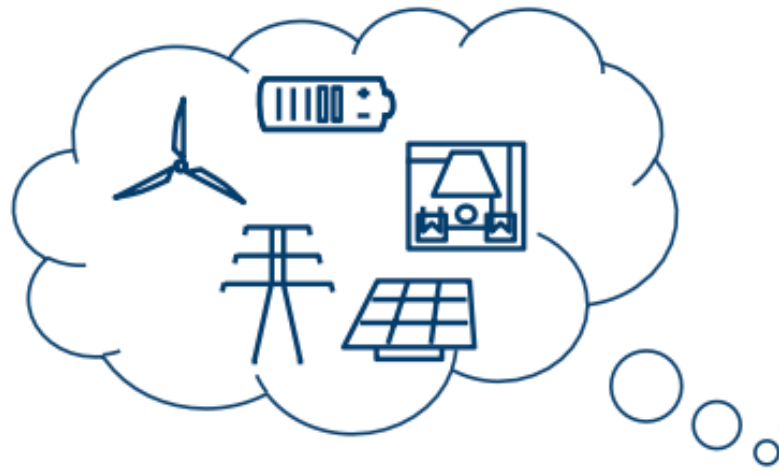
How can we streamline hundreds of scenarios into interpretable options?



Florian Baader



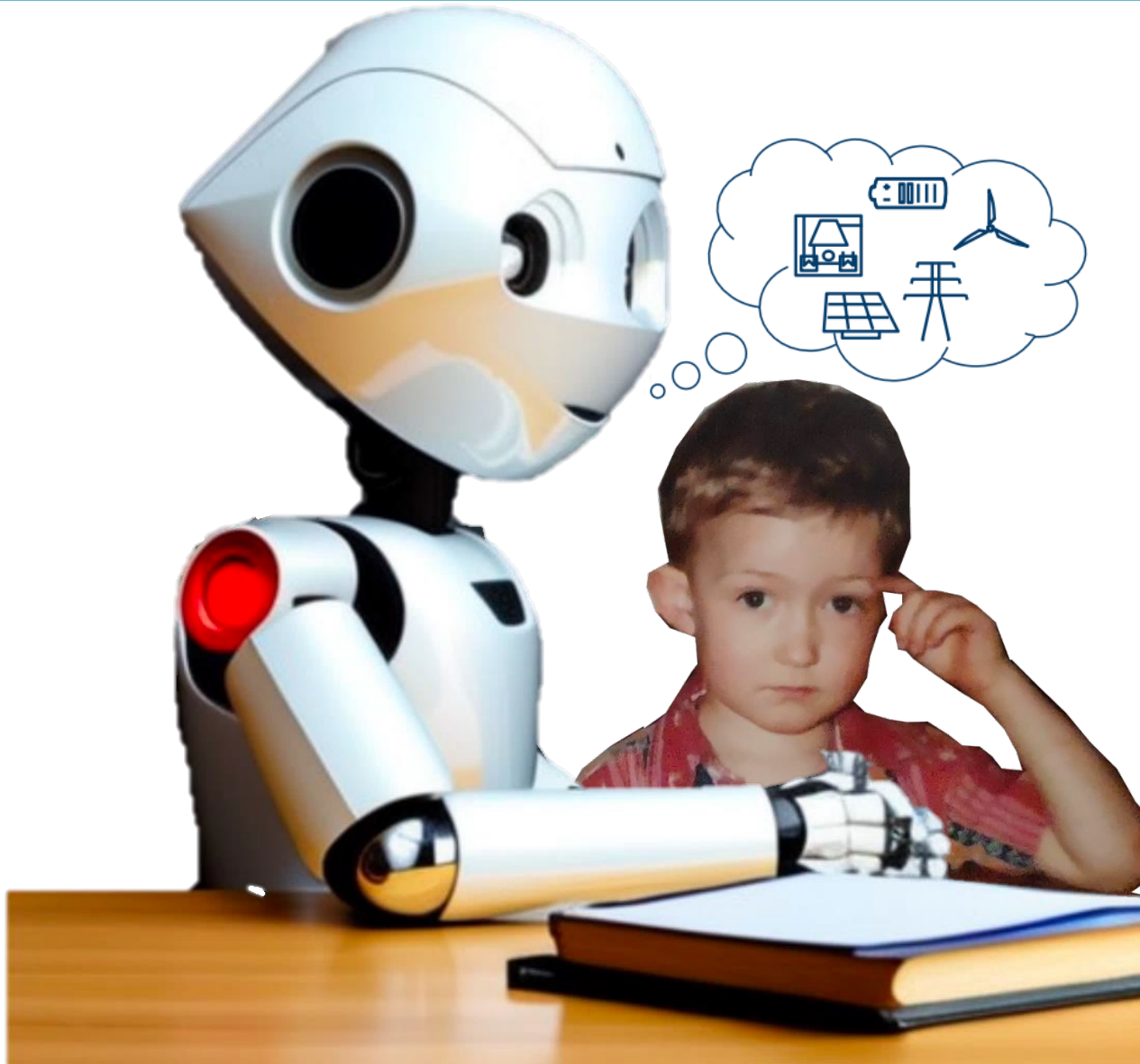
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How can we streamline hundreds of scenarios into interpretable options?



**Imperial College
London**



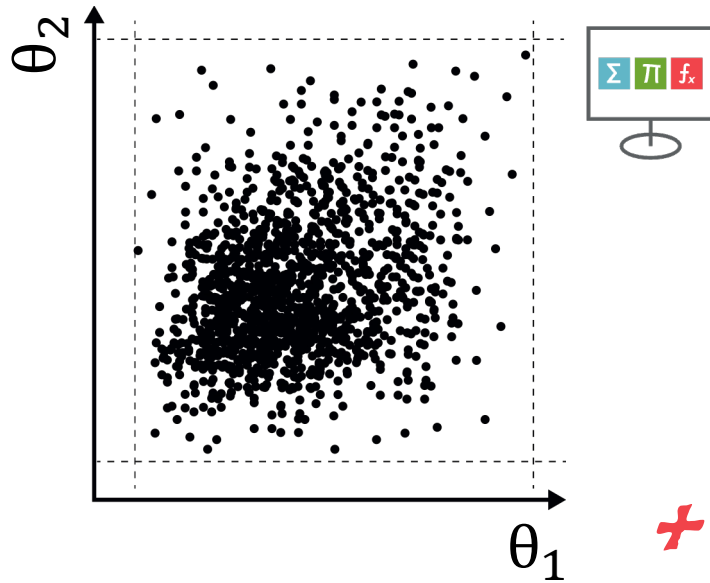
Florian Baader

Can Machine
Learning help us
create a story?



How can we streamline hundreds of scenarios into interpretable options?

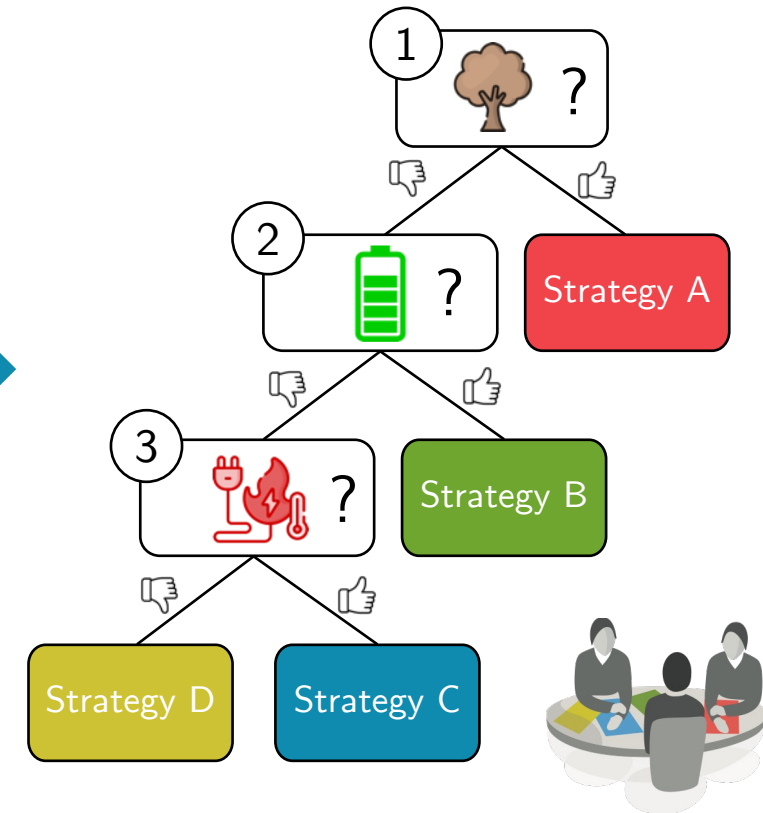
1) Generate **100s** of scenarios



2) Define **policy questions**



Decision
Trees



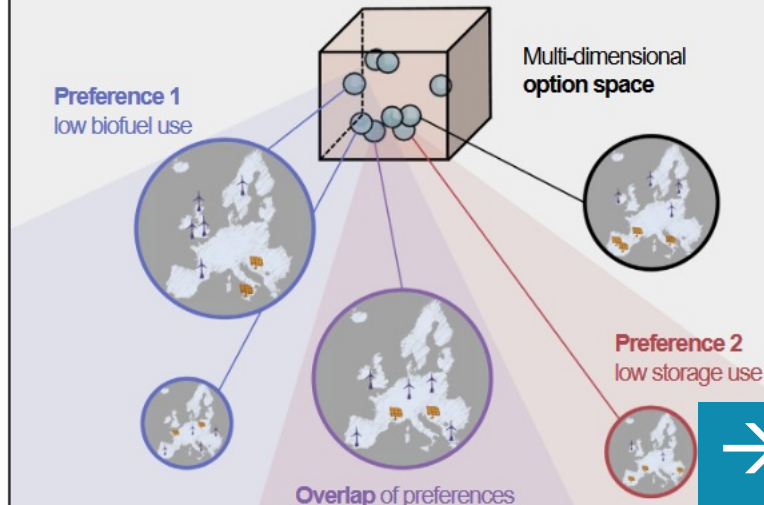


How can we streamline hundreds of scenarios into interpretable options?

Article

Diversity of options to eliminate fossil fuels and reach carbon neutrality across the entire European energy system

441 technically feasible and cost-effective options for an energy self-sufficient, carbon-neutral Europe



Almost anything is technically possible, but **preferences** restrict the spatial and technical **maneuvering space**

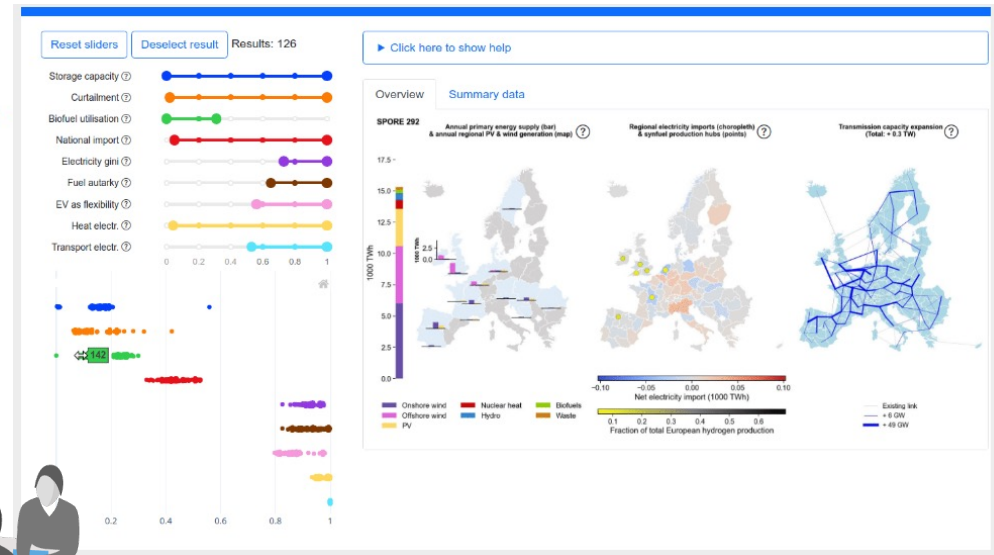
Bryn Pickering, Francesco Lombardi, Stefan Pfenninger
bryn.pickering@usys.ethz.ch

Highlights
Many cost-effective options exist for an energy self-sufficient, carbon-neutral Europe

A variety of spatial configurations are valid, and specific regions can be prioritized

Although firm capacity must have, limiting maneuvering space

For example, low bioenergy



→ What to do with 441 options?



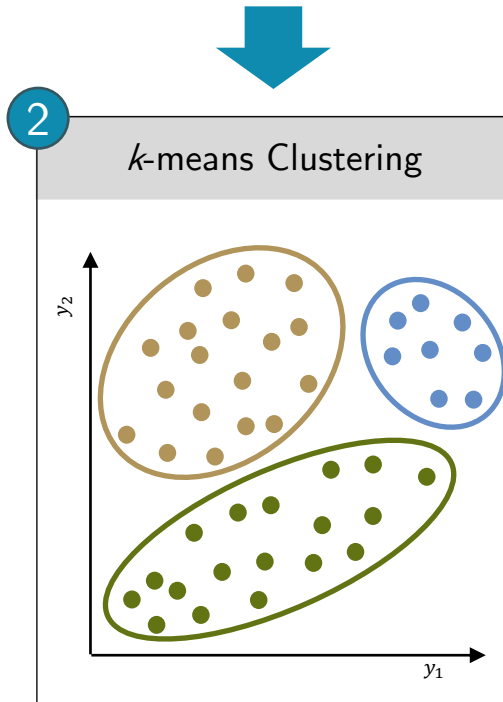
How can we streamline hundreds of scenarios into interpretable options?

- Methodology: 4 steps

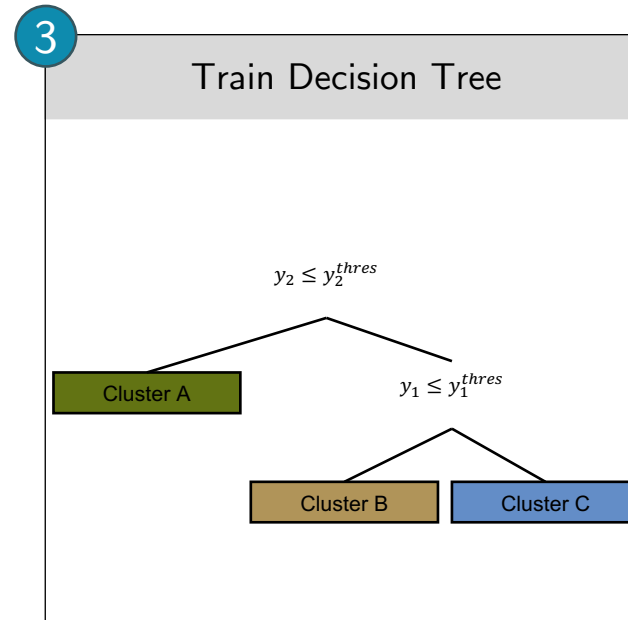
1

Run	y_1	y_2	[...]	y_m
1				
2				
3				
...				
N				

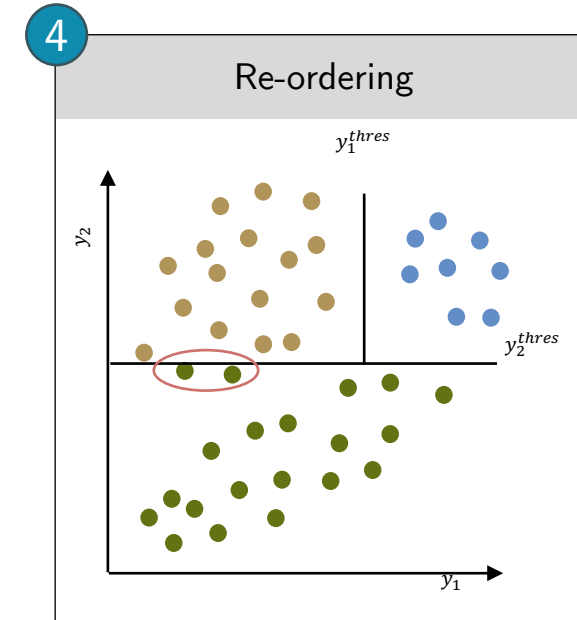
$N \times m$ matrix
 m : Outputs of Interest y_j
 N : runs



k Clusters



Number of leaves = k

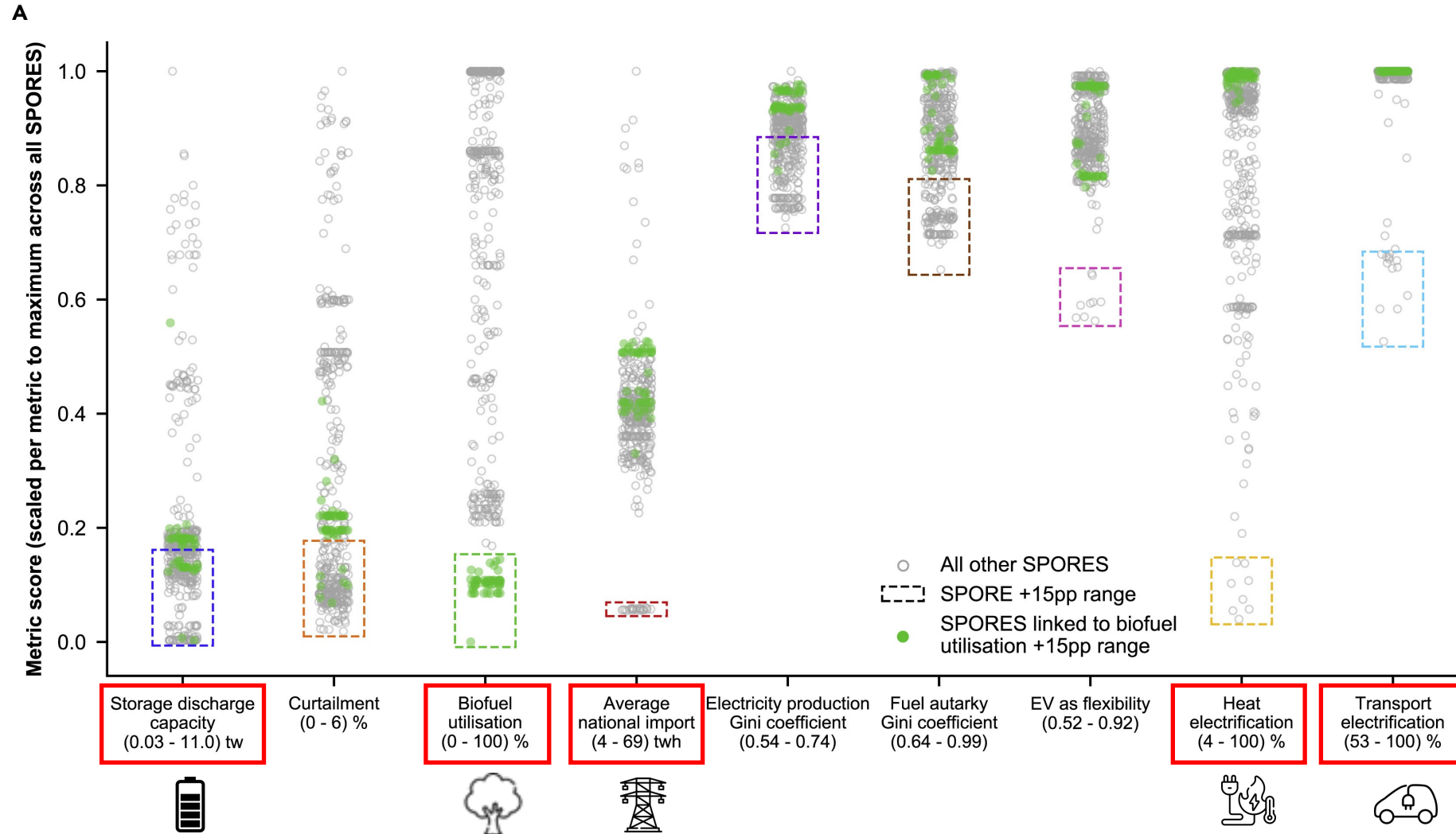


Accuracy > 99%



How can we streamline hundreds of scenarios into interpretable options?

Decision Tree for the European energy transition: 441 scenarios^[1]





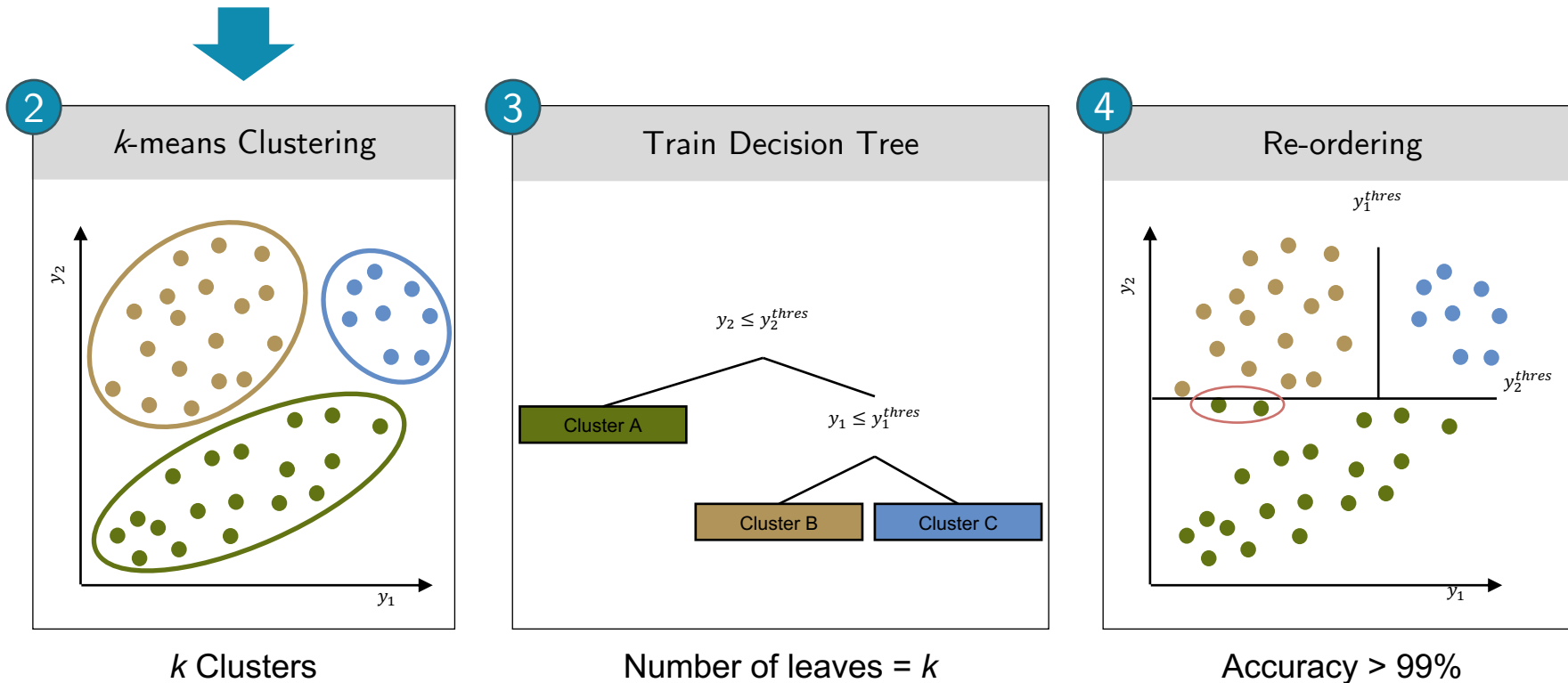
How can we streamline hundreds of scenarios into interpretable options?

- Methodology: 4 steps

1

Run	y_1	y_2	[...]	y_m
1				
2				
3				
...				
N				

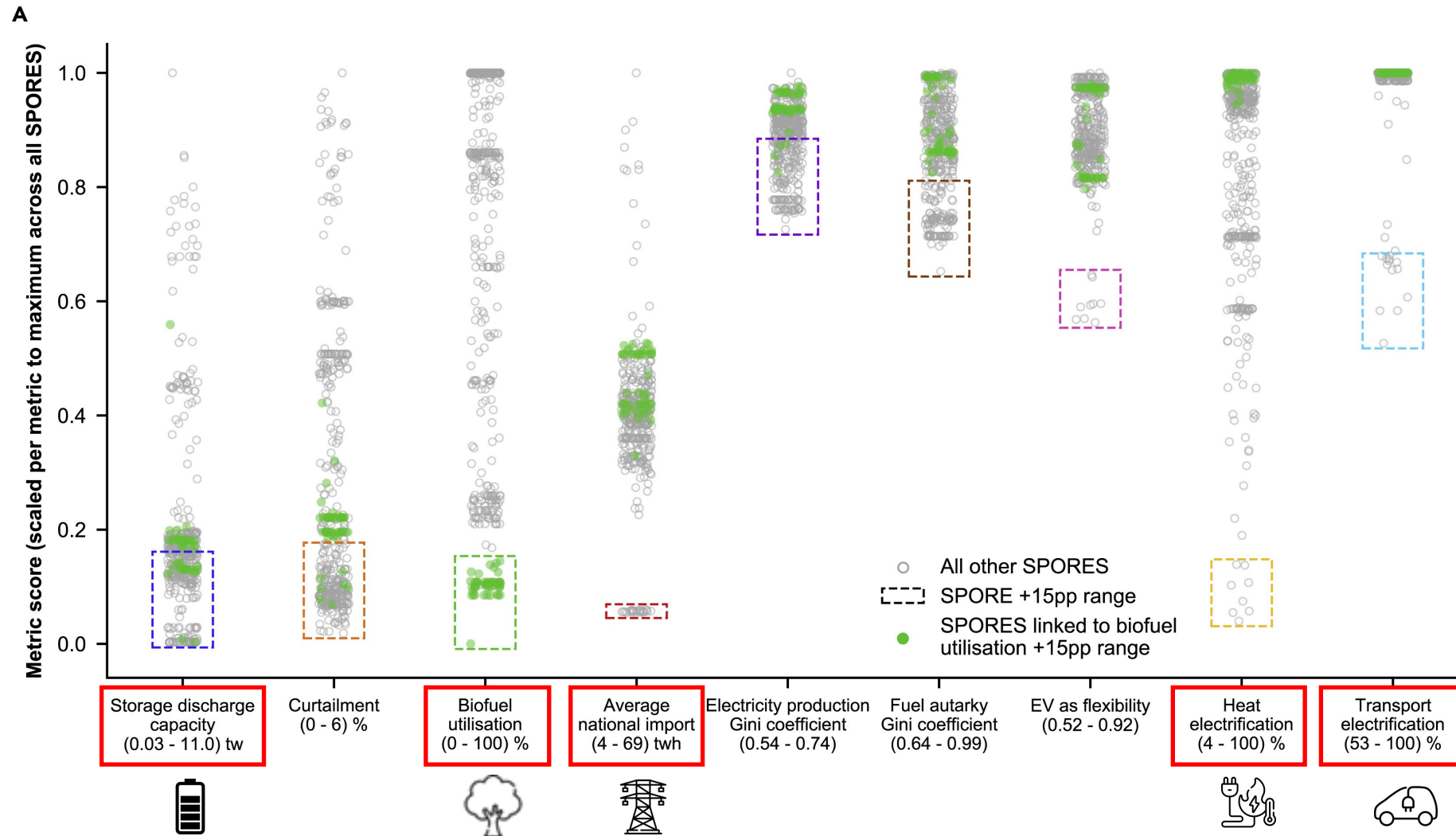
441 x 5 matrix
5: Outputs of Interest y_j
441: runs





How can we streamline hundreds of scenarios into interpretable options?

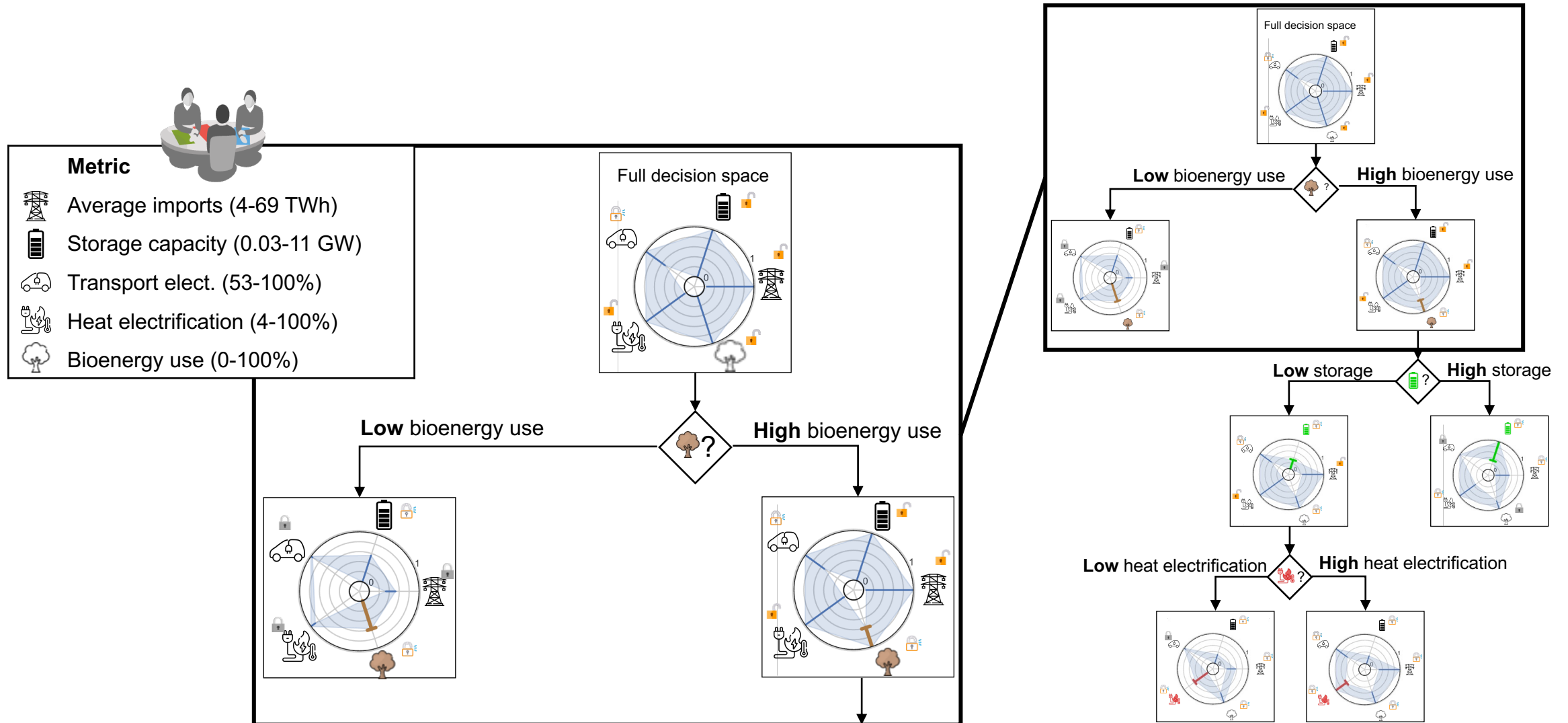
Decision Tree for the European energy transition: 441 scenarios^[1]





How can we streamline hundreds of scenarios into interpretable options?

Decision Tree for the European energy transition: 441 scenarios^[1]





Saying **No** means saying **Yes** to something else



How can we streamline hundreds of scenarios into interpretable options?



Low-Regrets & Must-Avoids for the use of biomass in the Swiss energy transition^[1]

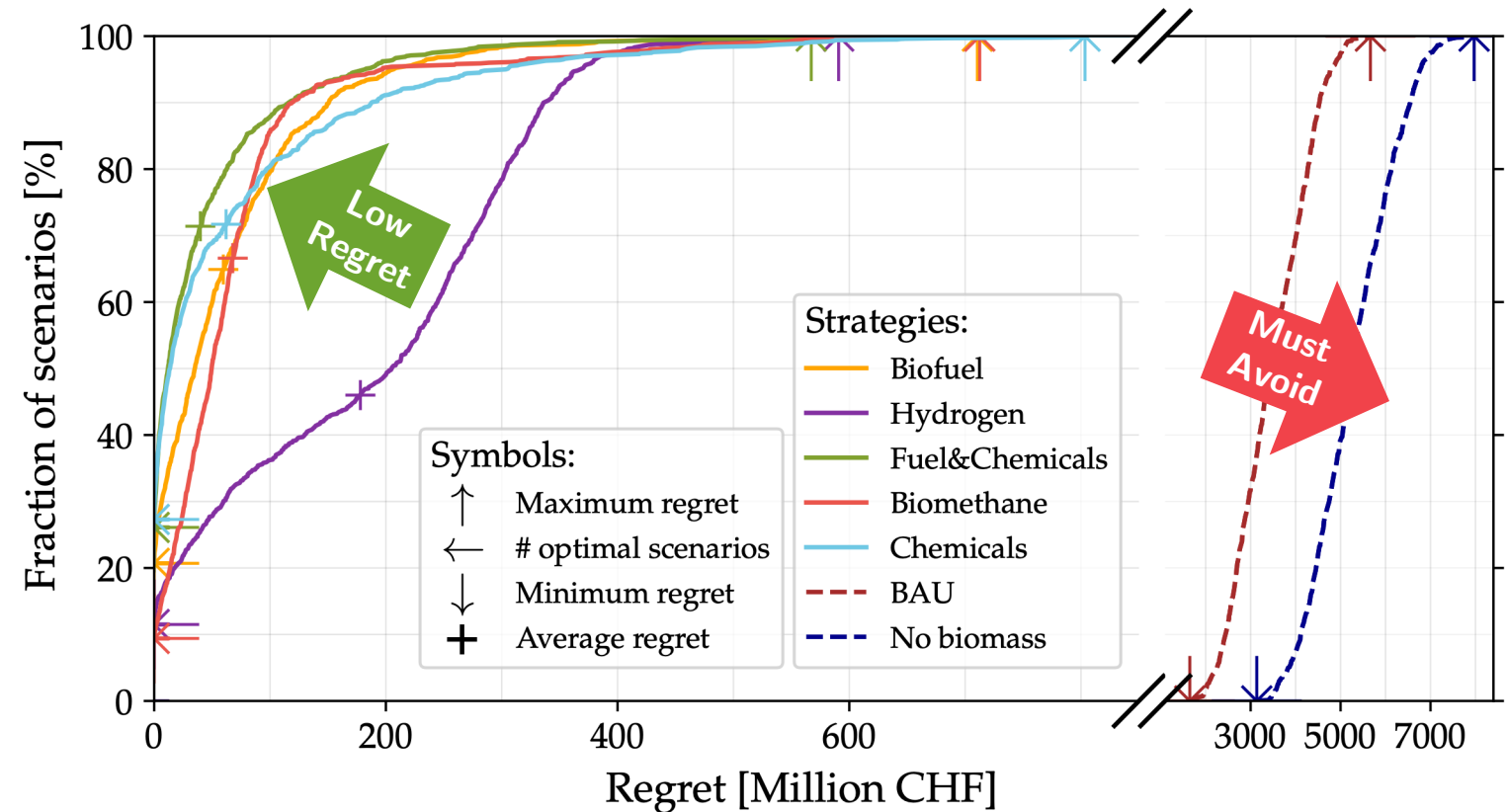


Gabriel Wiest



Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Federal Office of Energy





How can we streamline hundreds of scenarios into interpretable options?



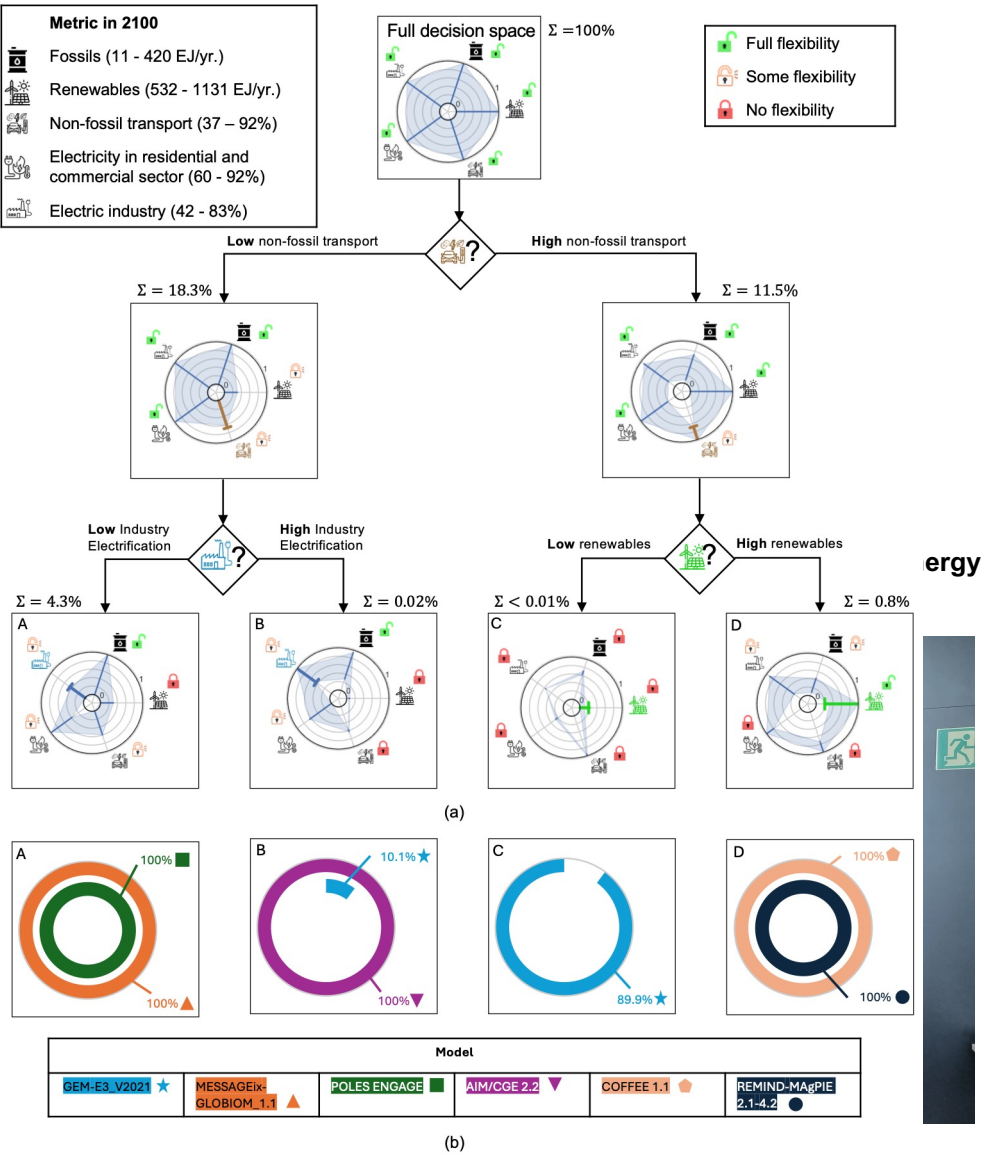
Low-Regrets & Must-Avoids for the use of biomass in the Swiss energy transition^[1]



Key decisions for the European energy transition



Global Energy Transition: IPCC AR6 Scenario Database

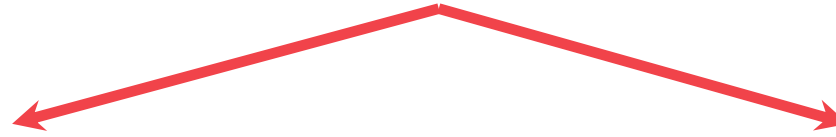




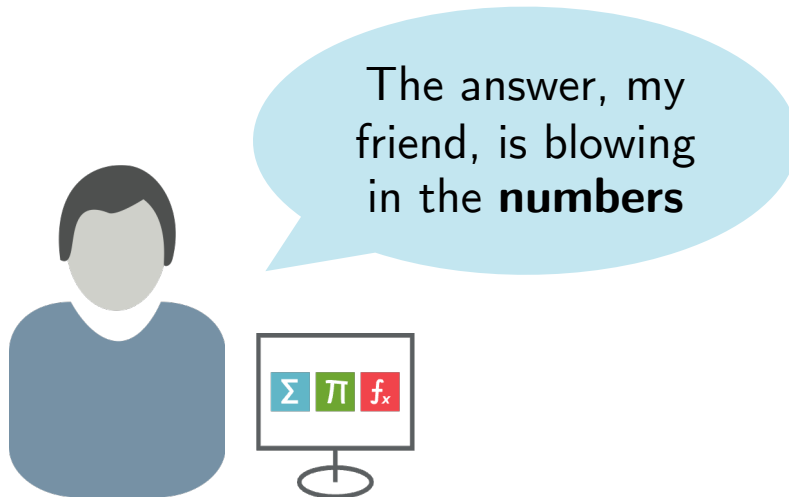
How can we streamline hundreds of scenarios into interpretable options?

Energy system scenarios have many **uncertainties**!

How can we explore the options?



The modeler's solution



The social scientist's solution





How can we streamline hundreds of scenarios into interpretable options?

Energy system scenarios have many **uncertainties!**

How can we explore the options?

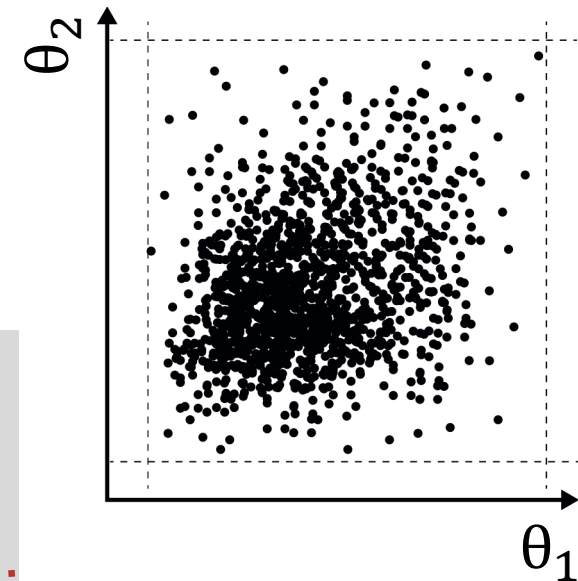
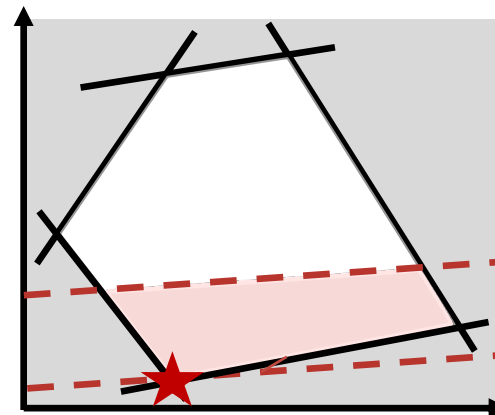


The modeler's solution

Generate **many alternatives**^[1,2]

+ **Quantitative analysis**

- no “soft” aspects
- **Hard to interpret 100s of scenarios**

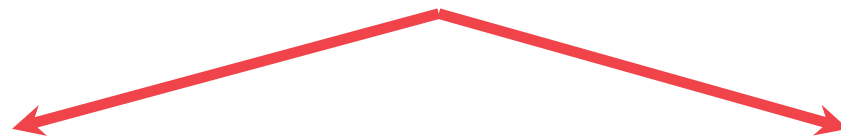




How can we streamline hundreds of scenarios into interpretable options?

Energy system scenarios have many **uncertainties**!

How can we explore the options?



The modeler's solution

Generate **many alternatives**^[1,2]

+ **Quantitative analysis**

- **no “soft” aspects**

- **Hard to interpret 100s of scenarios**

The social scientist's solution

Generate a **handful of storylines**:

- Generated with stakeholders

- Qualitative

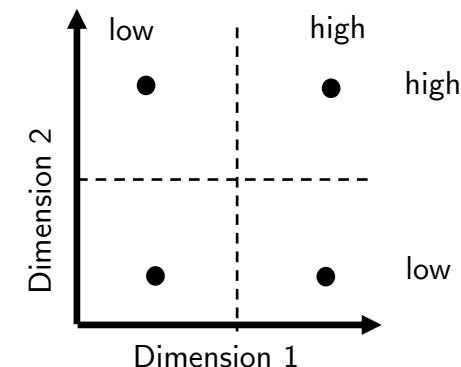
+ **“Soft” aspects & stakeholder views**

+ **Easier to communicate**

- **May reflect stakeholder bias**

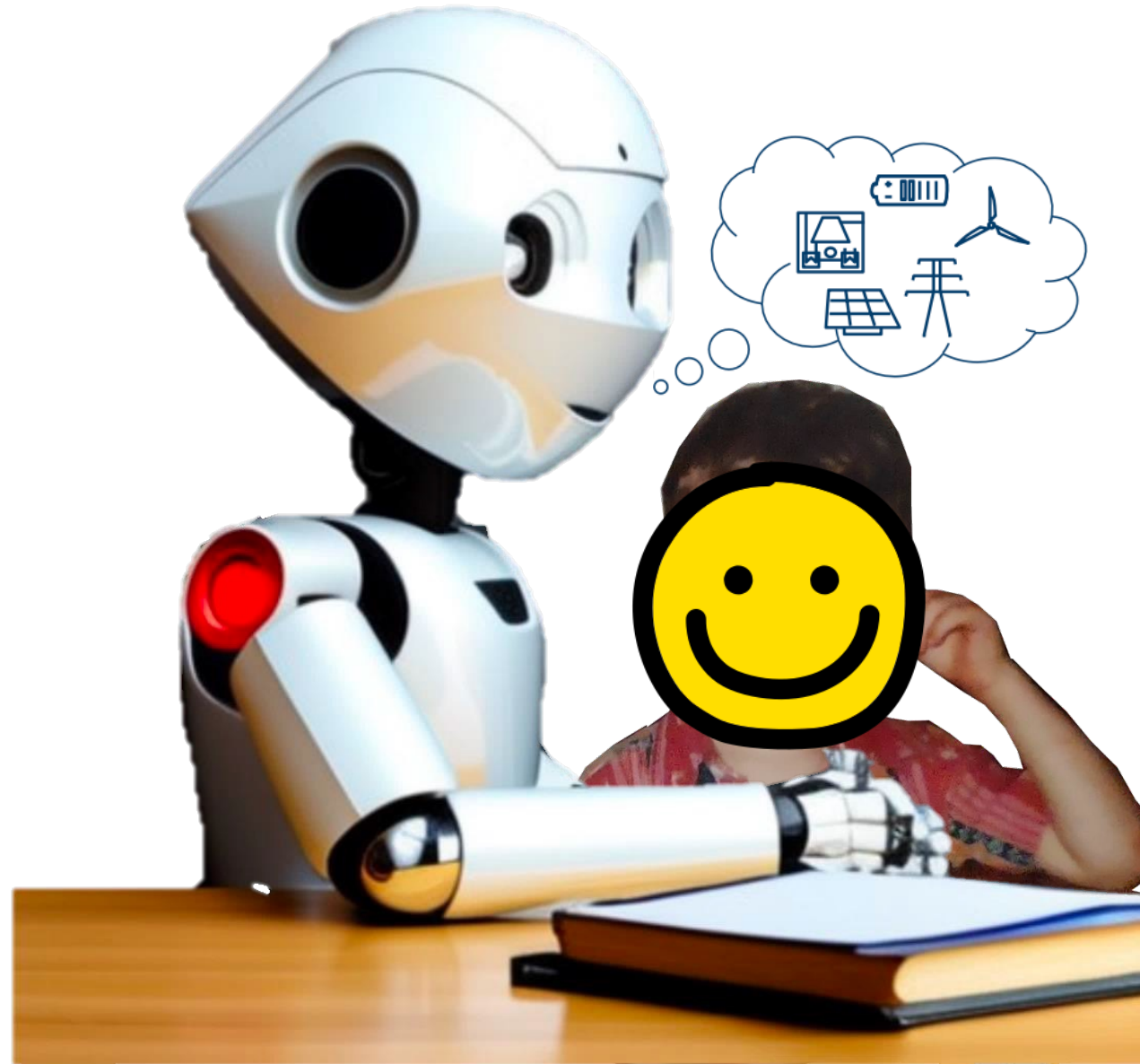
- **Potentially infeasible**

Reconciling these approaches and **narrow the gap** between
quantitative models and **real-world decisions**





How can we streamline hundreds of scenarios into interpretable options?



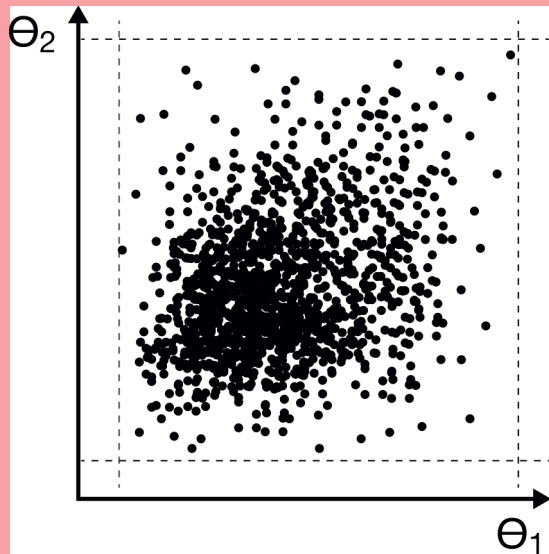


How can we streamline hundreds of scenarios into interpretable options?

Problem

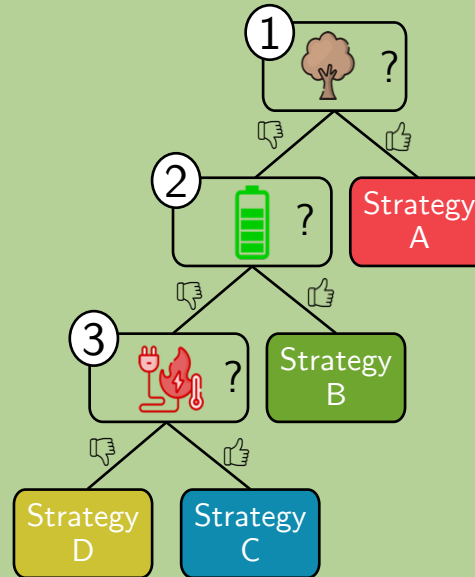


Complexity
of outputs



Solution

Machine Learning for
Decision Support^[1]

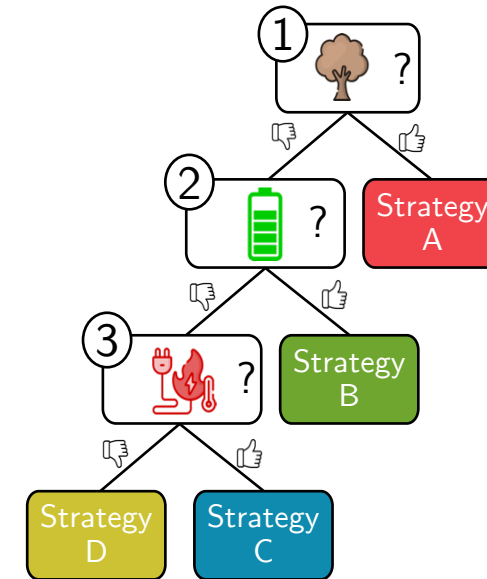
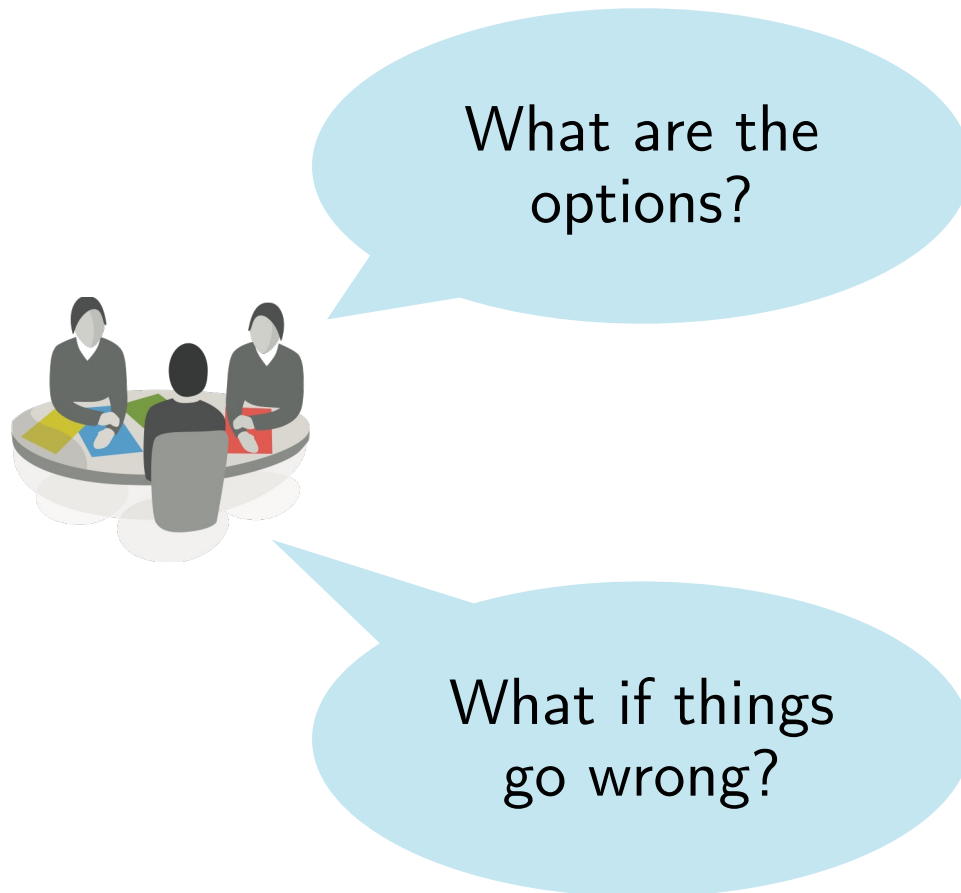


Impact

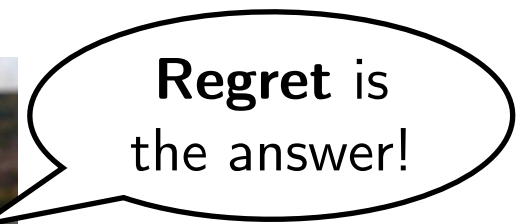
Key decisions and
options for the **energy**
transition



But this is just one part of the story...



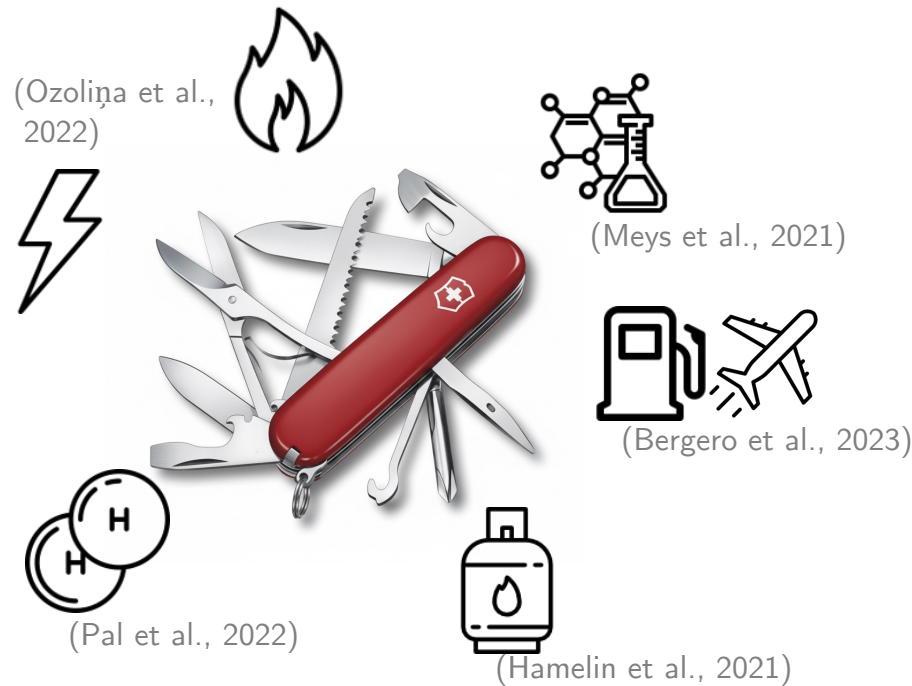
Gabriel Wiest



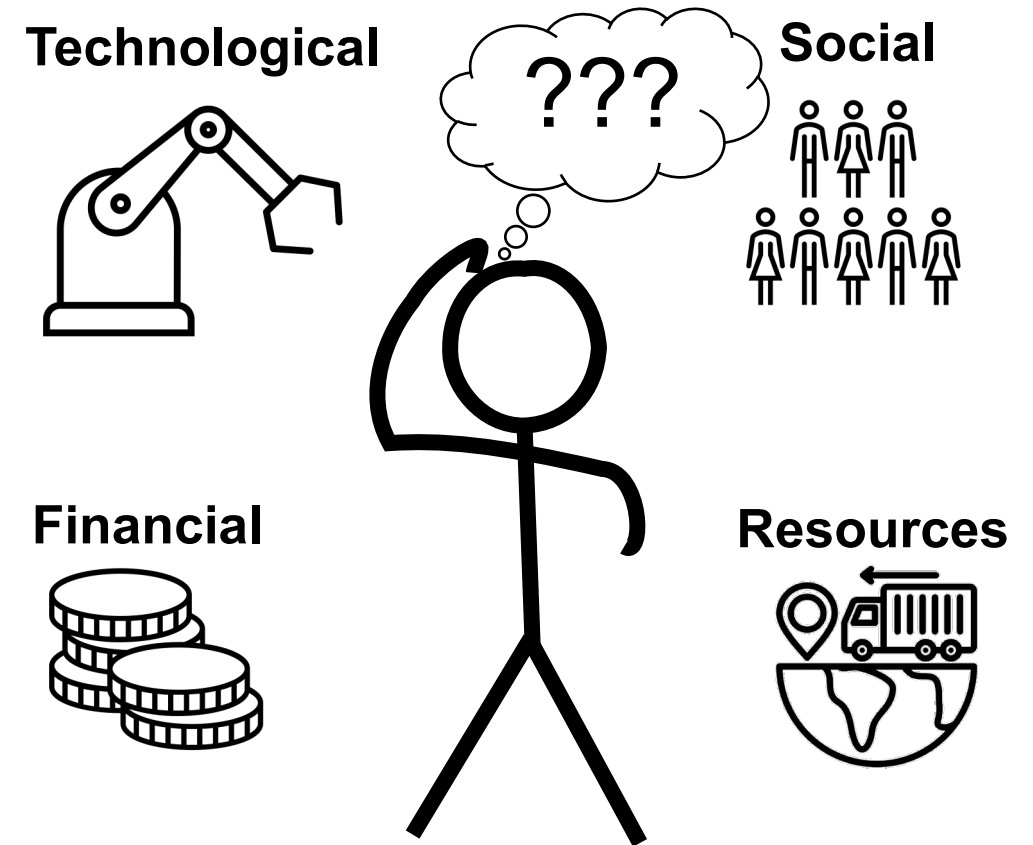


Which strategy will I regret the least if the future turns out differently than I expect?

Biomass



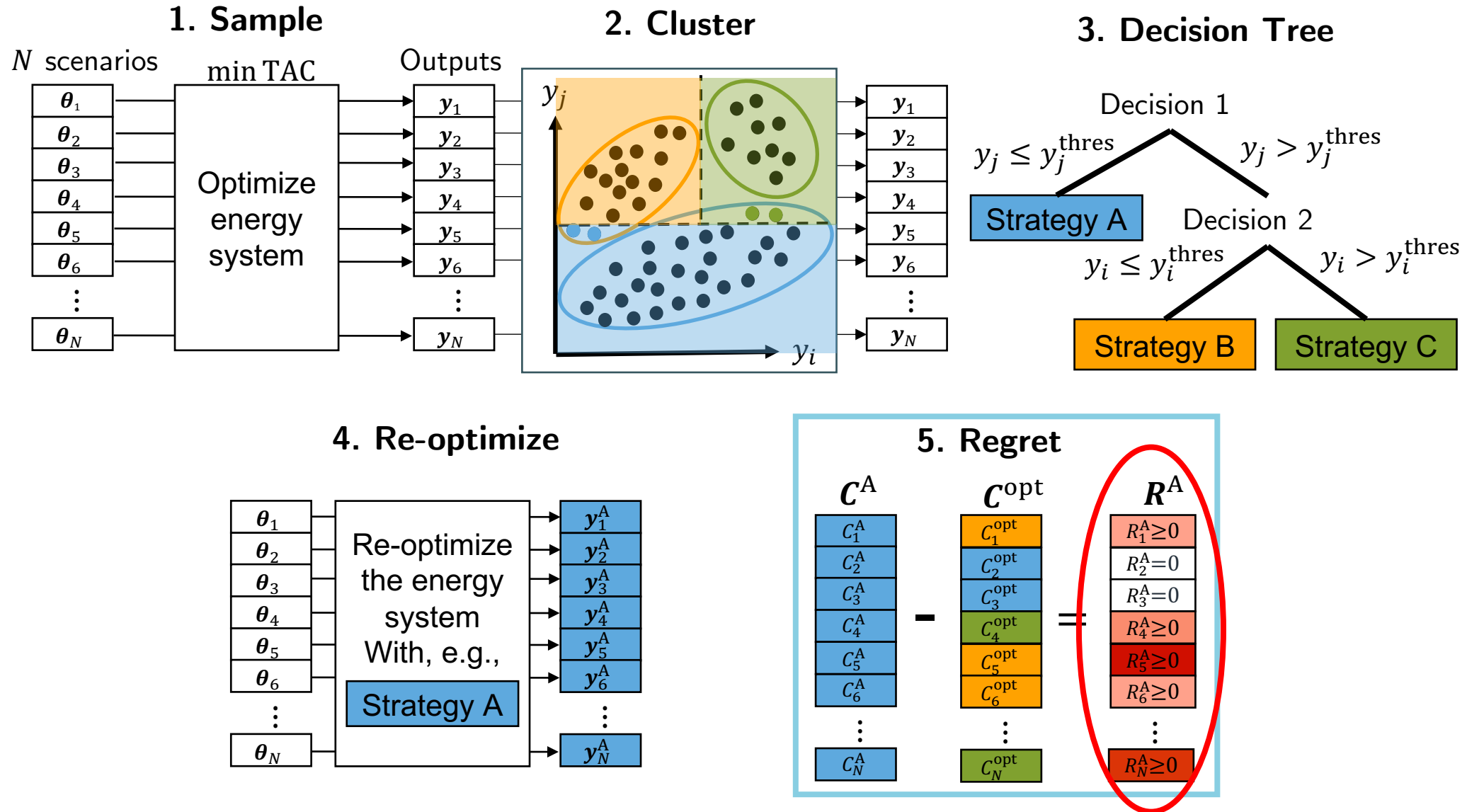
Uncertainties



What role should **biomass** play in the **future energy system**?
Can we identify **strategies** that we won't **regret**, i.e., that always perform well?

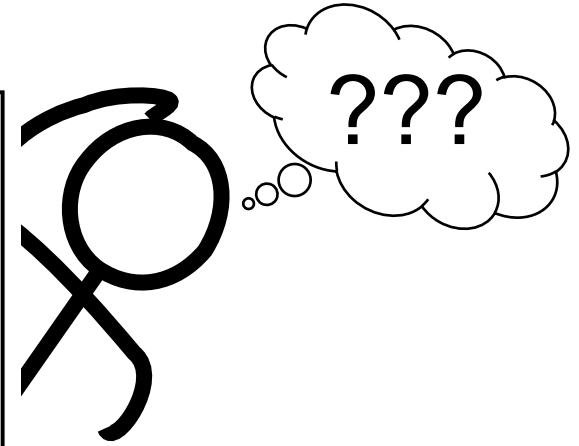
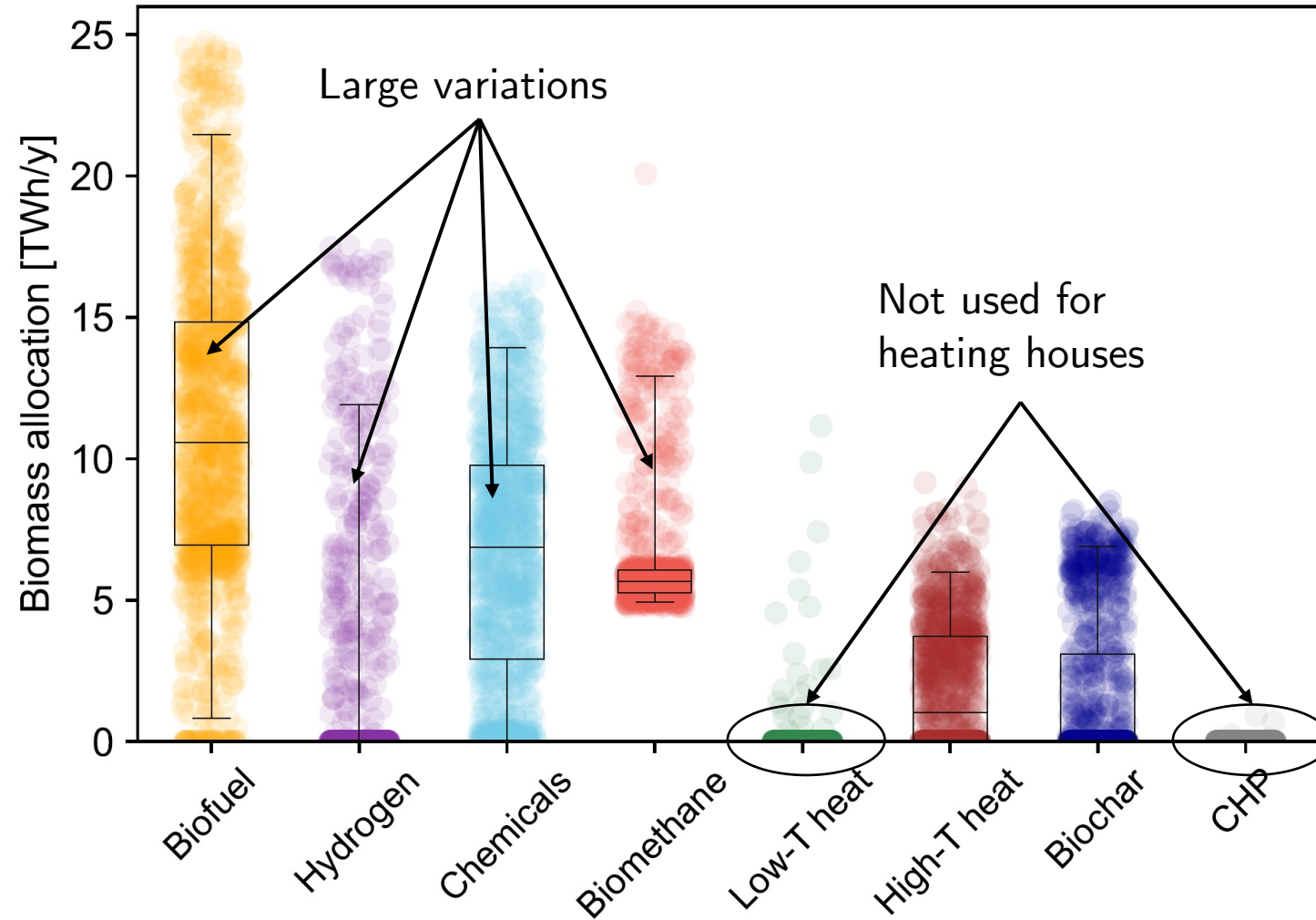


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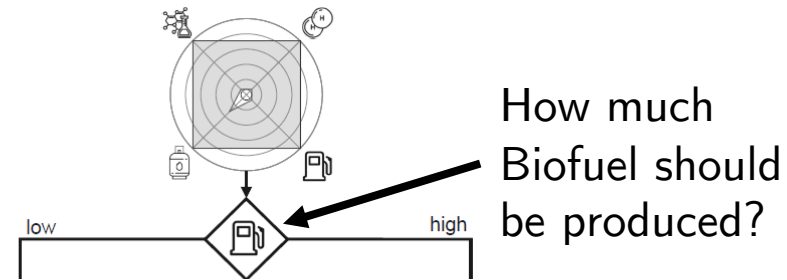


Which strategy will I regret the least if the future turns out differently than I expect?

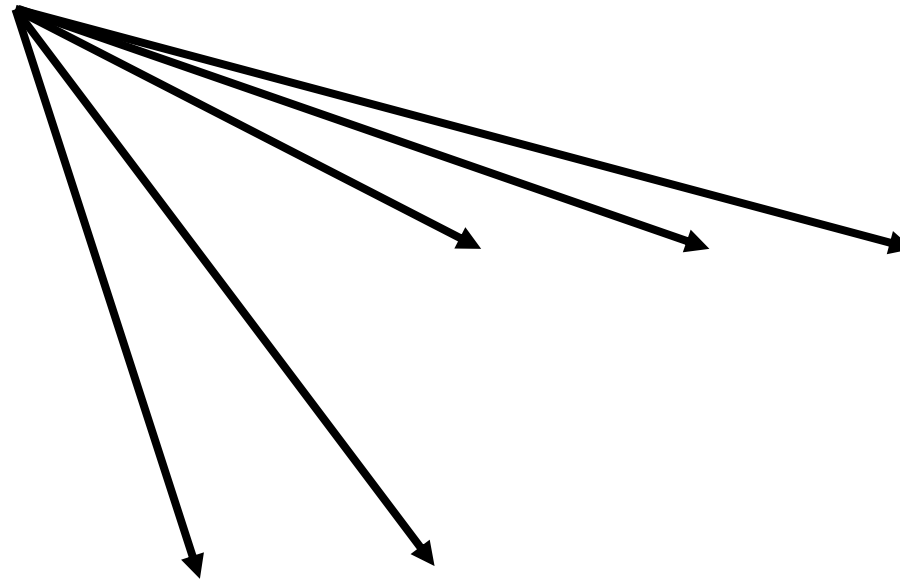




Which strategy will I regret the least if the future turns out differently than I expect?



Leaf nodes represent 5 biomass strategies

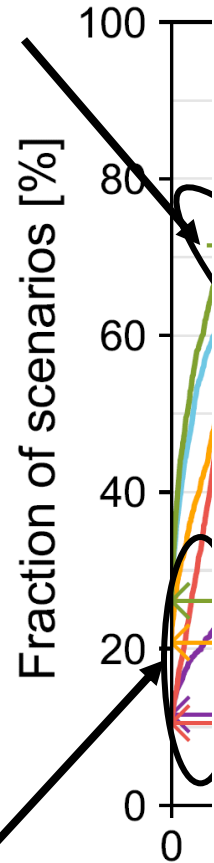




Which strategy will I regret the least if the future turns out differently than I expect?

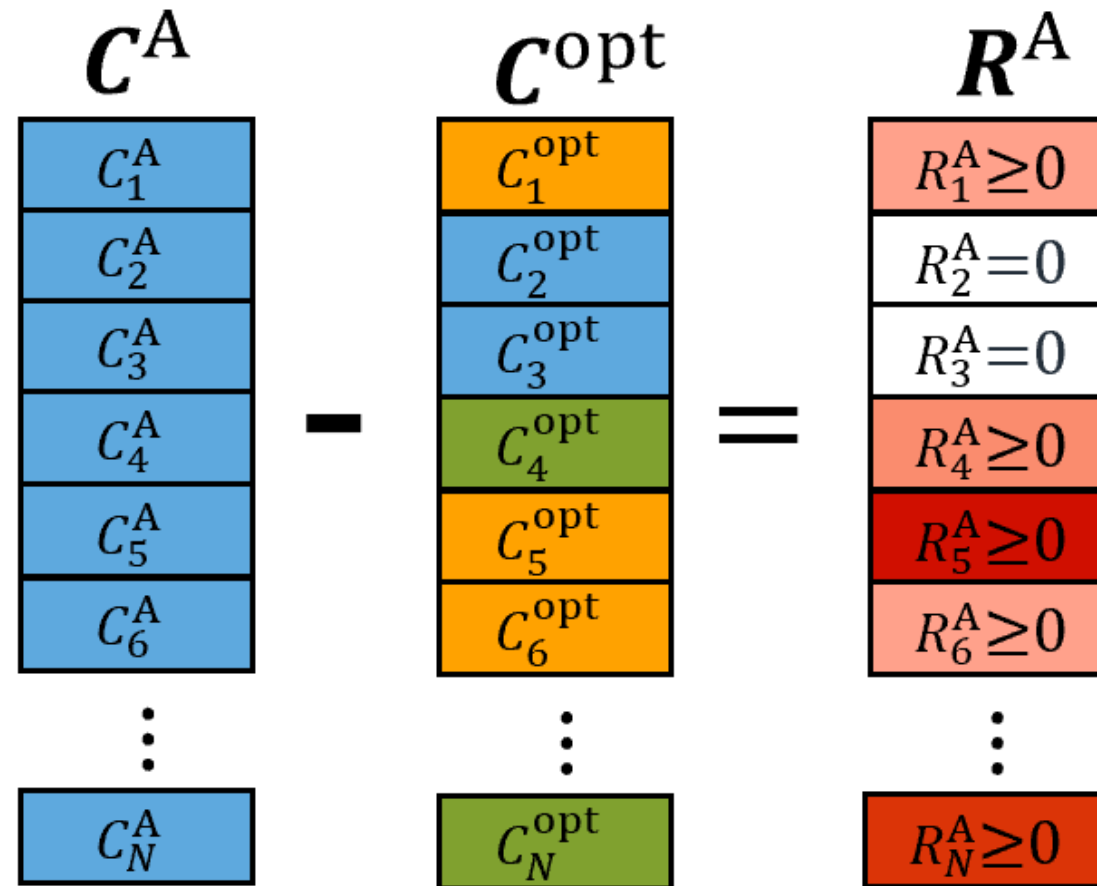
How does a strategy perform in the worst-case?

How does a strategy perform on average?



How often is a strategy the optimal one?

5. Regret

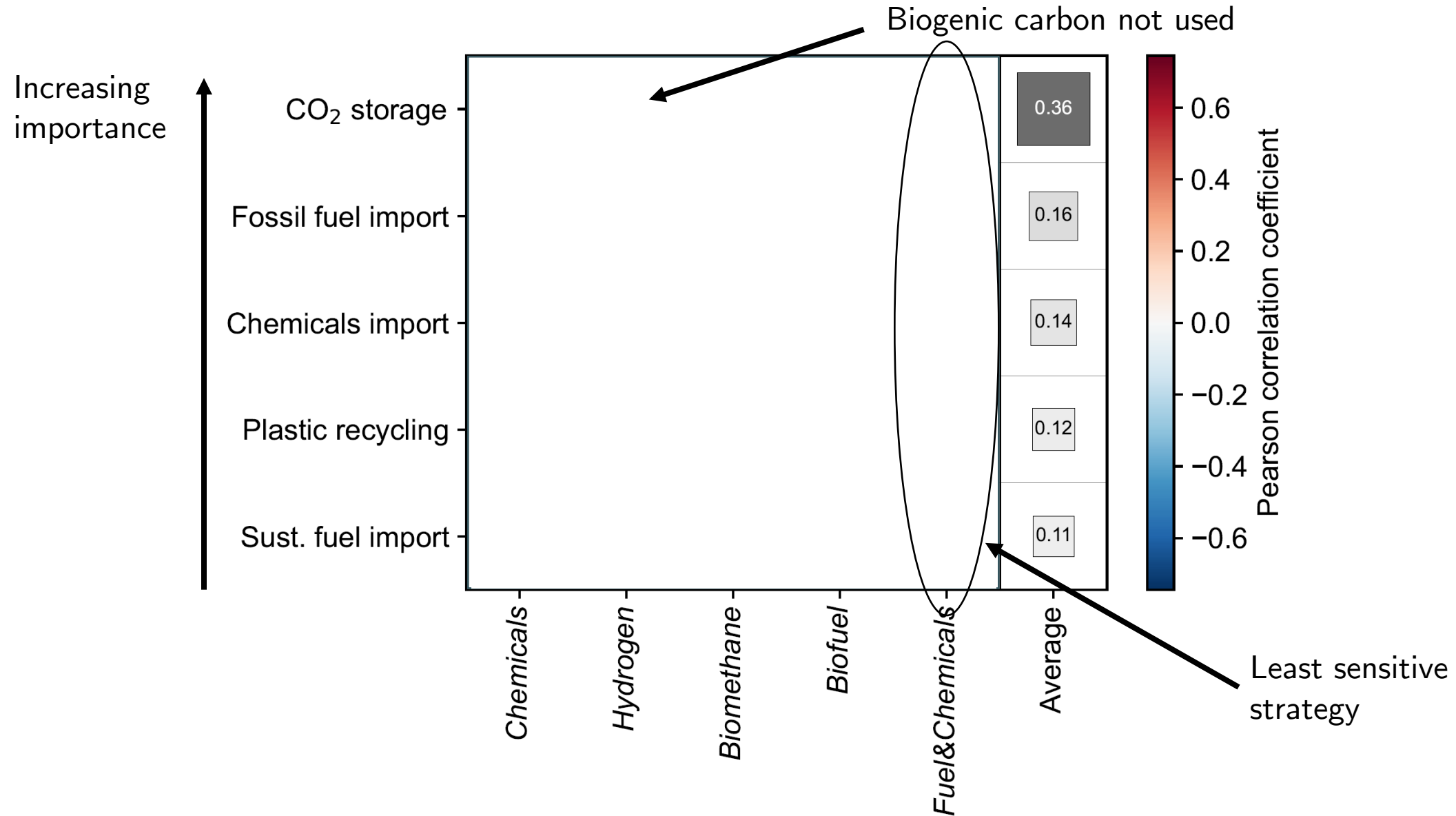


Biomass is valuable to the energy system

ing homes with
mass is a “must-avoid”



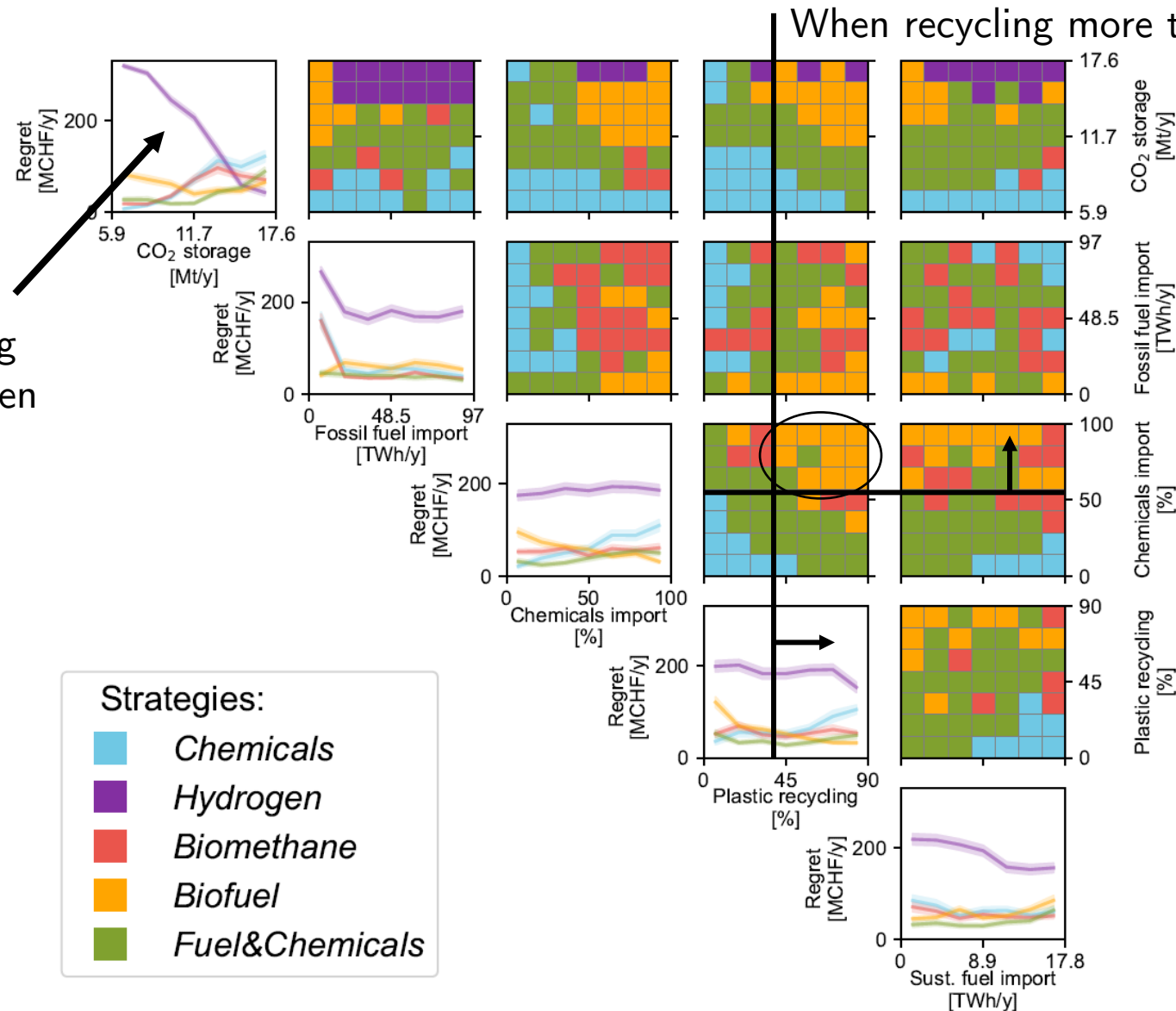
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Which strategy will I regret the least if the future turns out differently than I expect?

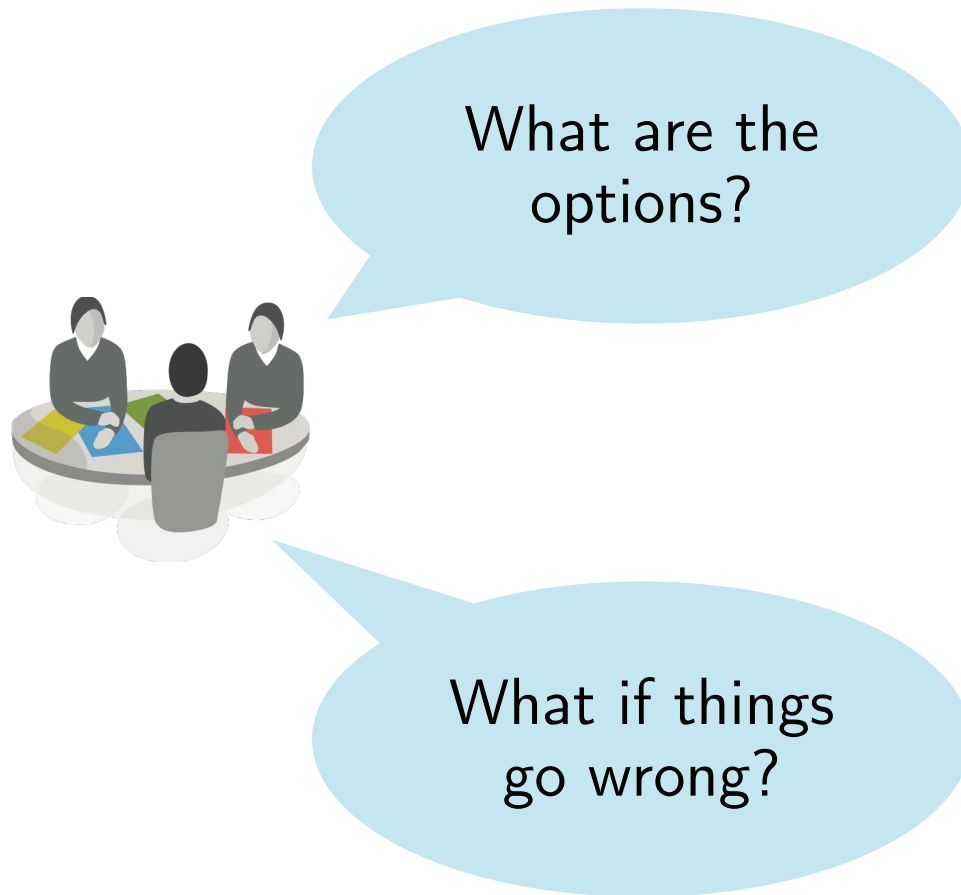
The regret of producing Hydrogen increases when CO₂ storage is limited



... and allow to import more than 60% of Chemicals ...

... then producing Biofuel is the lowest regret strategy

Summary and key references



Paper:

Baader et al., *Streamlining Energy Transition Scenarios to Key Policy Decisions*, arxiv, 2023
(coming soon an extended version: "Seeing the Forest for the Scenarios: Using Decision Trees to Draw Conclusions from Large Energy Scenario Sets")

Code:

<https://gitlab.ethz.ch/epse/systems-design-public/decide>

Paper:

G. Wiest et al., *Low-regret Strategies for Energy Systems Planning in a Highly Uncertain Future*, Cell Reports Sustainability, 2026

Code:

<https://gitlab.ethz.ch/epse/systems-design-public/low-regret-strategies/>

Thank you! Questions?

Stefano Moret

Associate Professor

Department of Management, Economics and Industrial Engineering | Politecnico di Milano

PRISMA summer school on uncertainty in energy and integrated assessment models of climate change
Geneva, June 15-19 2026

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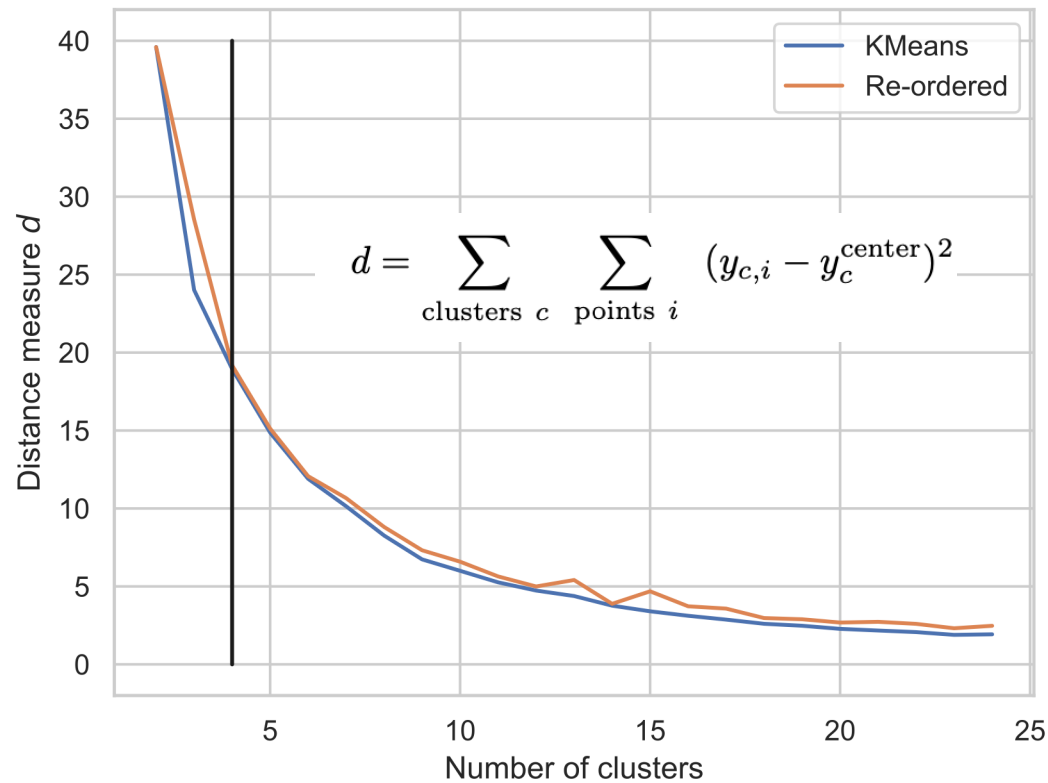
Annex



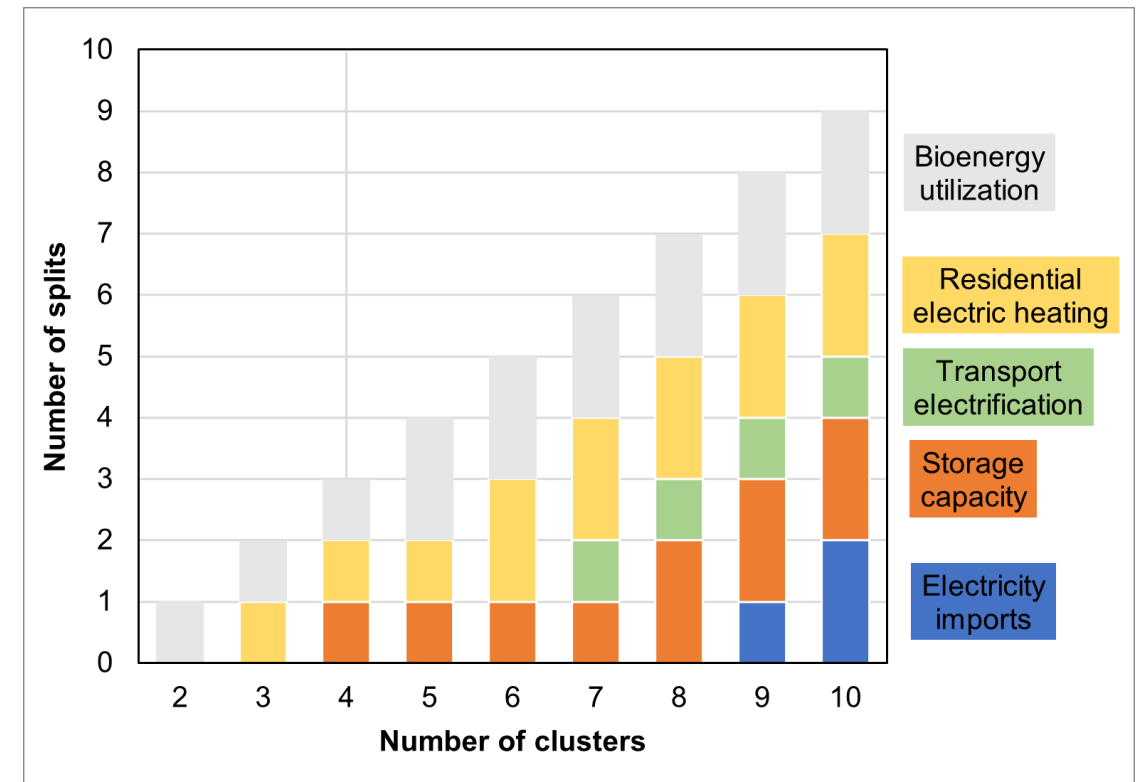
How can we streamline hundreds of scenarios into interpretable options?

Choosing k

1. “Elbow” method



2. Number of “splits”



$k = 4$



How can we streamline hundreds of scenarios into interpretable options?

Choosing the outputs of interest

