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InNOSys

# Assessing the sustainability of German energy transition scenarios using multi-criteria decision analysis

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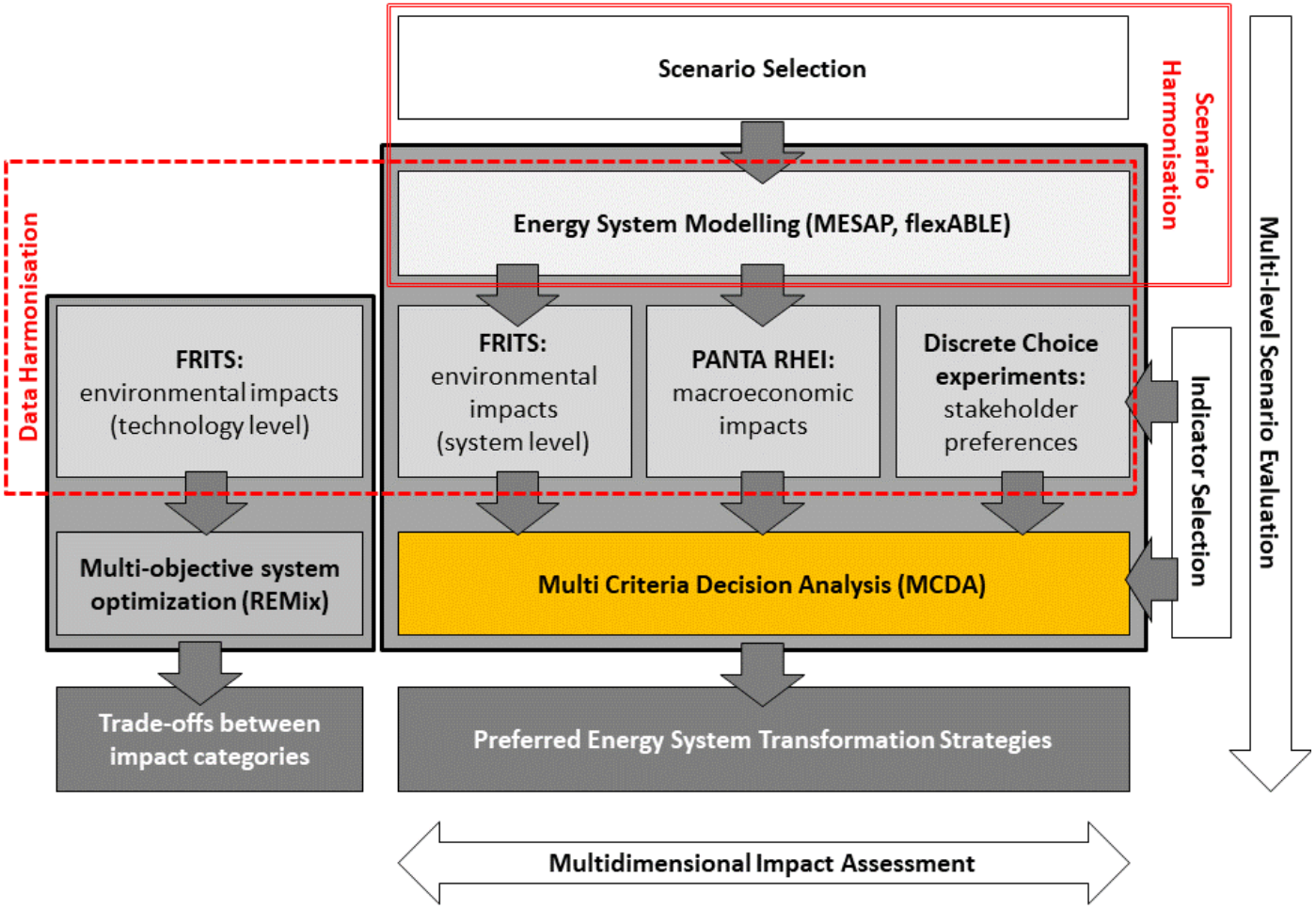
# Project structure and workflow – Step 7

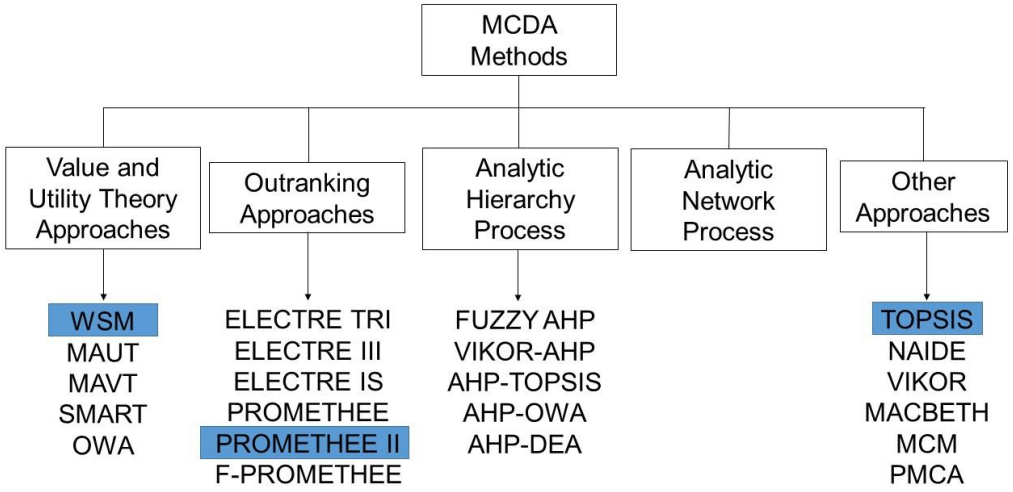


# Agenda

- Multi-criteria decision analysis (MCDA) methods and adjustments
- Results and analysis MCDA
  - for indicator set from discrete choice experiment (DCE)
  - for entire indicator set
- Sensitivity analysis
- Results analysis
- Conclusions
- Discussion

# Methods

- Each MCDA method is specific
- Applying several methods...
  - … provides more information
  - … increases reliability and confidence in the results
- Methods applied here:
  - Weighted Sum Method (WSM)
  - PROMETHEE
  - TOPSIS




[Greco et al., 2016]

# Weighted sum method (WSM)

- Sum of normalized and weighted alternative scores
- Min-max normalization

$$A_i = \sum_{j=1}^{n} w_j * a_{ij}$$

$A_i$: WSM score of alternative $i$

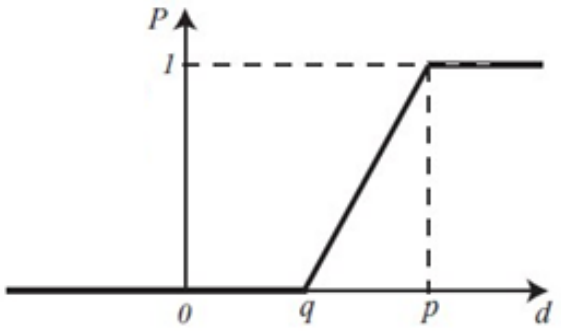
$w_j$: weight for criterion $j$

$a_{ij}$: normalized score of alternative $i$ for criterion $j$

# PROMETHEE

- PROMETHEE = Preference ranking organization method for enrichment evaluation
  - Pairwise score differences
  - Preference function: V-shape with preference threshold p and indifference threshold q

$$P(d) = \begin{cases} 0 & d \leq q \\ \frac{d-q}{p-q} & q < d \leq p \\ 1 & d > p \end{cases}$$




- PROMETHEE II:
  - Net outranking flows (highest = best)

# TOPSIS

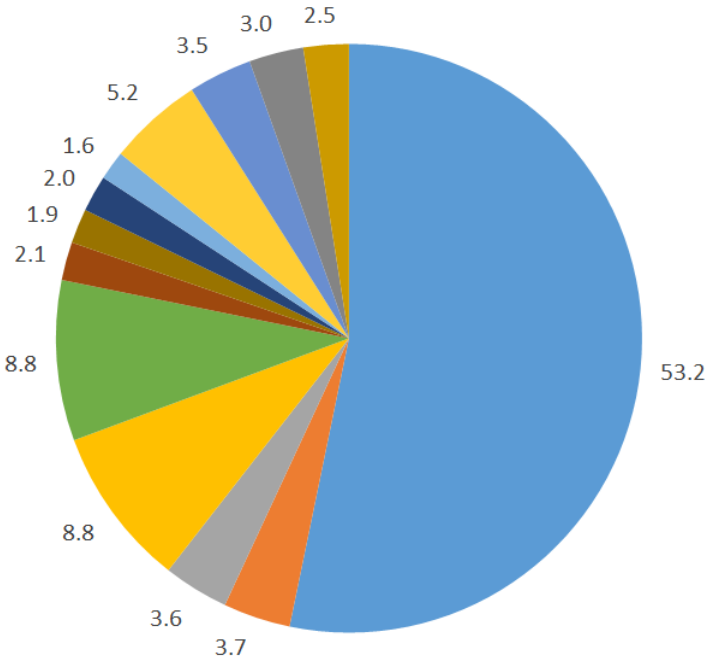
- TOPSIS = Technique of order preference by similarity to ideal solution
- Procedure
  - (Vector) normalization and weighting of the decision matrix
  - Determination of the ideal solution (positive and negative)
  - Calculation of the relative closeness coefficient
  - Best alternative is close to the positive-ideal solution and far from the negative-ideal solution

# Attribute properties

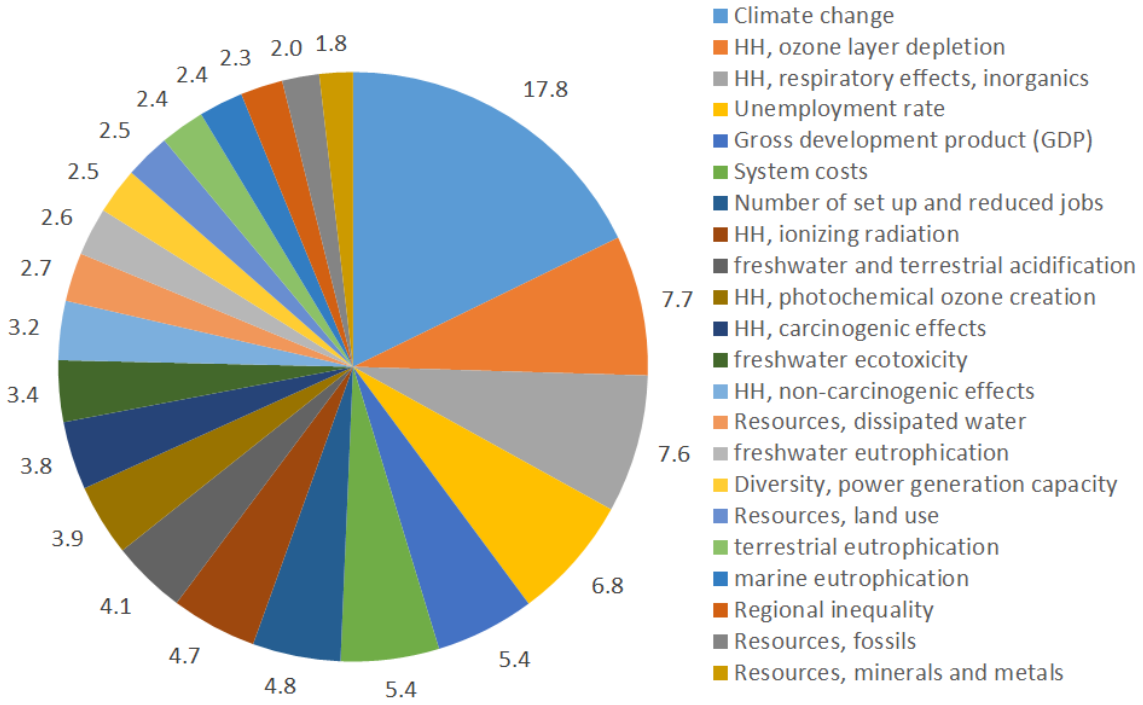
- Impact assessment delivers annual values
- Environmental indicators and system costs cumulative values from 2021-2050
  - Occur over the whole transformation period
- Socio-economic and socio-technical indicators for 2050
  - State in target year is decisive

# Weighting sets

## DCE indicator set

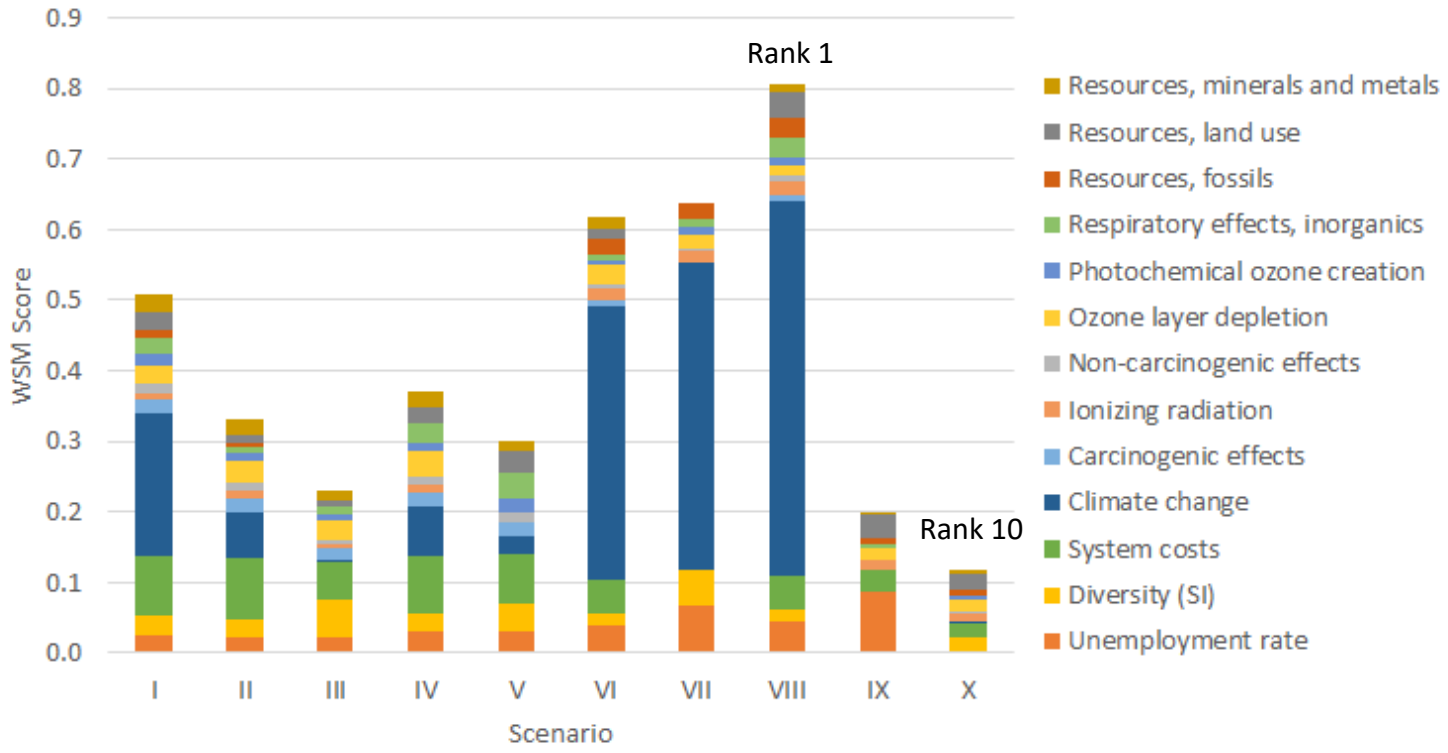



## Entire indicator set




Weights (%)

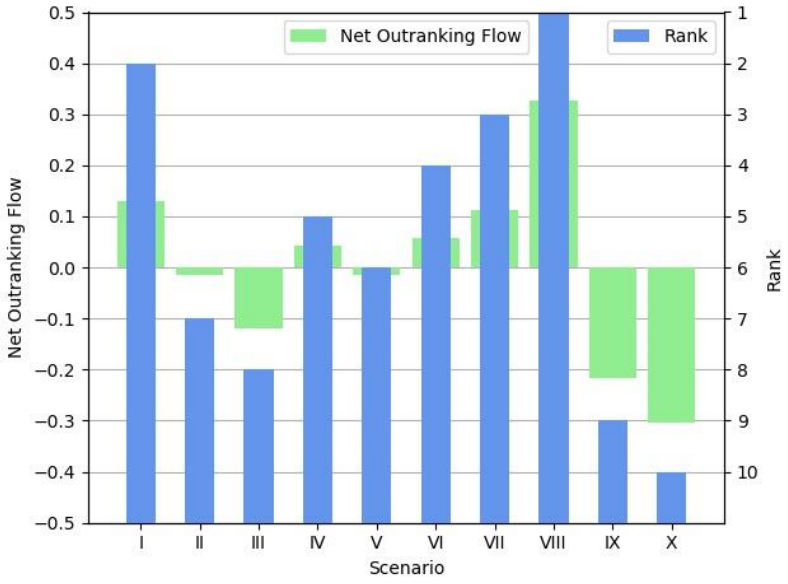
# Results and analysis WSM – DCE indicator set



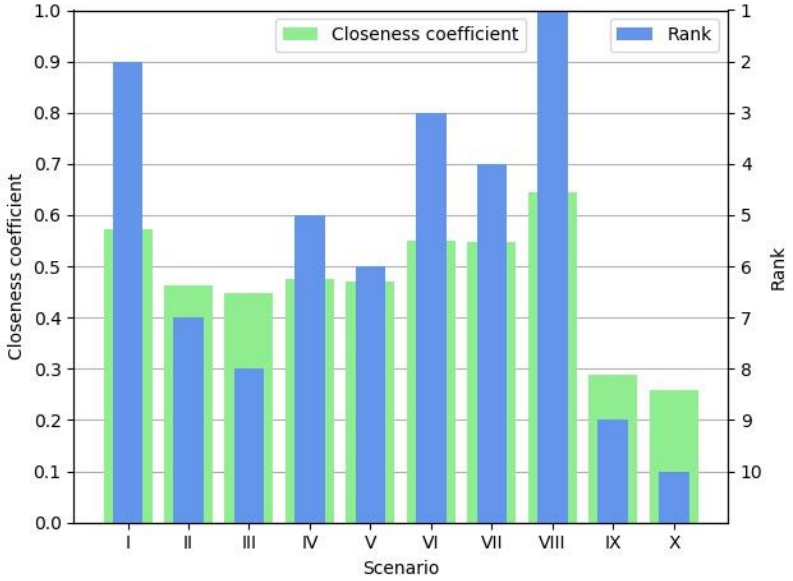

- Some scores are very close
- Climate change dominates clearly
- Non-environmental indicators add up to nearly the same

# Results DCE indicator set

## PROMETHEE

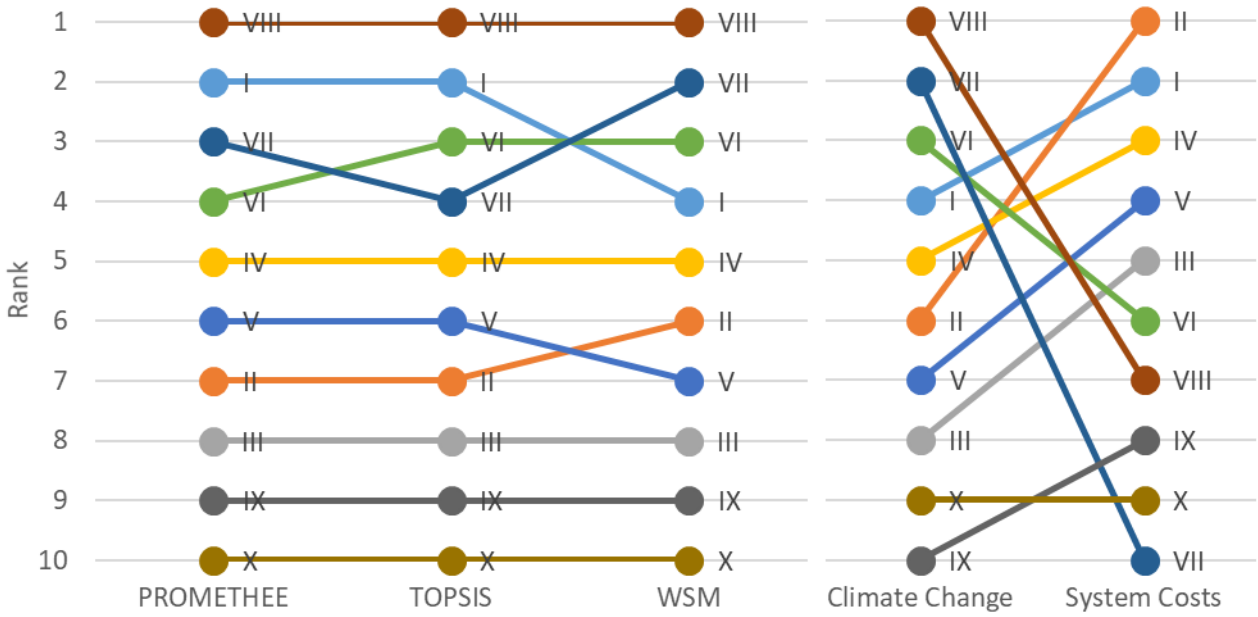



## TOPSIS

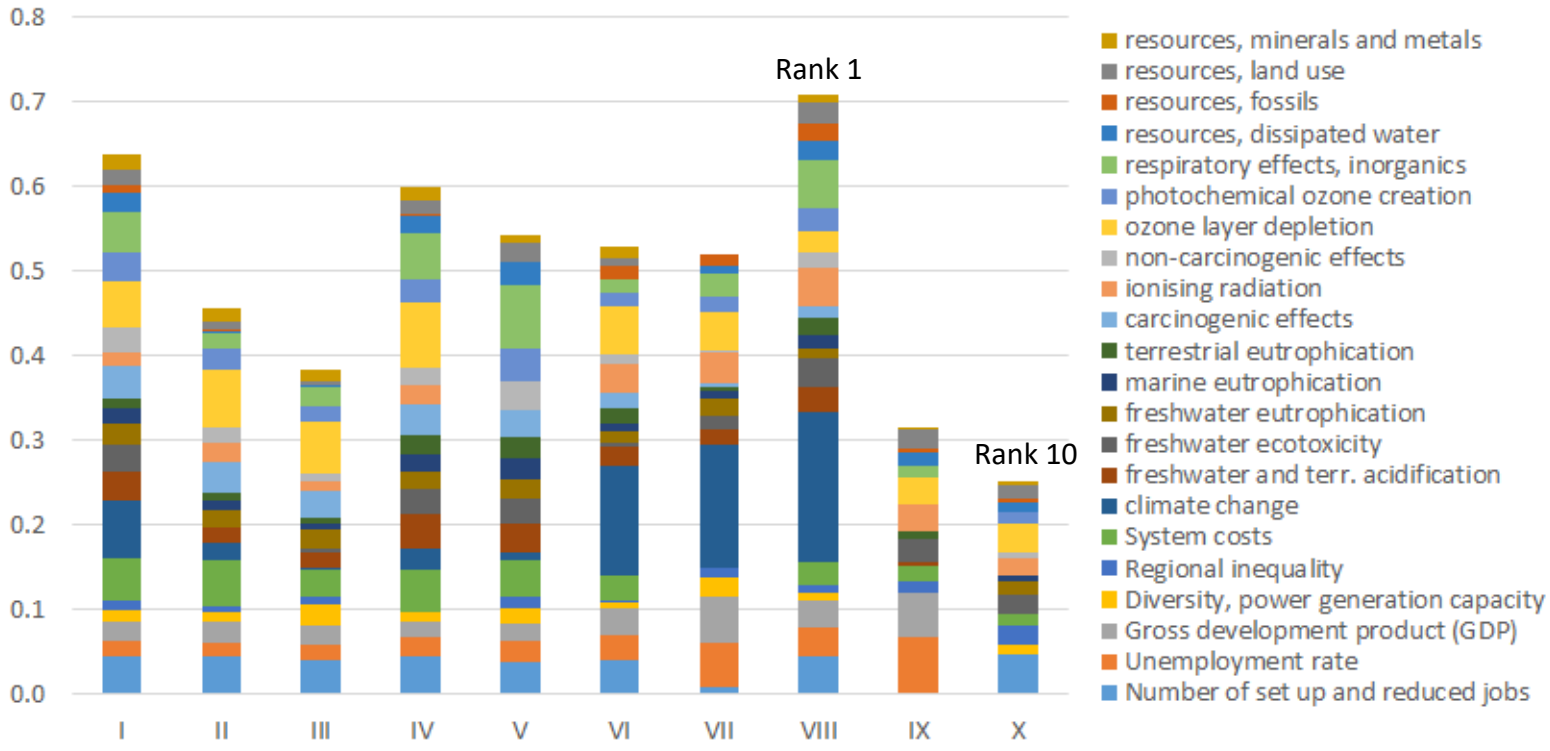


# Comparison results DCE indicator set

- Rank 1, 5, 8, 9 and 10 stable
- PROMETHEE and TOPSIS only one rank reversal
- More rank changes for WSM
- CC ranking very close to WSM
- Costs very different



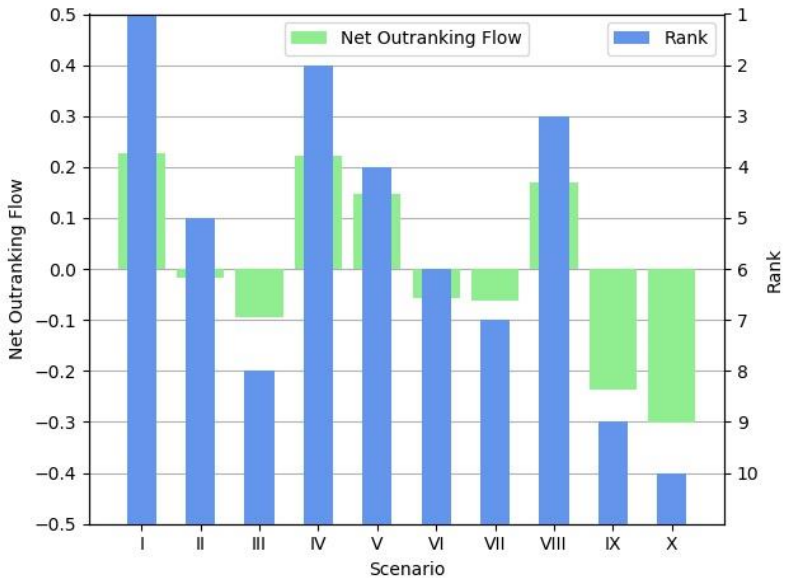
# Results and analysis WSM – Entire indicator set



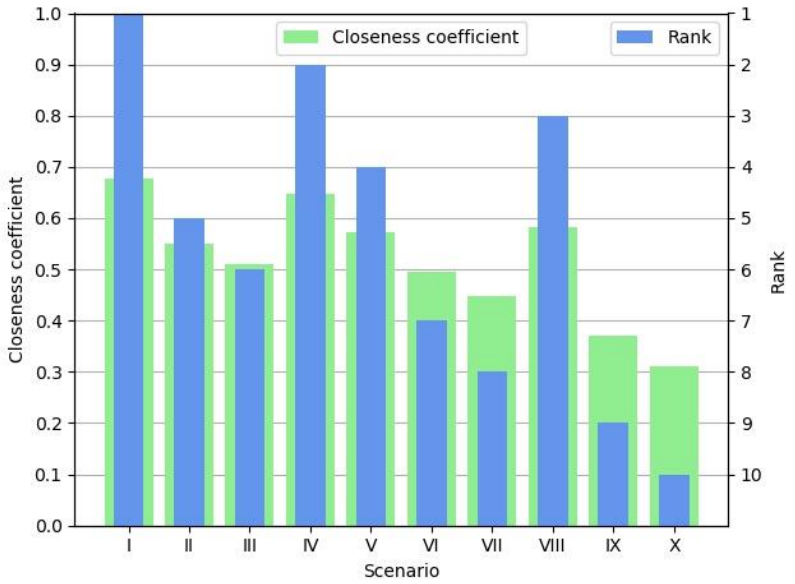

- Some scores are very close
- Decisive indicators: climate change, ozone layer depletion, system costs, respiratory effects

# Results entire indicator set

## PROMETHEE

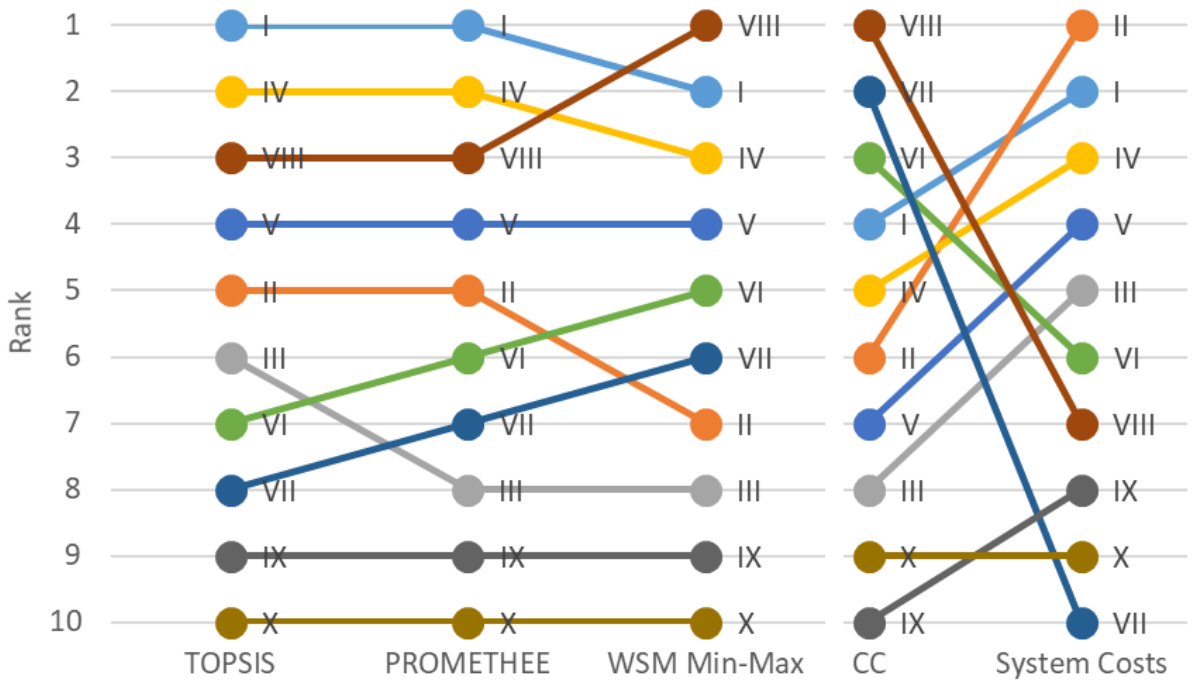



## TOPSIS

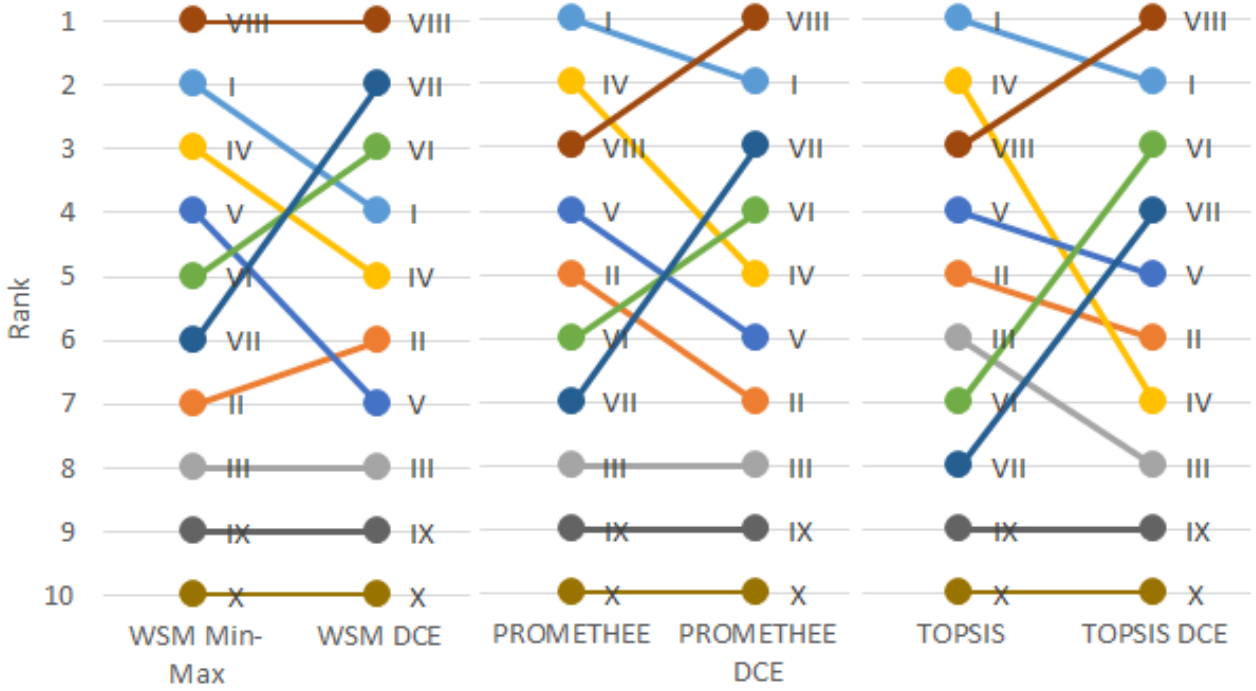


# Comparison results entire indicator set

- Rank 4, 9 and 10 stable
- PROMETHEE and TOPSIS only three rank differences
- More rank changes for WSM
- Low correlation to climate change and system costs ranking



# Comparison entire and DCE indicator set




- Except last ranks strong rank changes

# Sensitivity analyses

- For environmental indicators: comparison to Environmental Footprint, TOPSIS vs. NR-TOPSIS
- Variation normalization for WSM and TOPSIS
- Variation p values for PROMETHEE
- Variation weights for DCE indicator set

# Results over all sensitivities

- Scenario VIII or I mostly rank 1, at least 4
- Scenario IX and X always rank 9 or 10, most stable
- Scenarios VI and VII most unstable between rank two and seven or eight, respectively
- 80 % reduction scenarios as well as 95 % reduction scenario can achieve top rank
- 95 % scenarios do not necessarily perform better
- Between PROMETHEE and TOPSIS fewer rank changes than between P/T and WSM

# Conclusions

- Application of MCDA shows at least tendency for more or less sustainable scenarios
- Application of more than one method meaningful, unambiguity does not hold up
- Ranking: Evaluation via absolute values (closeness coefficient, weighted sum...) also meaningful
- Weighting has strong influence, but also other settings to be defined by modelers
- Sufficient stakeholder involvement in the weighting poses a problem due to large number and high complexity of criteria
- Decisive criteria vary depending on method
- No leading indicator can be identified at least for the entire indicator set
- Climate change and costs are important, but not the only decisive factors

# We look forward to the following discussion

Deutsches Zentrum für Luft- und Raumfahrt
German Aerospace Center

GWS SPECIALISTS IN EMPIRICAL ECONOMIC RESEARCH

INATECH DEPARTMENT OF SUSTAINABLE SYSTEMS ENGINEERING

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