Beyond Optimal Cost in Energy Models

Brief summary of the suggested readings

Beyond Optimal Cost in Energy Models

- **Energy Modelling**
- **Energy System Optimization Models (ESOMs)**
- **Modelling to Generate Alternatives (MGA)**
- **SPORES**

Energy Modelling

- **Energy System Models**

Primary Energy → Process Chain → Final Energy

- **Purpose:**

Prediction, Exploratory, Backcasting

- **Analytic Approach:**

Bottom-up, Top-down, Hybrid

- **Methodology**

Optimization, Simulation, Econometric, …

Energy System Optimization Models

Energy trilemma

1. Affordability
2. Environmental Goals
3. Energy Security

Energy System Optimization Models

Main Challenges:

1. Improving temporal resolution
2. Enhancing the spatial resolution
3. Increasing sector disaggregation
4. Uncertainty quantification
5. Transparency
6. Addressing increasing complexity of future energy systems
7. Integration of human behavior & social aspects
8. Capturing features for developing countries
9. Data quality & availability
10. Projection of technology costs, performance, and weather data

Energy System Optimization Models

Guiding Principles for ESOM-based Analysis:

1. Let the problem drive the analysis
2. Make the analysis as simple as possible, and as complex as necessary
3. Apply quality assurance procedures to the input data
4. Consider the range of sectoral detail across the model
5. Re-evaluate the modelling approach & objectives during the analysis
6. Consider endogenous & exogenous uncertainties
7. Make transparency a goal of model-based analysis

Energy System Optimization Models

Uncertainties:

1. Structural
2. Parametric

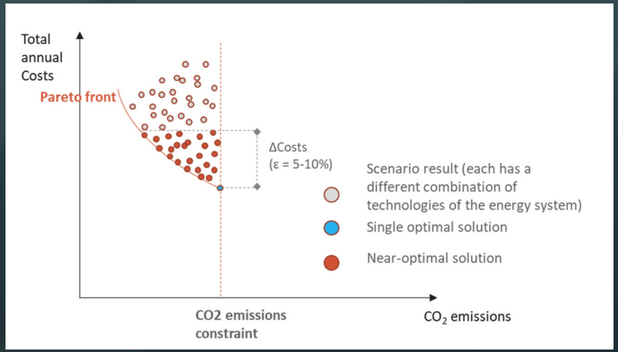
Policymakers may choose a more costly or environmentally damaging solution due to political, socio-economic, or environmental reasons.

Therefore, ideal solution is more likely to be located within the **model's inferior region** rather than at a **single optimal point**.

The near-optimal region should be explored.

Modelling to Generate Alternatives

Forcing an optimization model to search the feasible, near-optimal region for alternative solutions that are maximally different in decision space.



1. Starting point = The optimal solution
2. Adding an amount of slack to the value of the objective function
3. Formulate a new objective function that minimizes the weighted sum of decision variables that appeared in the previous solutions
4. Iterate the re-formulated optimization
5. Terminate the procedure when the changes between solutions become negligible

Modelling to Generate Alternatives

Outcome?

SPORES: Spatially explicit, practically optimal results

A set of solutions that perform well with regard to modeled objectives, but may be very different in decision space. This difference could be in the technology type, or the distribution of the technology in the region.

The ability to automatically generate a set of feasible alternative solutions provides valuable insight at modest computational cost, without the need to further constrain the model.

SPORES

Insights?

1. Providing a set of plausible alternatives
2. Generating a decision space, one can navigate around
3. Assessing which technology options appear to be the most robust across different scenarios
4. Wide variability across scenarios –no single technology is indispensible in all circumstances

SPORES

Sensitivity to different characteristics of scenarios

1. Weather data
2. Future demand
3. Cost fluctuations

Hence, an overcapacity of renewables & storage, with a preference for local instead of long-distance generation, is suggested.

SPORES

Cluster Analysis

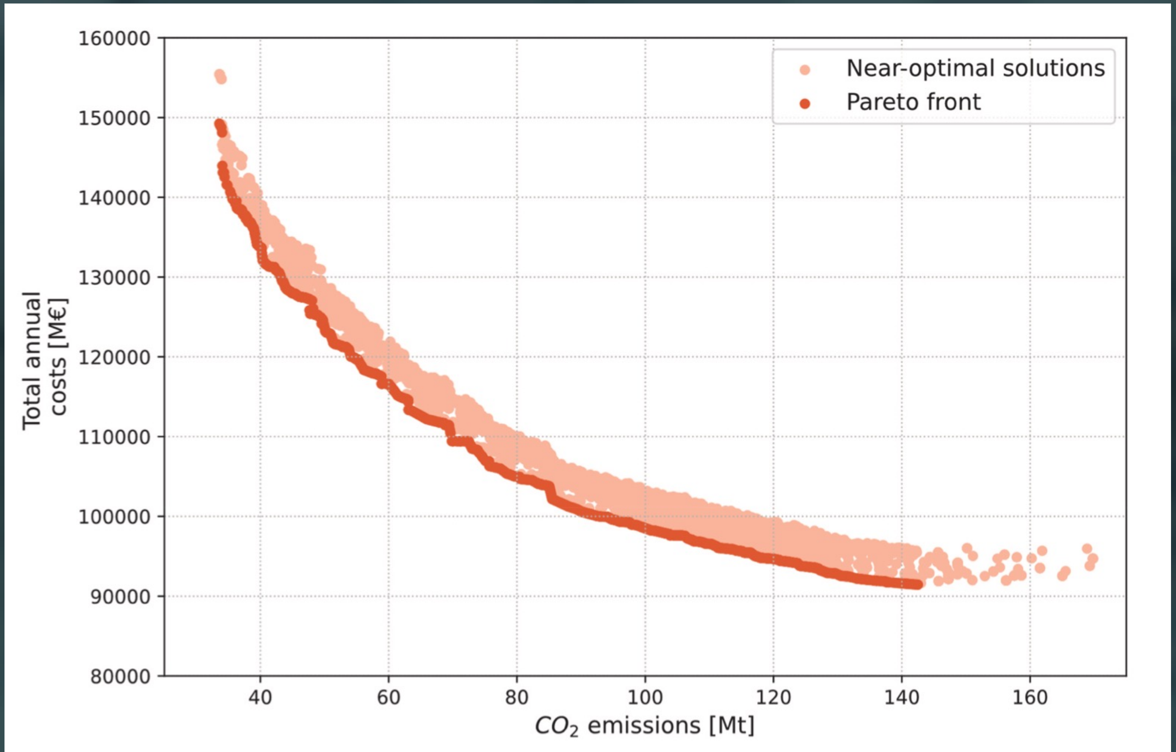
Identification of groups of similar solutions in the near-optimal space.

One scenario in each cluster is selected to represent the cluster. (the closest to the centroid criterion)

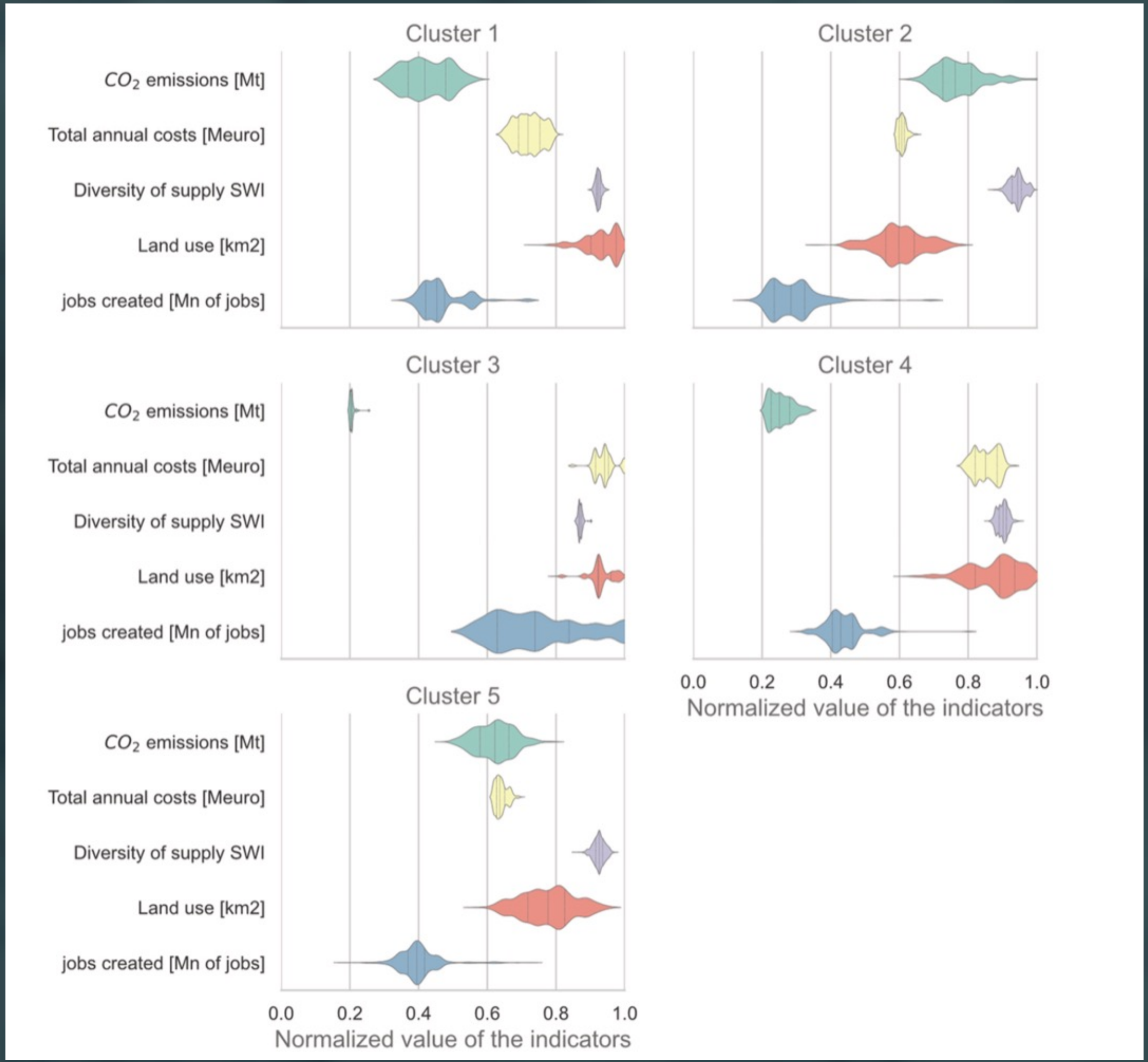
Methods:

1. K-Means Method
2. Elbow Method
3. Silhouette Score

SPORES

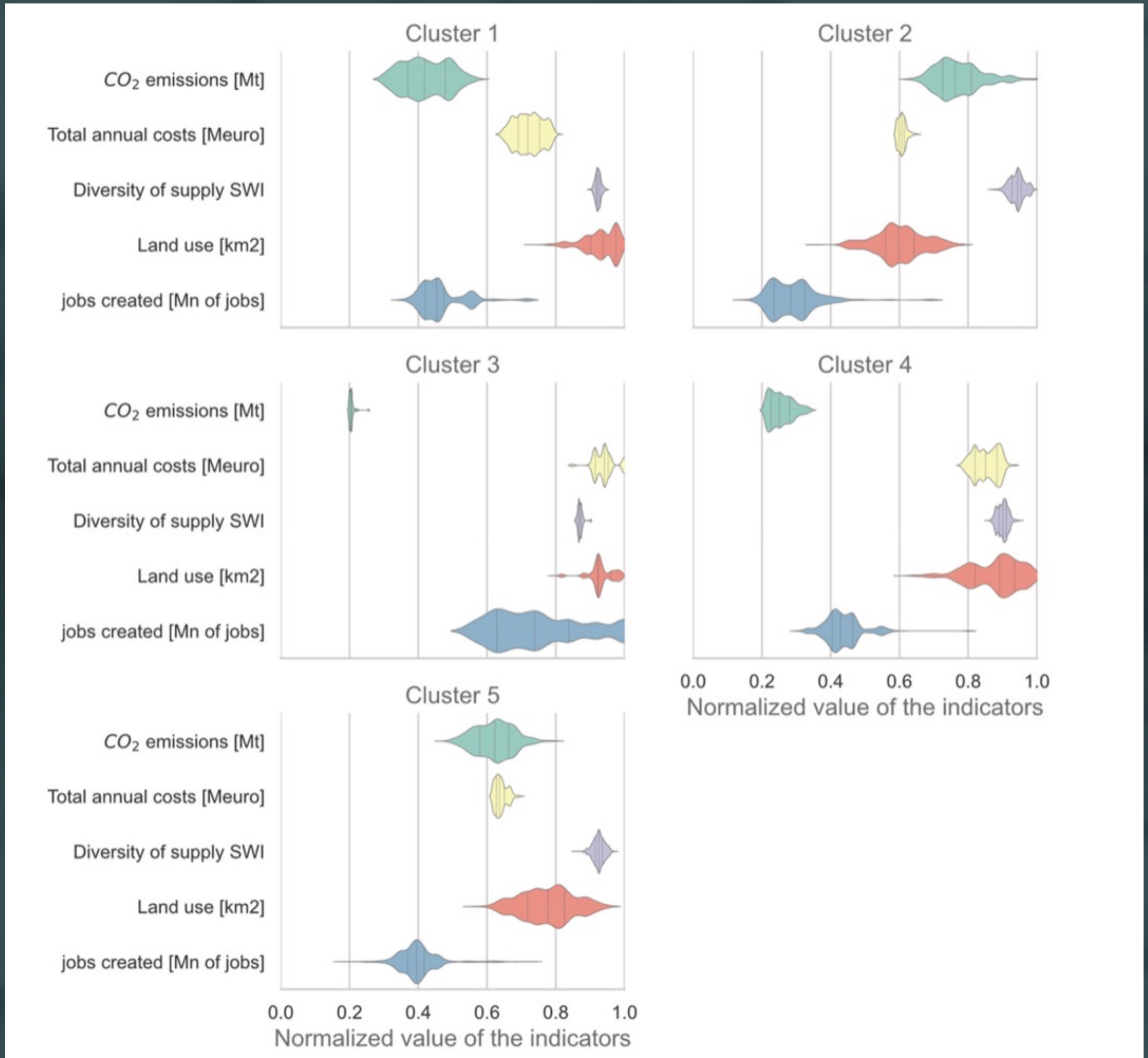


Near-optimal solutions
Pareto front
Total annual costs [M€]
160000
150000
140000
130000
120000
110000
100000
90000
80000
40
60
80
100
120
140
160
CO_2 emissions [Mt]



Cluster 1
Cluster 2
Cluster 3
Cluster 4
Cluster 5
CO_2 emissions [Mt]
Total annual costs [Meuro]
Diversity of supply SWI
Land use [km2]
jobs created [Mn of jobs]
0.0
0.2
0.4
0.6
0.8
1.0
Normalized value of the indicators

SPORES



Trade-offs

Policymakers can prioritize different objectives depending on their policy goals & constraints.

SPORES

Limitations?

The number of meaningful alternatives is infinite, and the conventional form of MGA fails to represent the range of available options well.

Configurations with very low or very high shares of a particular technology in the overal capacity mix (near the corners of the multi-dimensional decision space) are left unexplored.

Hybrid search

The main batch of spores = “evolving-average method”

Parallel batches of spores = “relative-deployment method”

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