Sustainable energy technologies? Conflicting targets and Multi-Criteria Decision Analysis

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Conflicting targets in sustainability assessment

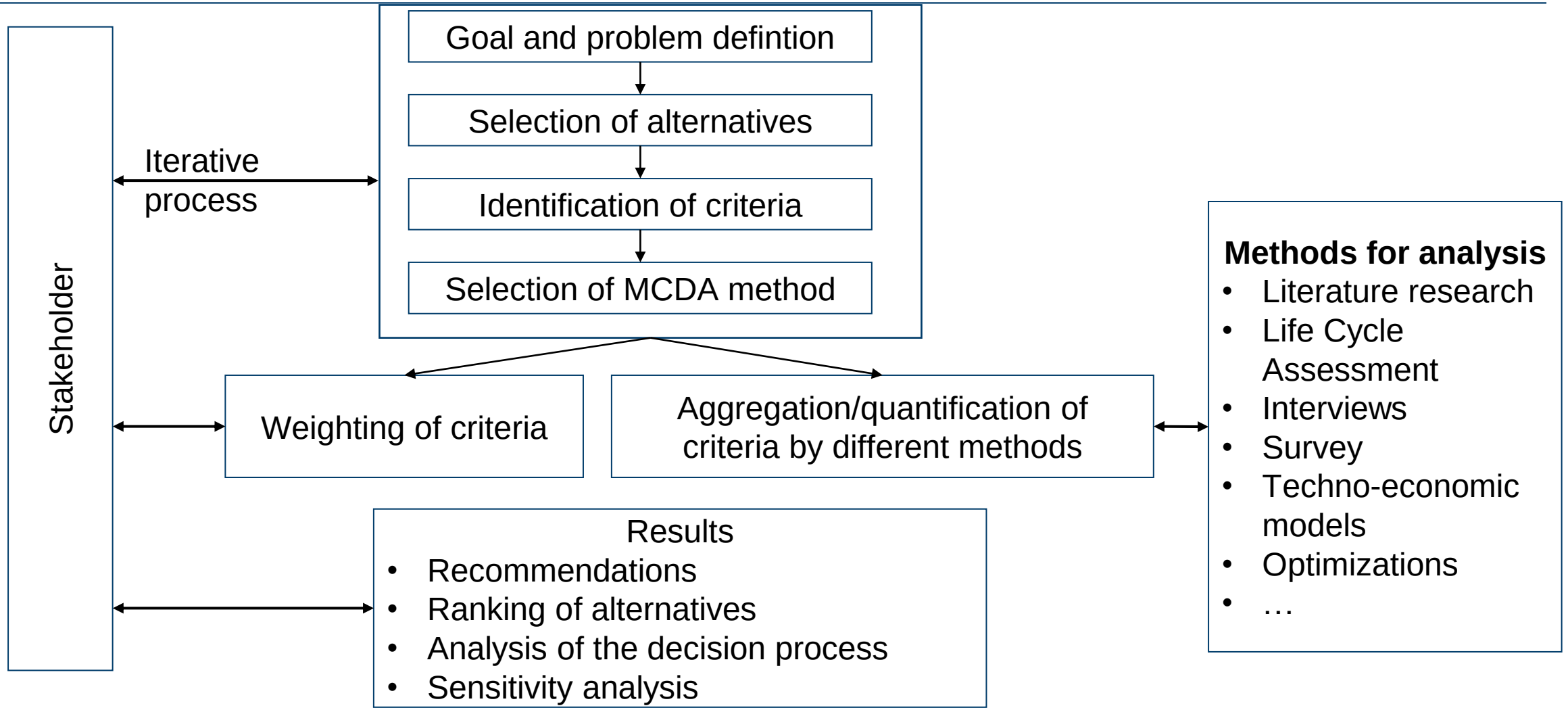
- Construction of LNG terminals in Germany
  - Diversification of energy supply → security of energy supply
  - Causes local environmental damage
  - High investment costs
- Electricity generation from wind power
  - Low greenhouse gas emissions
  - Local source of energy
  - Disturbance of residence through moving shadows and noise
  - Impact on birds and bats
  - Higher demand of metal resources

Source: Marco Sabadin/AFP

Comparing assessment

- Multi-Criteria Decision-Analysis (MCDA)
  - Mathematical methods for the assessment of alternatives (products, technologies, strategies etc.)
  - Guidance to find compromise in case of conflicting targets
  - Aggregation of single criteria to make a recommendation
- Simplest form: Weighted sum
- $A_{Sus} = \sum_{i=1}^{n} w_i * a_i$
  - w_i: weighting factor of criterion i
  - a_i: result of criterion i
  - A_{Sus}: Sustainability index

MCDA approach



Based on Haase, M., Baumann, M., Wulf, C., Rösch, C., Zapp, P., 2021. Multikriterielle Analysen zur Entscheidungsunterstützung in der Technikfolgenabschätzung, Nomos, Baden-Baden, pp. 306-320.

Selection of MCDA method

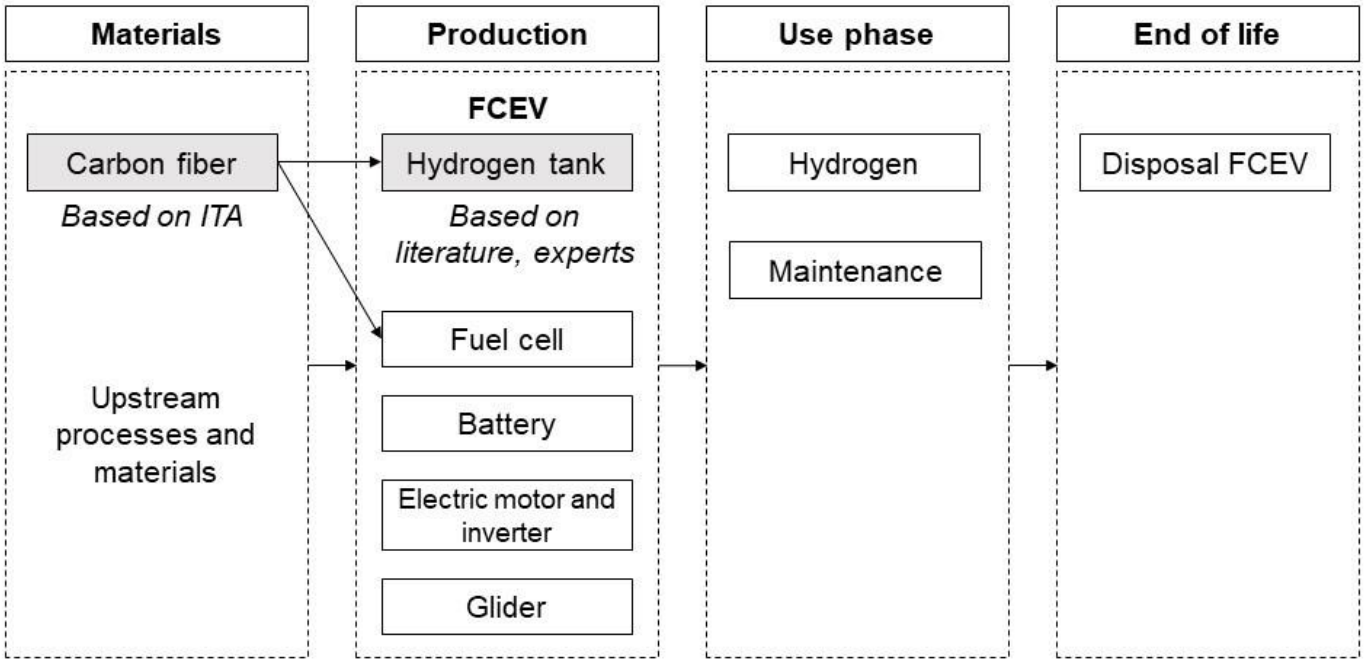
- Weighted sum
  - Indicator compensation
  - Easy to perform, comprehensible for outsiders
  - Additional normalization step is necessary
- TOPSIS - **T**echnique for **O**rder **P**reference by **S**imilarity to **I**deal **S**olution
  - Toned down compensation of indicators
  - More complex, but still illustrative
  - Problem: Rank reversal
- PROMETHEE - **P**reference **R**anking **O**rganisation **Meth**od for **E**nrichment **E**valuation
  - Outranking
  - Complex, results hard to understand for outsiders
  - Robust results

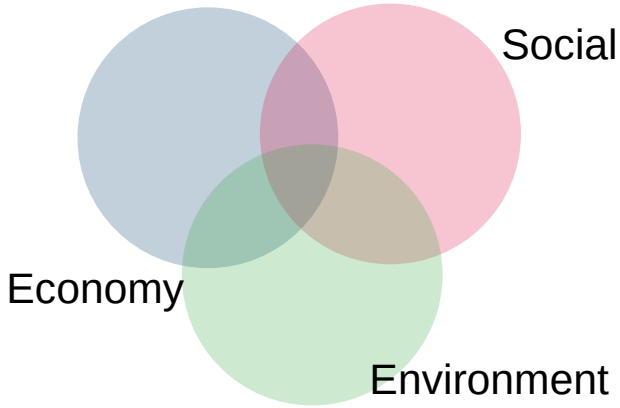
Source: www.mcda.it

Weighting of criteria

- Equal weighting
  - Every criteria is equally important
  - Within a hierarchy: Each cluster/group is equally important, within each cluster all criteria are equally important
- Stakeholder integration
  - Survey among experts/users/neighbours/decision makers
  - Different methods for the elicitation of weighting factors
    - AHP: Analytical Hierarchy Process
    - SMART: Simple Multi Attribute Rating Technique
    - …
  - Methods have different degree of complexity: Selection depends on number of criteria and time/money for the survey

Life Cycle Sustainability Assessment





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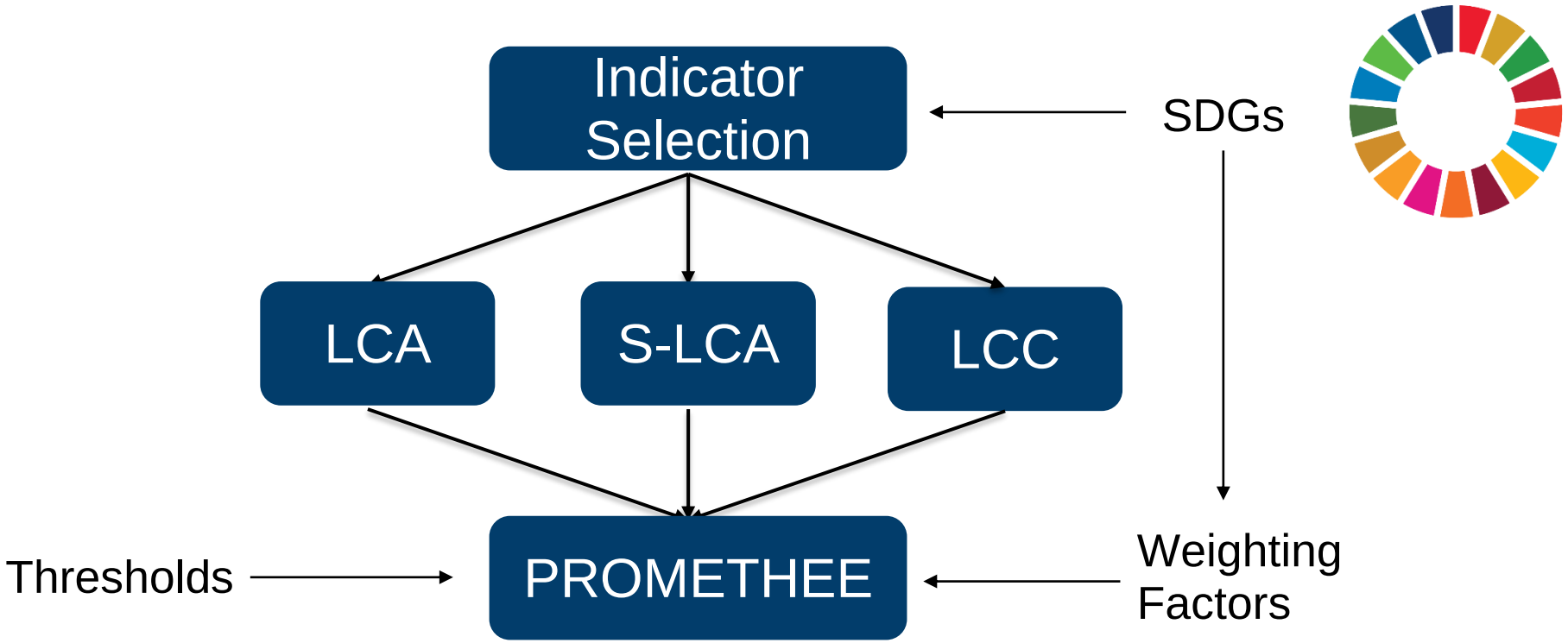
Approach Life Cycle Sustainability Assessment



LCSA indicator selection based on SDGs

Fair salary
Unemployment

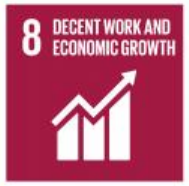
Human toxicity, cancer + non-cancer
Ionizing radiation
Ozone depletion
Particulate matter
Photochemical ozone creation
Health expenditure
Safety measures
Sanitation coverage
Social security expenditures

Illiteracy, total
Youth illiteracy, total

Women in the sectoral labour force
Gender wage gap

Drinking water coverage
Sanitation coverage

Levelized cost of hydrogen



Assoc. + barg. rights
Child labour, total
Fair salary
Goods produced by forced labour
Frequency of forced labour
Social security expenditures
Trade unionism
Trafficking in persons
Violations of employment laws
Weekly hours of work per employee
Net present value
Profitability index

Marginal cost

Indigenous rights

Abiotic resource depletion

Climate change

Ecotoxcity, fw.
Eutrophication, fw
Eutrophication, marine

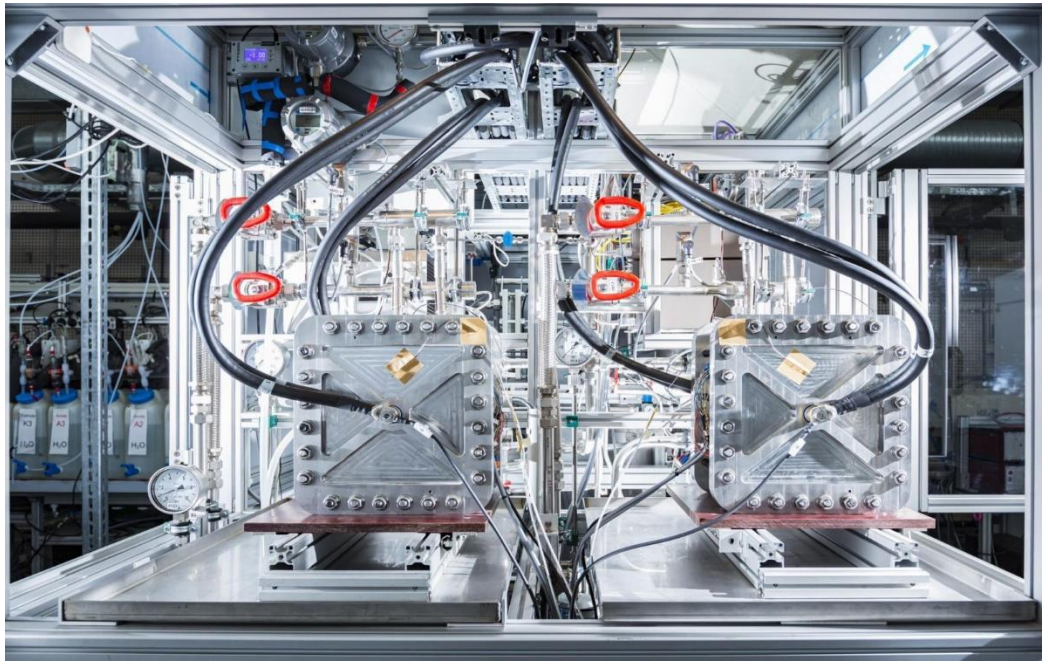
Acidification
Eutrophication, terrestrial

Assoc. + barg. rights
Trade unionism
Violations of employment laws and regulations

Case study

Comparison of hydrogen production with an alkaline water electrolyzer in three different countries

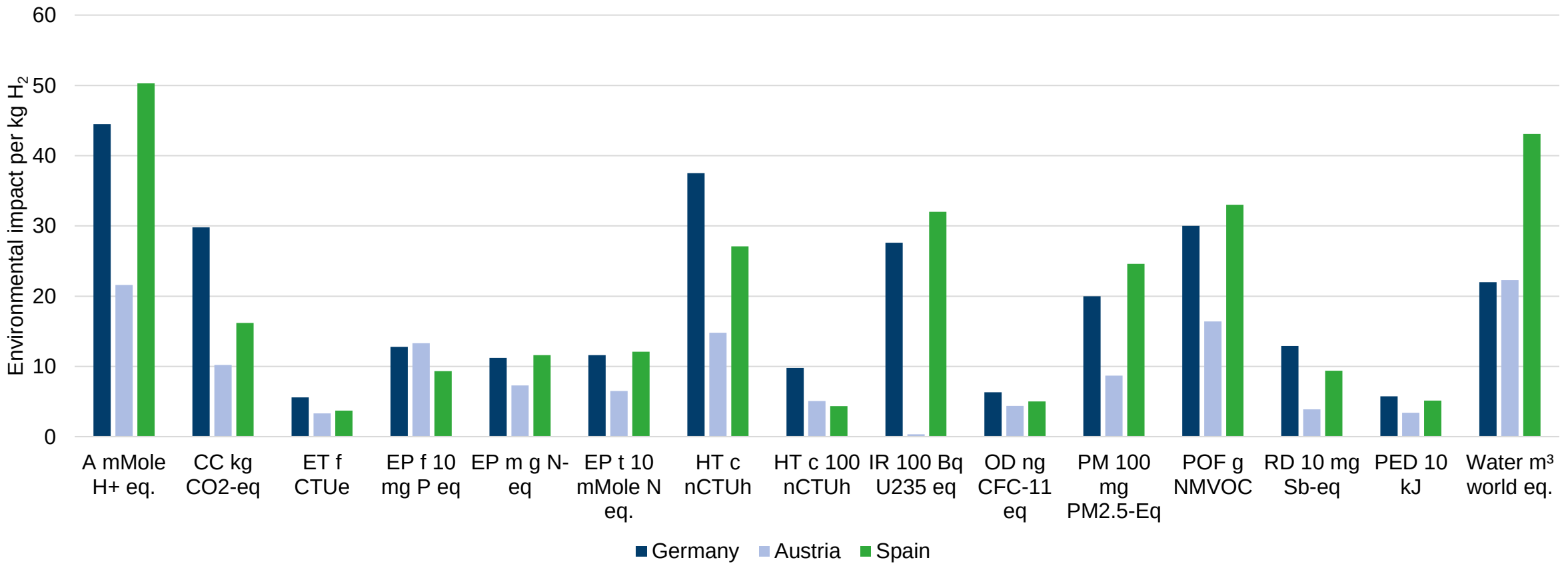
- Industrial hydrogen production by alkaline water electrolysis
- Comparison of Germany, Spain and Austria as production sites → different structures of electricity generation
- Same electrolyzer for all sites
- 1 kg hydrogen as functional unit
- Main inputs electricity and water



Source: FZJ

Results case study

Environment



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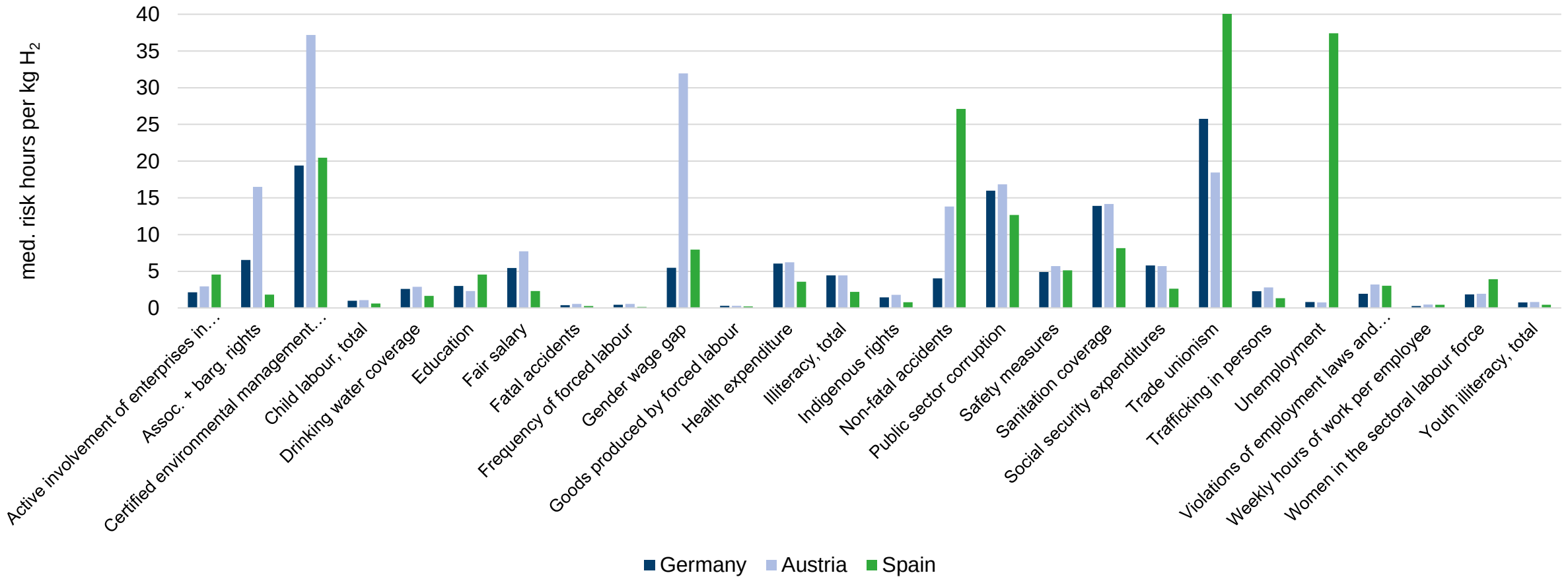
Results case study

Social



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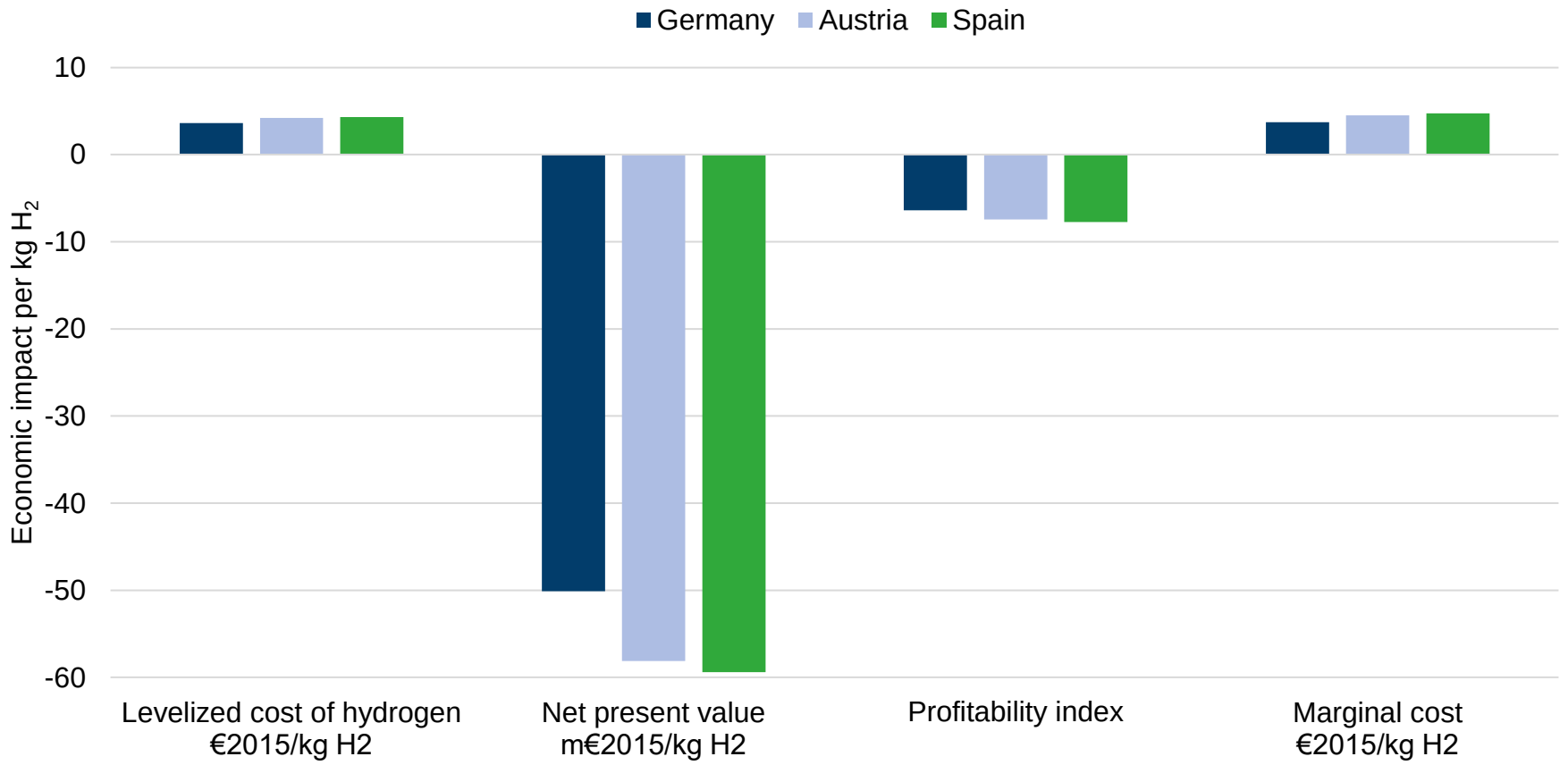
Results case study

Economy



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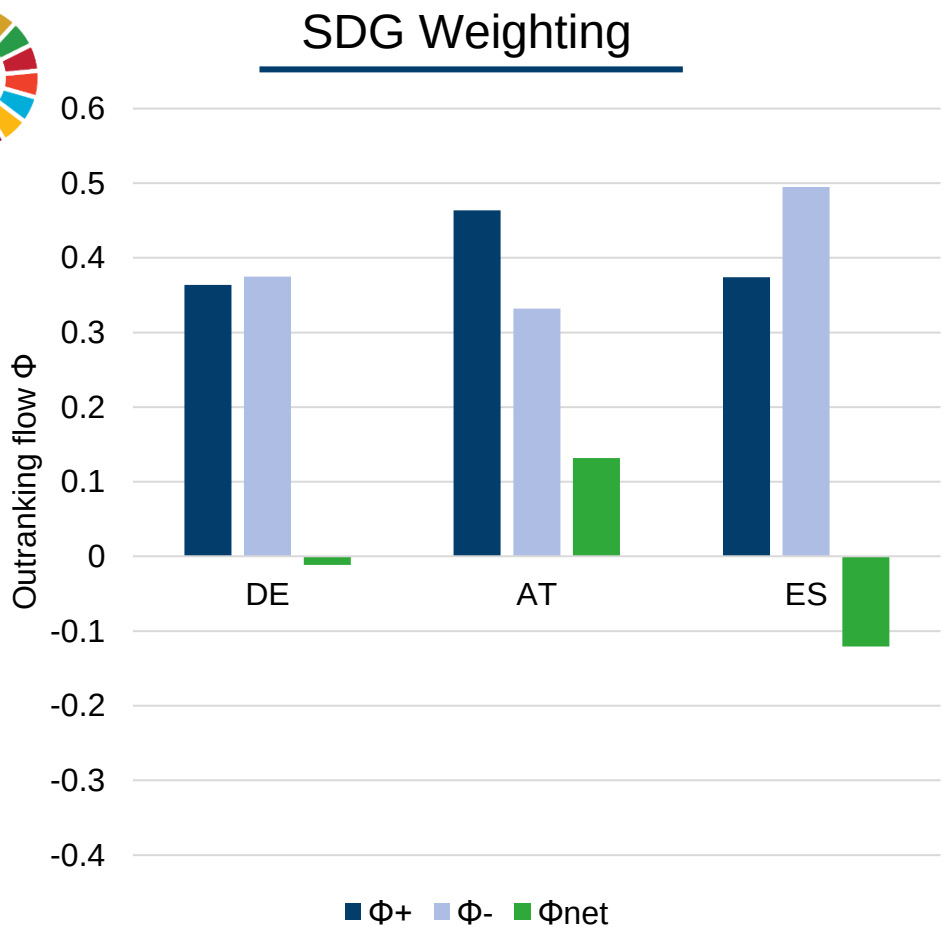
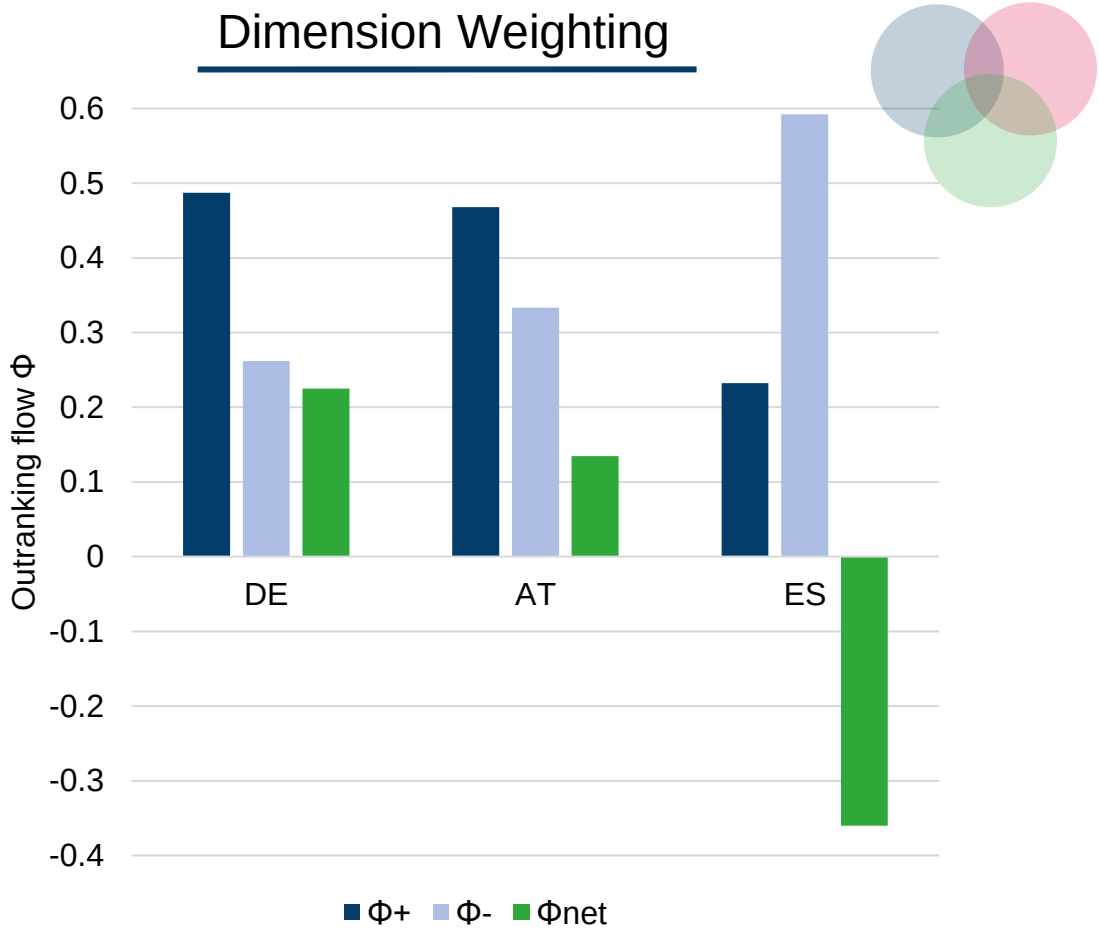
PROMETHEE Results





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Conclusions

- Sustainability strongly depends on the viewpoint and the integrated stakeholders
- MCDA methods help to guide and quantify through an assessment process with conflicting targets and multiple stakeholders
- Example illustrates: Classification according to SDGs results different recommendation than classification according to sustainability dimensions
- Limitations to SDG approach: SDGs do not cover corruption and stakeholder group consumers


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Questions?

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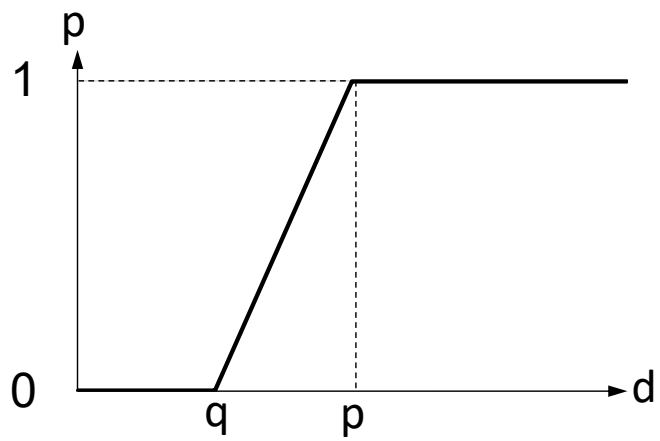
Backup

PROMETHEE

- Outranking verschiedener Optionen - kein vollständiger Ausgleich zwischen den Indikatoren
- Instrument zur Unterstützung der Entscheidungsfindung durch Aufdeckung der Konflikte und Synergien des Problems
- Lineare Präferenz mit Indifferenzschwelle für die Präferenzfunktion
- Indifferenzschwelle q = 5 % von x_{min}
- Präferenzschwelle p = 10 % von x_{min}



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PROMETHEE II

- Aufsummieren aller Einzelvergleiche

$$\pi(A_i, A_j) = \sum_{k=1}^{K} w_k * p_k\,(A_i, A_j)$$

- Gewichtung kann hinzugefügt werden

	DE	AT	ES
DE	0	0	0,66
AT	0,66	0	1
ES	0,33	0	0

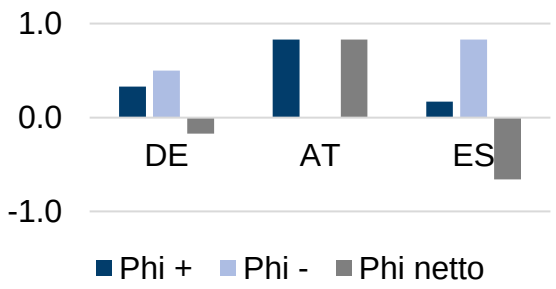
PROMETHEE II

- Aufsummieren aller Einzelvergleiche

$$\pi(A_i, A_j) = \sum_{k=1}^{K} w_k * p_k\,(A_i, A_j)$$

- Gewichtung kann hinzugefügt werden
- Berechnung der Aus- und Eingangsflüsse Φ^+ und Φ^-

$$\Phi_i^+ = \frac{1}{n-1}\sum_{j=1}^{n} \pi\,(A_i, A_j) \qquad \Phi_i^- = \frac{1}{n-1}\sum_{j=1}^{n} \pi\,(A_j, A_i)$$



	DE	AT	ES	Φ+
DE	0	0	0,66	0,33
AT	0,66	0	1	0,83
ES	0,33	0	0	0,17
Φ-	0,50	0	0,83	