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Ingela Tietze
Heidi Hottenroth
Tobias Viere

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Sustainability analyses of the German energy transition using TOPSIS

Project InNOSys - Integrated sustainability assessment and optimization of energy systems

- Main objectives
  - development of a new generic modelling and assessment approach for energy scenarios
  - multicriteria assessment and optimisation of technically and structurally feasible development pathways of the energy system in Germany
- Funded by Federal Ministry of Economic Affairs and Energy
- 2018 - 2021

Deutsches Zentrum für Luft- und Raumfahrt
German Aerospace Center

GWS SPECIALISTS IN EMPIRICAL ECONOMIC RESEARCH

INATECH DEPARTMENT OF SUSTAINABLE SYSTEMS ENGINEERING

Supported by:

Federal Ministry for Economic Affairs and Energy

on the basis of a decision by the German Bundestag

INEC INSTITUTE FOR INDUSTRIAL ECOLOGY PFORZHEIM

ITAS Institute for Technology Assessment and Systems Analysis

zirius Center for Interdisciplinary Risk and Innovation Studies

Decarbonisation implies manifold changes to the German energy sector

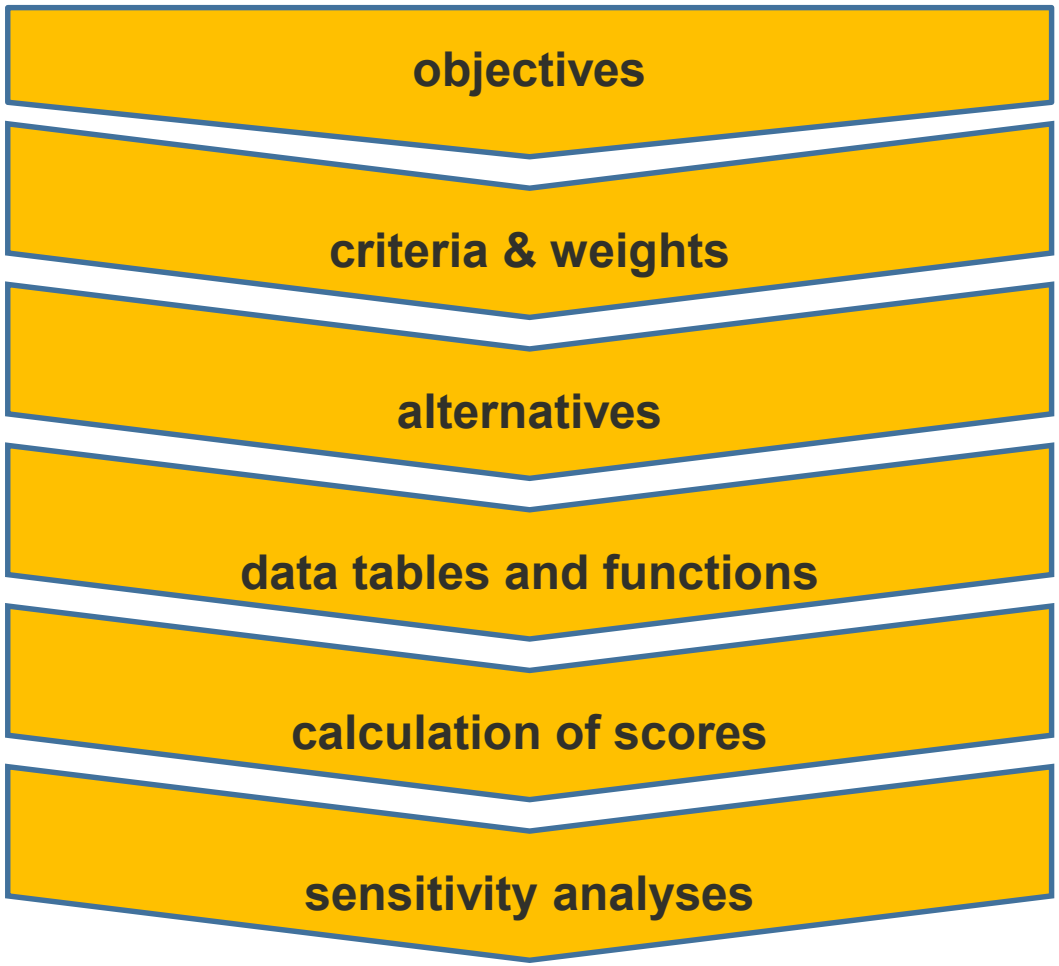
- Different pathways to decarbonisation
  - Several research institutes calculated scenarios (e.g. Lutz et al. 2018; dena 2018; Pfluger et al. 2017)
  - Similar main assumptions, but different results in terms of final energy demand of the sectors, storage needs and utilisation of individual technologies

  ⇒ Different overall impacts
- Sustainability as umbrella concept for desirable future development
  - Comprehensive sustainability indicator set for energy transition developed by Rösch et al. 2017
  - Identification of interdependencies and conflicting targets
  - Different units of measurement

  ⇒ Which scenario is best?

Multi-attributive decision making (MADM)

- Structuring decision making process to identify best of given alternatives
- Compromise between conflicting targets
- Different methods, e.g.
  - AHP
  - PROMETHEE
  - TOPSIS
  - …



Dias et al. 2019

TOPSIS
Technique of order preference by similarity to ideal solution

- Originally introduced by Hwang and Yoon 1981
- Assesses alternatives in comparison to best and worst performance within each criterion
- Procedure
  (1) normalizing the initial decision matrix
  (2) weighting the normalized decision matrix
  (3) determining the ideal solutions (positive and negative)
  (4) calculating the relative closeness coefficient
- Ranking of alternatives according to the closeness coefficient

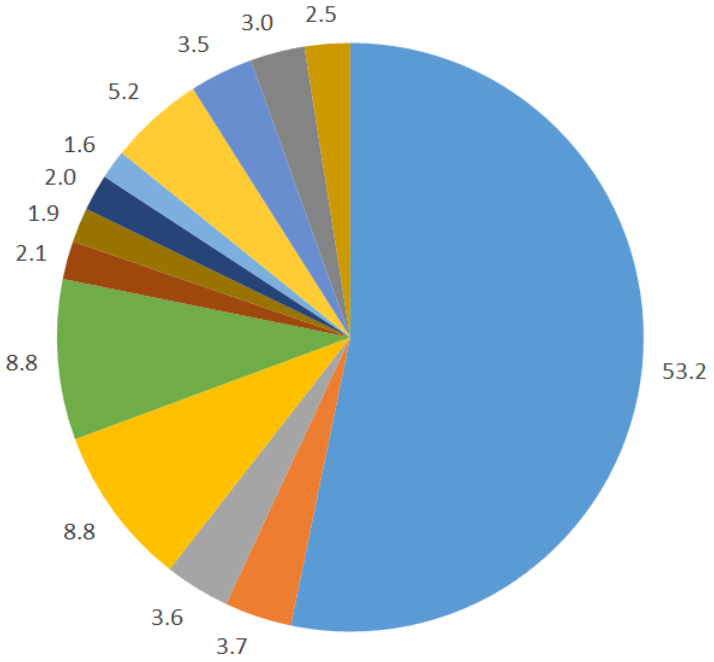
Applying TOPSIS: objectives & criteria

Category	Indicator	Calculation method	Critería subset for DCE
Climate change	Climate change	Life cycle approach	X
Ecosystem quality	Freshwater and terrestrial acidification		
	Freshwater ecotoxicity		
	Freshwater eutrophication		
	Marine eutrophication		
	Terrestrial eutrophication		
Human health	Carcinogenic effects		X
	Ionizing radiation		X
	Non-carcinogenic effects		X
	Ozone layer depletion		X
	Photochemical ozone creation		X
	Respiratory effects, inorganics		X
Resources	Dissipated water		
	Fossils		X
	Land use		X
	Minerals and metals		X
Socio-economic	System costs	other	X
	Number of set up and reduced jobs	Macroeconomic assessment	
	Regional inequality		
	Unemployment rate		X
Socio-technical	Diversity, power generation capacity	other	X

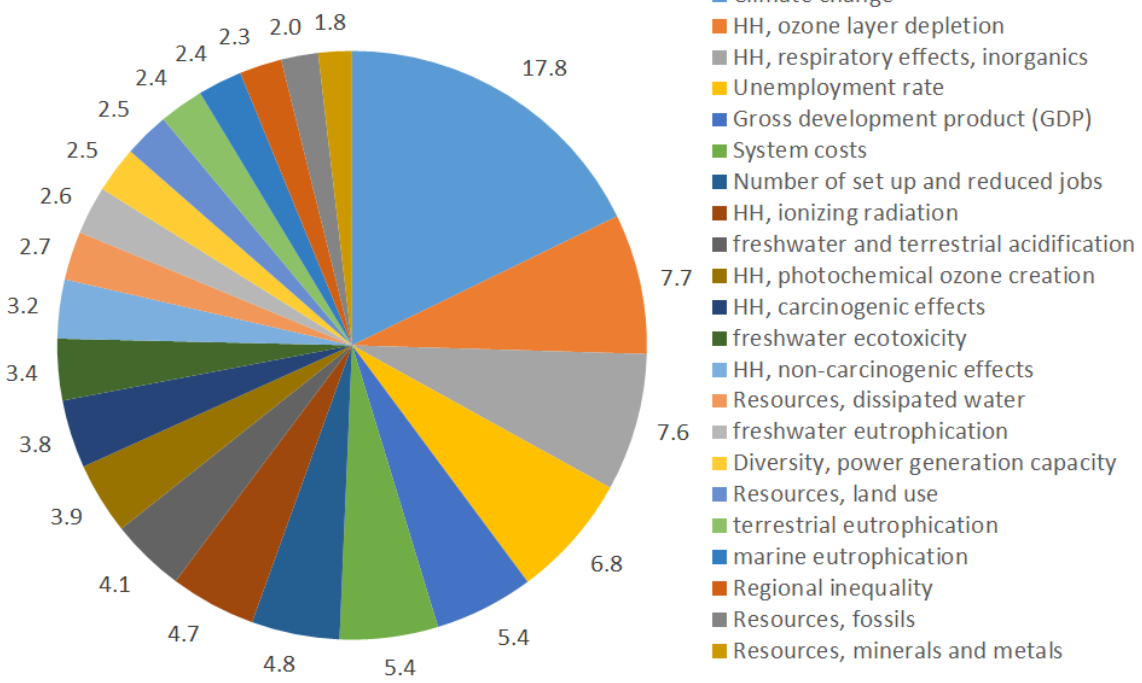
DCE = discrete choice experiment for elicitation of preferences

Applying TOPSIS: weights

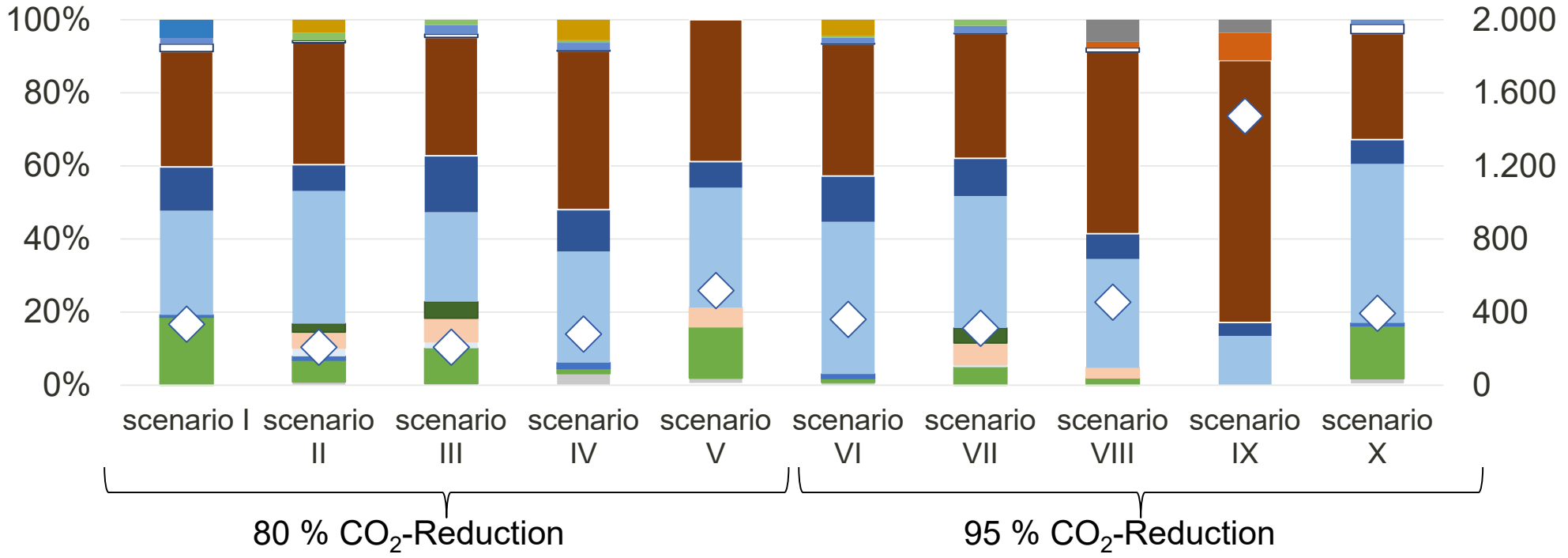
DCE indicator set



Entire indicator set

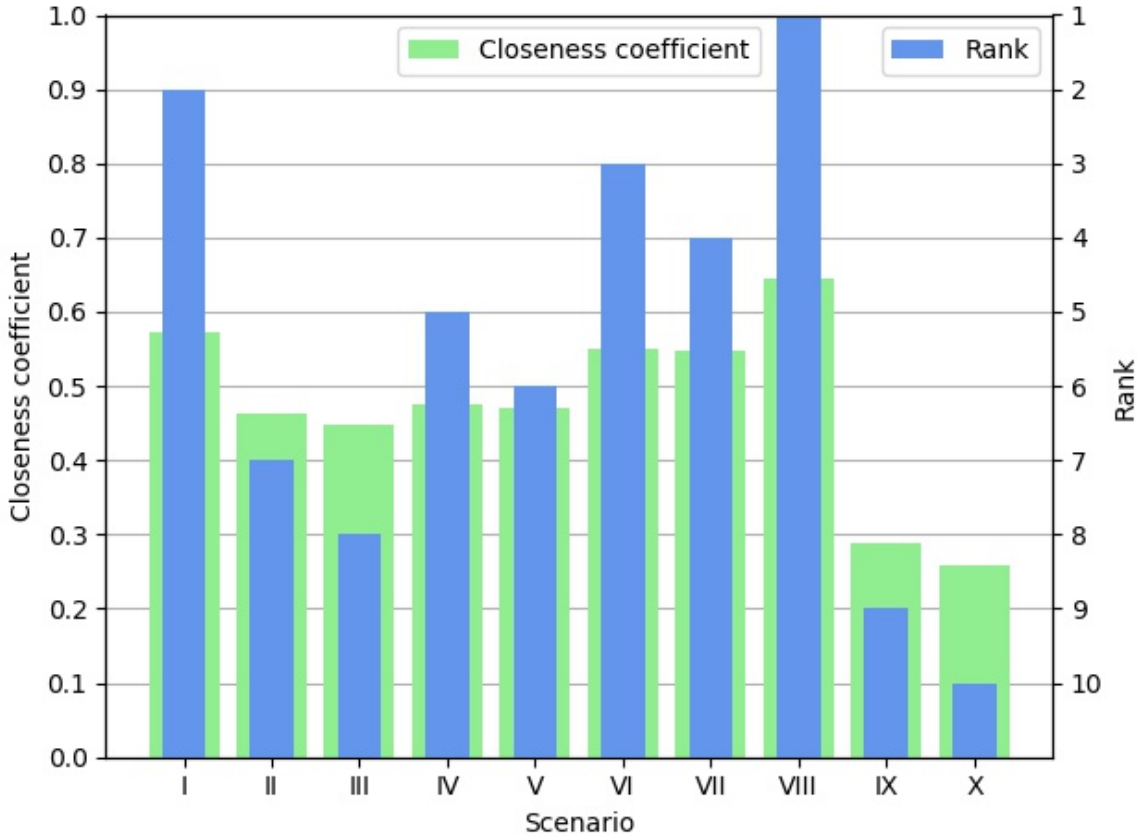


Applying TOPSIS: installed electrical capacity of alternatives in GW

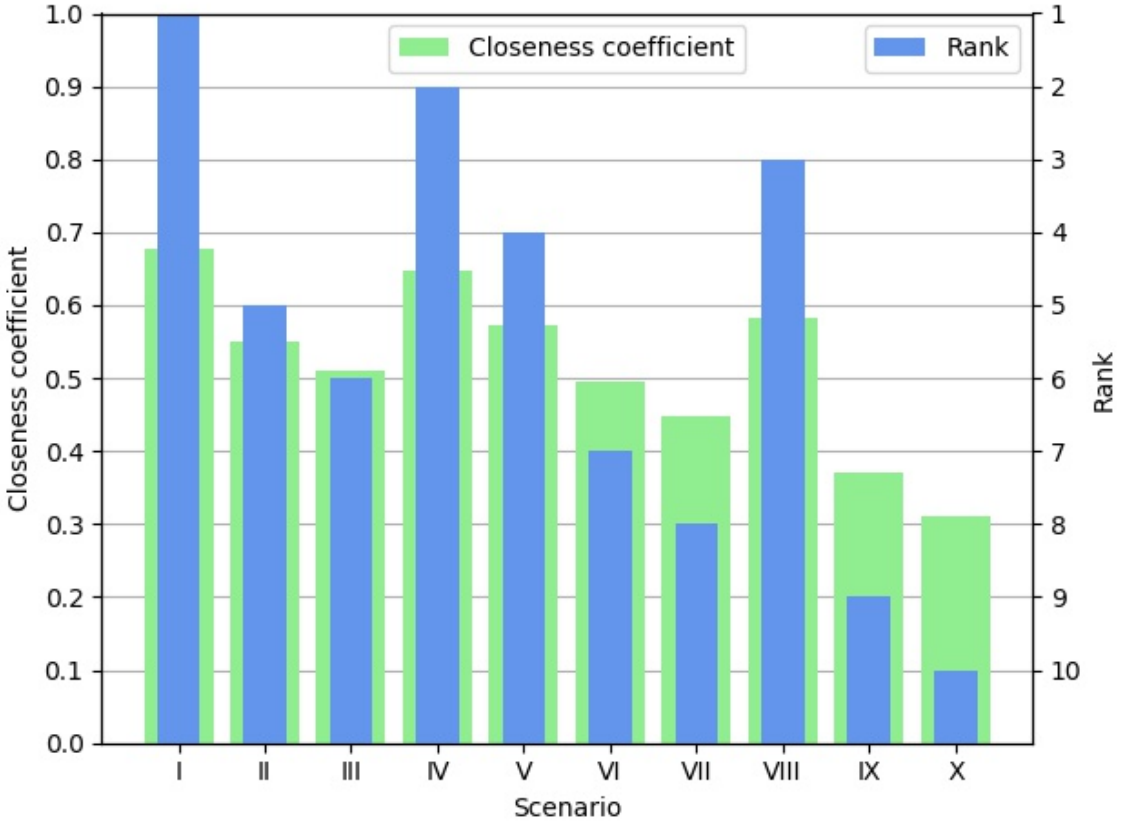


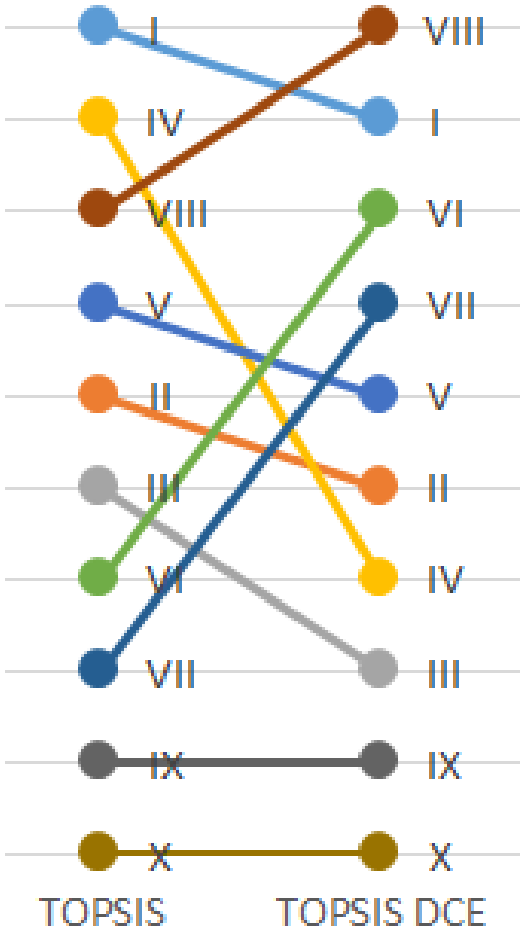
Calculated by DLR

TOPSIS results
DCE indicator set



TOPSIS results
entire indicator set & comparison





Conclusions & Outlook

- Conclusions
  - Application of TOPSIS shows at least tendency for more or less sustainable scenarios
  - Ranks ⇔ closeness coefficients
  - Strong influence of weights, but sufficient stakeholder involvement in the weighting poses a problem due to large number and high complexity of criteria
  - No leading indicator and technologies can be identified
  - 95% reduction scenarios as well as 80 % reduction scenarios can reach top ranks
- Outlook
  - Comparison with results of other MADM methods (PROMETHEE and Weigted Sum Method)
  - Principal Component Analysis to identify important indicators and technologies
  - Application of a TOPSIS variation (NR-TOPSIS according to Yang 2020) to implement a global normalization perspective

Thank you!

Prof. Dr. Ingela Tietze
Sustainable Energy Economics
Institute for Industrial Ecology, Hochschule Pforzheim, Tiefenbronner Str. 65, D-75175 Pforzheim
ingela.tietze@hs-pforzheim.de https://www.hs-pforzheim.de/en/research/research_institutes/inec/

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