

# **Stakeholders integration for MCDA sustainability assessment of energy technologies: a use case in energy storage**

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# Agenda

**Motivation**

**Objectives**

**Methodology**

**Use case**

# Motivation

## Stakeholders integration in sustainability assessment

1. High effort, resources: time, money, human capital.
2. More empirical research is needed to test which approach works best under some specific conditions<sup>1</sup>

1. Dean, M. (2022). Including multiple perspectives in participatory multi-criteria analysis: A framework for investigation. *Evaluation*, 28(4), 505-539. doi:10.1177/13563890221123822



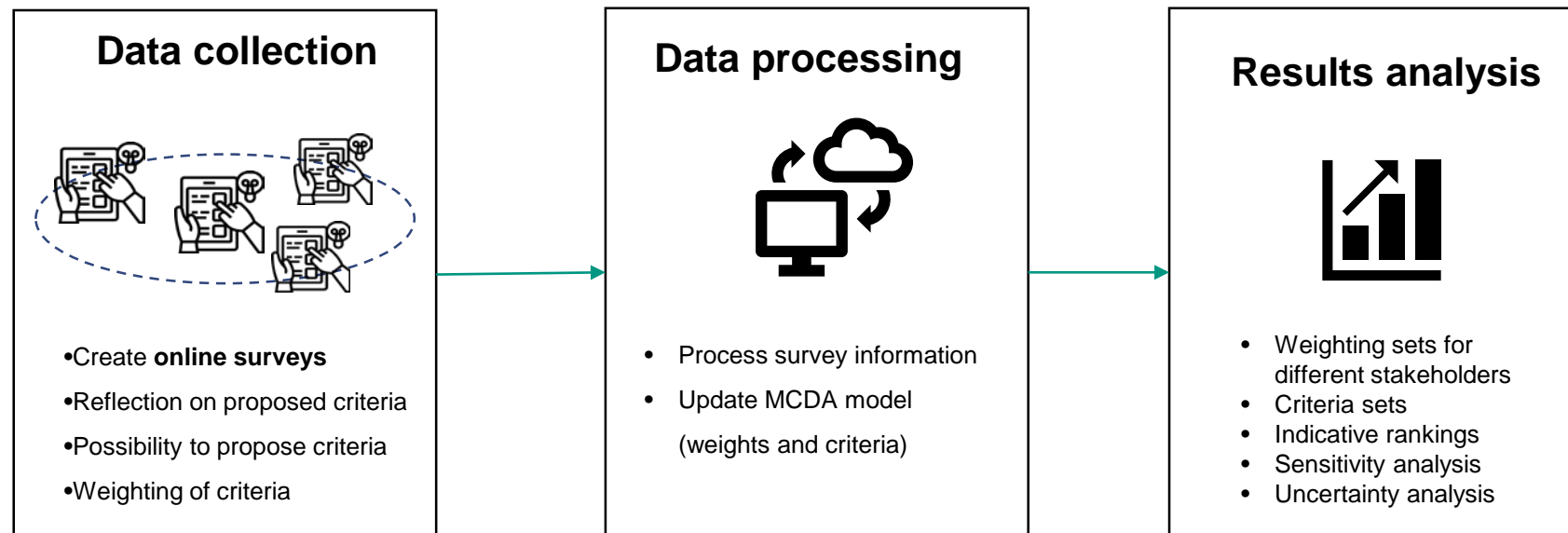
## What do we need?

- Model **sustainability**-related decision problems
- Reach a **broad audience** of stakeholders (onsite/online)
- Support **dialogue** among participants (**consensus**)
- Minimize resources: **time**
- Include **weights uncertainty** on decision-making processes

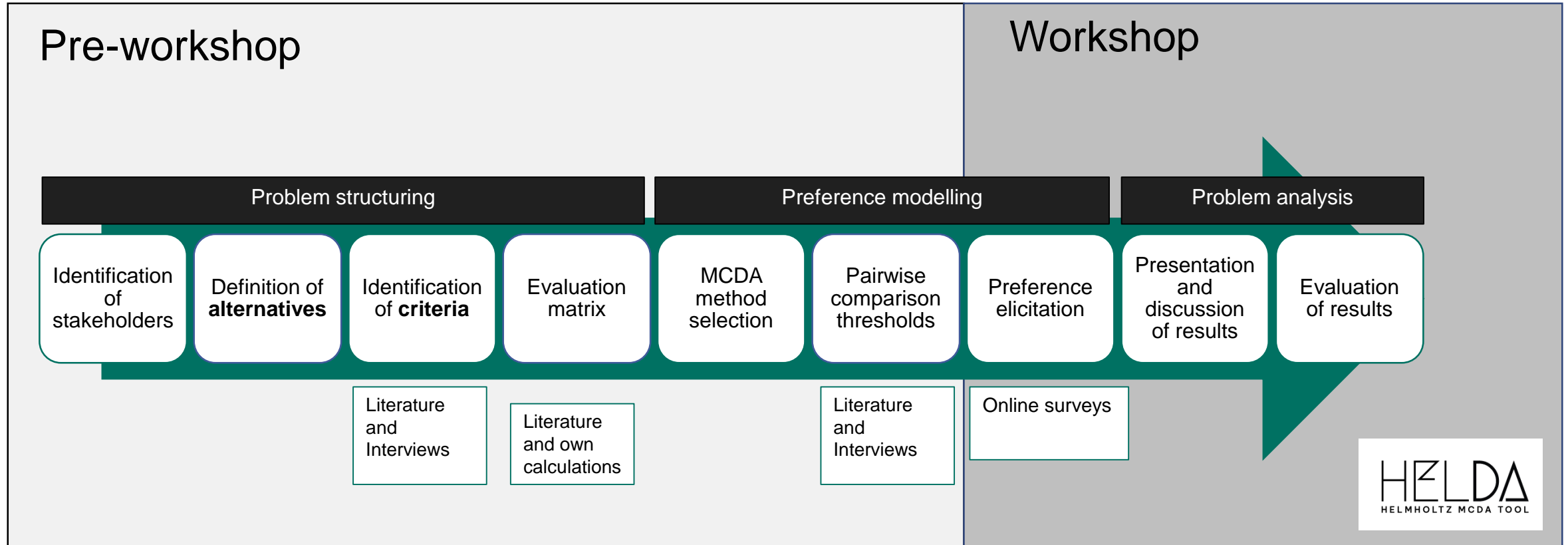
# Objectives

1. **Real-time integration of stakeholder preferences** for MCDA-sustainability assessment
2. Analyse the influence of **weights uncertainties** in decision-making processes

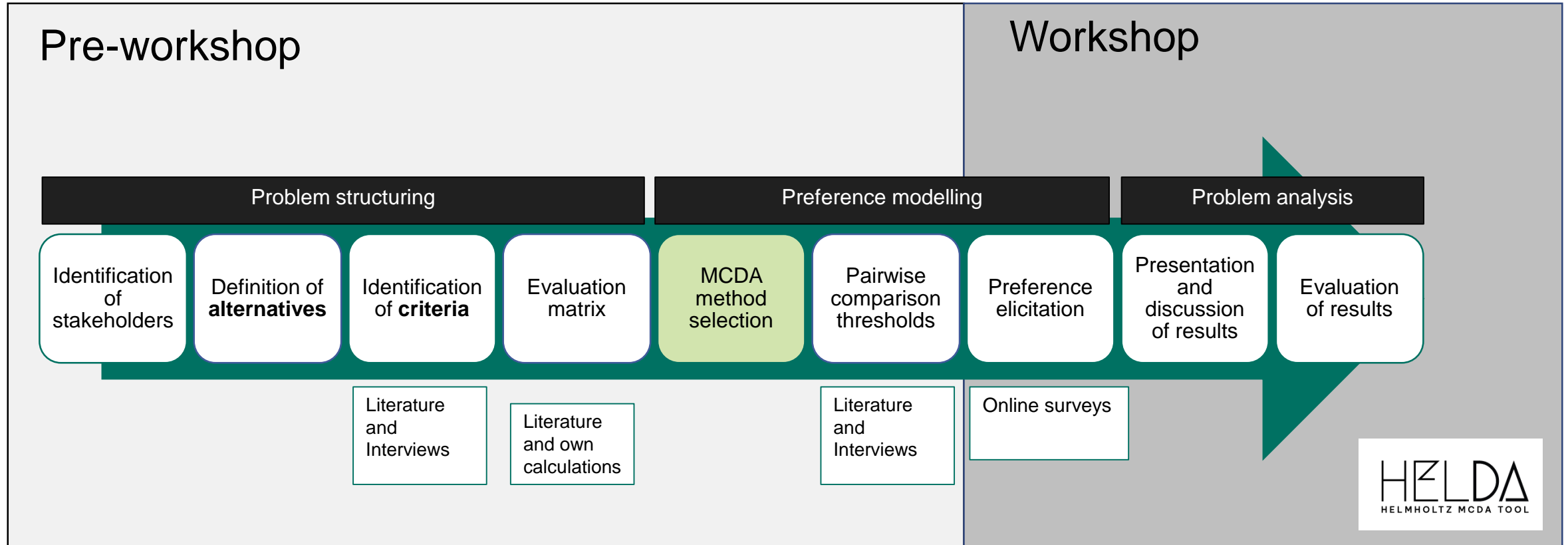
HELDA  
HELMHOLTZ MCDA TOOL



# Methodology



# Methodology



# Methodology

## ■ MCDA method selection

### ELECTRE III (aggregation)

- Ordinal recommendation (ranking)
- 4 preference relations
- Pseudo-criteria
- Concordance and discordance



Criteria for selection	Desired properties
Problem statement	Ranking
Scale used by the method	Qualitative and quantitative
Compensation level between criteria	Null/partial
Weights of criteria	Yes



# Methodology



## ■ MCDA method selection

### ELECTRE III (aggregation)

- Ordinal recommendation (ranking)
- **4 preference relations**
- Pseudo-criteria
- Concordance and discordance

Preference relations
Indifference
Strict preference
Weak preference
Incomparability





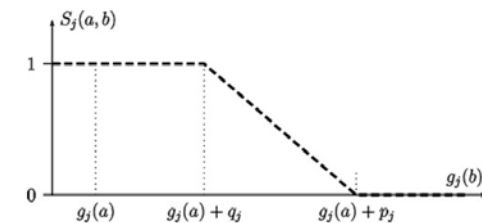
# Methodology

## ■ MCDA method selection

### ELECTRE III (aggregation)

- Ordinal recommendation (ranking)
- 4 preference relations
- **Pseudo-criteria**
- Concordance and discordance

Discriminating thresholds	
Imperfect knowledge of data	
<ul style="list-style-type: none"> <li>• Preference (p), indifference (q)</li> </ul>	
<hr/>	
(1) $g_j(a) - g_j(a') > p_j(g_j(a'))$	$\Leftrightarrow aP_ja'$ ,
(2) $q_j(g_j(a')) < g_j(a) - g_j(a')$	$\Leftrightarrow aQ_ja'$ (hesitation between
$\leq p_j(g_j(a'))$	$aI_ja'$ and $aP_ja'$ ),
(3) $-q_j(g_j(a)) \leq g_j(a) - g_j(a')$	$\Leftrightarrow aI_ja'$ .
<hr/>	





# Methodology

## ■ MCDA method selection

### ELECTRE III (aggregation)

- Ordinal recommendation (ranking)
- 4 preference relations
- Pseudo-criteria
- **Concordance and discordance**



Reasons **FOR** and **AGAINST** an outranking situation

Concordance: “majority principle”

$$c_j(a, b) = \begin{cases} 1, & \text{if } g_j(a) + q_j \geq g_j(b) \\ 0, & \text{if } g_j(a) + p_j \leq g_j(b) \\ \frac{p_j + g_j(a) - g_j(b)}{p_j - q_j}, & \text{otherwise} \end{cases}$$

$$C(a, b) = \frac{1}{k} \sum_{j=1}^r k_j c_j(a, b), \text{ where } k = \sum_{j=1}^r k_j$$

$k_j$  = importance coefficient for criterion  $j$

Discordance: “respect of minorities”

$$d_j(a, b) = \begin{cases} 0, & \text{if } g_j(a) + p_j \geq g_j(b) \\ 1, & \text{if } g_j(a) + v_j \leq g_j(b) \\ \frac{g_j(b) - g_j(a) - p_j}{v_j - p_j}, & \text{otherwise} \end{cases}$$

**Veto threshold (v)**

# Methodology

## ■ MCDA method selection

### SRF - deck of cards method (weighting)

$$G = \{g_1, g_2, g_3, g_4, g_5, g_6\}$$

- Set of cards
- Ranking

$$\{g_3\} \prec \{g_4, g_5\} \prec \{g_1\} \prec \{g_2\} \prec \{g_6\}$$

- White cards

$$\{g_3\} [2] \{g_4, g_5\} [1] \{g_1\} [0] \{g_2\} [3] \{g_6\}$$

- Ratio z

## 1. Non-normalized weights $k(r)$

$$k(r) = 1 + u(e_0 + \dots + e_{r-1}) \quad \text{with } e_0 = 0$$

$$\begin{cases} e_r = e'_r + 1 & \forall r = 1, \dots, \bar{n} - 1, \\ e = \sum_{r=1}^{\bar{n}-1} e_r, \\ u = \frac{z-1}{e} \end{cases}$$

## 2. Normalized weights $k_i$

$$\begin{cases} K' = \sum_{i=1}^n k'_i, \\ k_i^* = \frac{100}{K'} k'_i. \end{cases}$$

Figueira, J. R. & Roy, B. (2002). Determining the weights of criteria in the ELECTRE type methods with a revised Simos' procedure. *Eur. J. Oper. Res.*, 139, 317-326.

# Use case

## Storage Research Infrastructure Eco-System

### Key Research Priority:

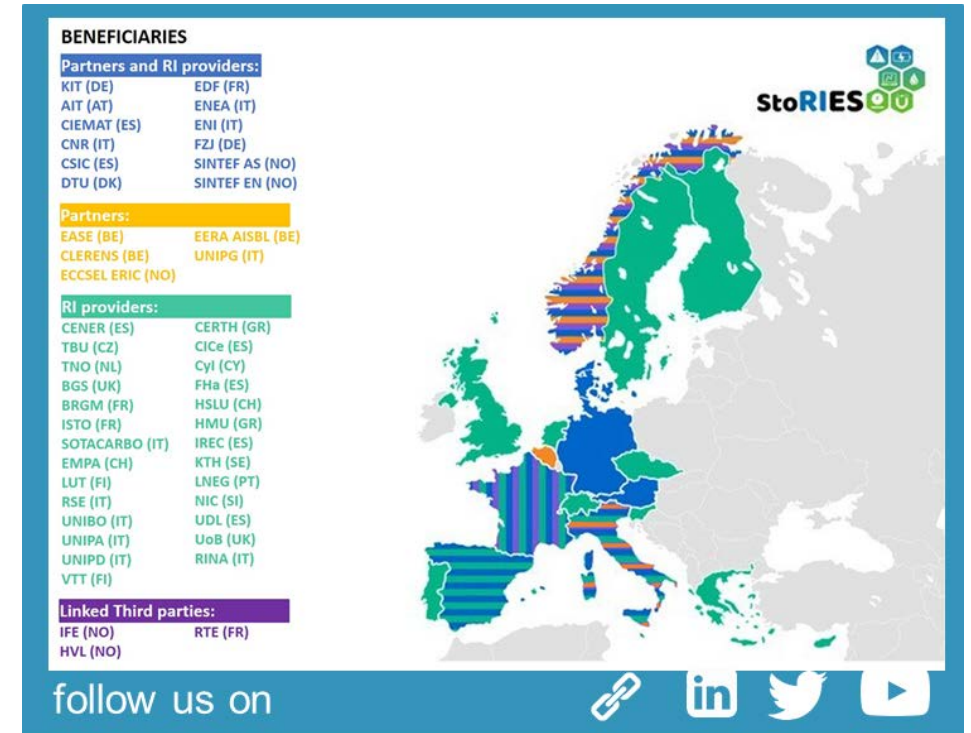
Hybridisation of Energy Storage



**Coordinator:** KIT (DE)  
**Duration:** 4 years (2021-2025)  
**Start:** 1<sup>st</sup> November 2021  
**Budget:** 7 Mio €  
**Beneficiaries:** 47 organisations  
**Research Infrastructures:** 64  
**Countries involved:** 17

### Main Objectives

- Foster a **European ecosystem** of industry and research on hybrid energy storage technologies
- **Provide access** to the most advanced scientific infrastructure in the field of energy storage



**BENEFICIARIES**

**Partners and RI providers:**

KIT (DE)	EDF (FR)
AIT (AT)	ENEA (IT)
CIEMAT (ES)	ENI (IT)
CNR (IT)	FZJ (DE)
CSIC (ES)	SINTEF AS (NO)
DTU (DK)	SINTEF EN (NO)

**Partners:**


EASE (BE)	EERA AISBL (BE)
CLERENS (BE)	UNIPG (IT)
ECCSEL ERIC (NO)	

**RI providers:**

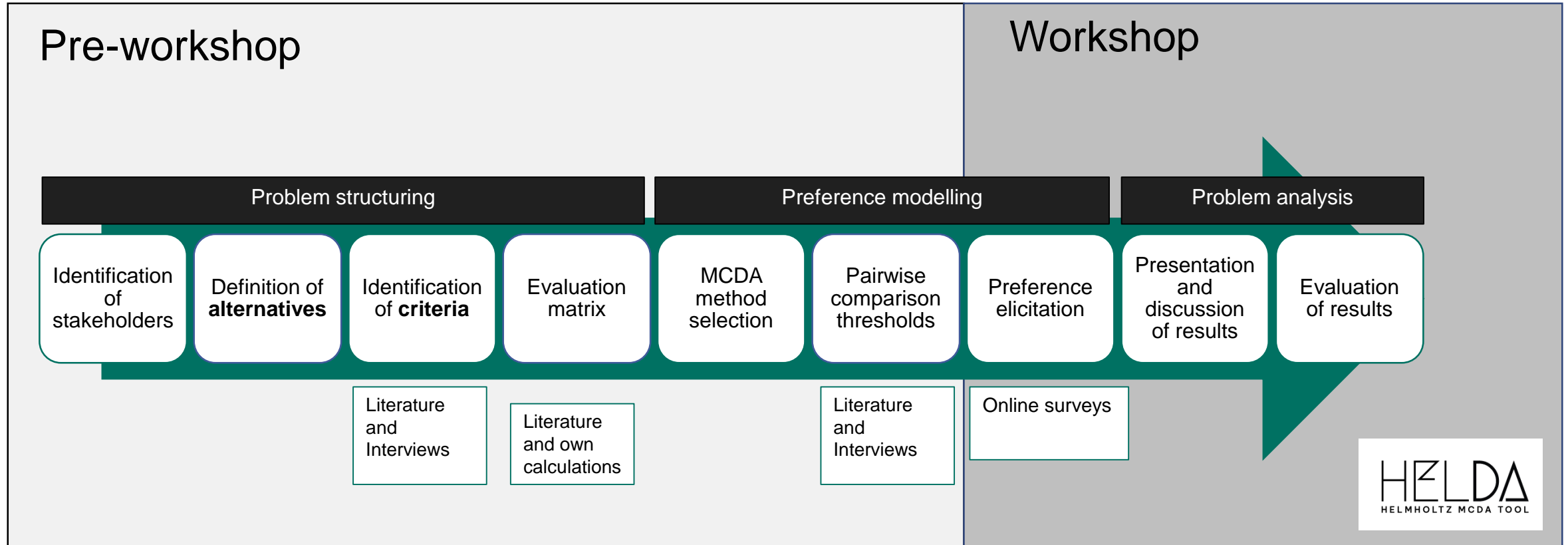
CENER (ES)	CERTH (GR)
TBU (CZ)	Cice (ES)
TNO (NL)	Cyl (CY)
BGS (UK)	FHa (ES)
BRGM (FR)	HSLU (CH)
ISTO (FR)	HMU (GR)
SOTACARBO (IT)	IREC (ES)
EMPA (CH)	KTH (SE)
LUT (FI)	LNEG (PT)
RSE (IT)	NIC (SI)
UNIBO (IT)	UDL (ES)
UNIPA (IT)	UoB (UK)
UNIPD (IT)	RINA (IT)
VTT (FI)	

**Linked Third parties:**

IFE (NO)	RTE (FR)
HVL (NO)	

follow us on 

# Methodology



# Use case

## Problem structuring

### ■ Stakeholders (categories)

- Association (e.g. trade or industry)
- Government Energy & Environmental Agencies
- Researcher/ Academia – Engineering/manufacturing
- Researcher/ Academia – Sustainability
- Researcher/ Academia – Market integration
- Researcher/ Academia – Policy Analysis
- Non-Governmental Organization (NGO)
- Energy supplier

**40** participants approx.

### ■ Alternatives

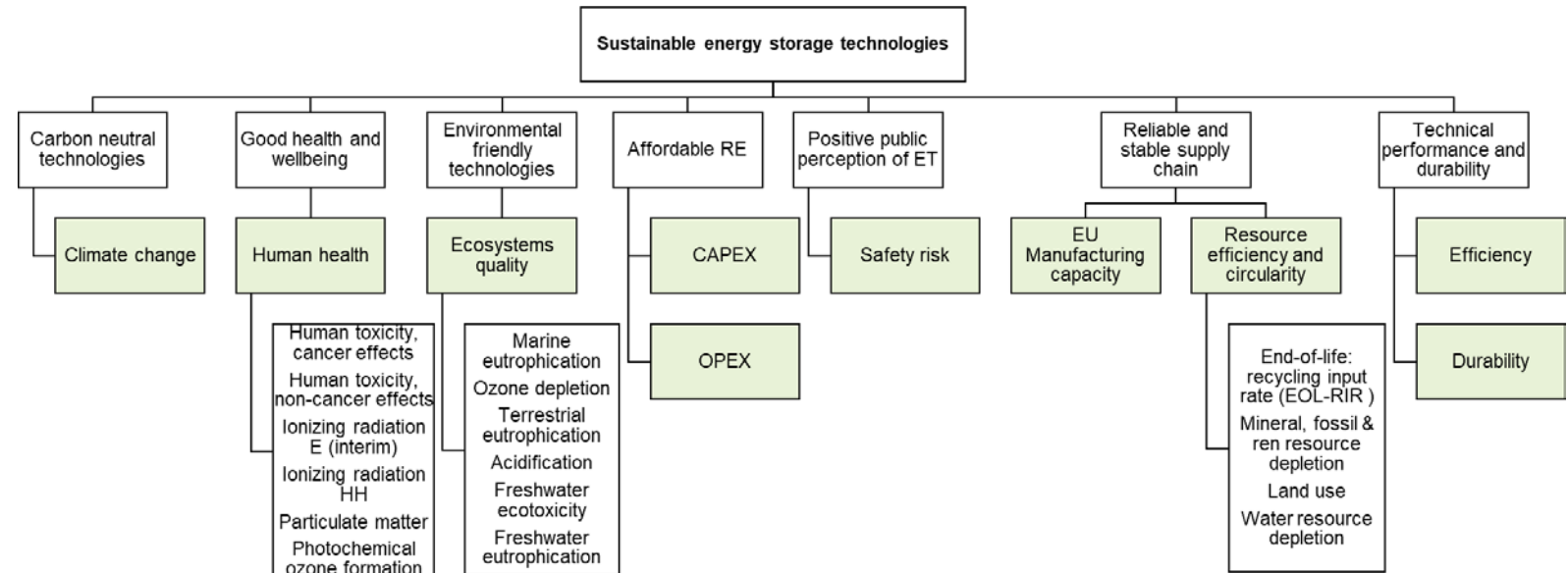
	Short/medium-term energy storage	Long term energy storage
<b>Use case</b>	4 hours/day	1000 hours/year
<b>Charged energy</b>	Wind power	Wind power
<b>Alternatives</b>	<b>a1.</b> Pumped Hydro storage (PHS) <b>a2.</b> Lithium Iron Phosphate battery (LFP) <b>a3.</b> All-Vandium Redox Flow Battery (VRFB)	<b>a4.</b> Norwegian Pumped Hydro storage (NPHS) <b>a5.</b> Power-to-Hydrogen (PtH <sub>2</sub> ) <b>a6.</b> Power-to-Methane (PtCH <sub>4</sub> )

# Use case

## Problem structuring

### Criteria

- Literature review
- Interviews with 6 stakeholders (academia and industry)
- Value focus thinking protocol<sup>2</sup>
- Flat structure of criteria
- Relation to SDGs



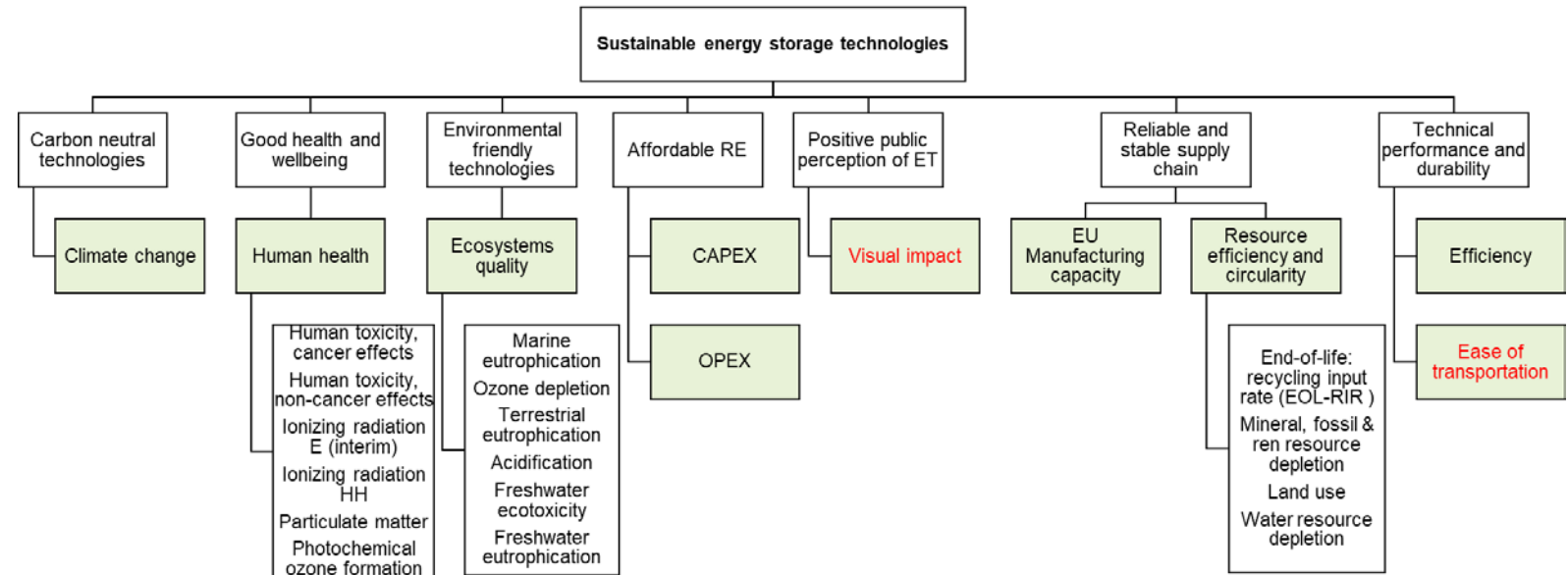
2. Keeney, R. (2008). Applying Value-Focused Thinking. *Military Operations Research*, 13, 7-17. doi:10.5711/morj.13.2.7

# Use case

## Problem structuring

### Criteria

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2. Keeney, R. (2008). Applying Value-Focused Thinking. *Military Operations Research*, 13, 7-17. doi:10.5711/morj.13.2.7



# Use case

## Problem structuring

### ■ Evaluation matrix

	Climate change (g1)	Impact on human health (g2)	Impact on ecosystems quality (g3)	CAPEX (g4)	OPEX - Fixed cost (g5)	Safety risk (g6)	EU Manufacturing capacity (g7)	Resource efficiency and circularity (g8)	Efficiency (g9)	Durability (g10)
Unit	kg CO2 eq / kWh	Qualitative judgment (1-5)	Qualitative judgment (1-5)	€/kW	€/kW-yr	Qualitative judgment (1-5)	Qualitative judgment (1-5)	Qualitative judgment (1-5)	%	years
Preference	min	min	min	min	min	min	max	max	max	max
<b>a1</b>	0.0732	Very low (1)	Low (2)	1880	28	Very low (1)	Very high (5)	Very low (1)	77	75
<b>a2</b>	0.0781	Very high (5)	High (4)	1350	3.8	High (5)	Very low (1)	Very low (1)	87	20
<b>a3</b>	0.0649	Medium (3)	High (4)	1850	5.3	Low (2)	Medium (3)	Low (2)	75	25
						<b>Visual impact (g11)</b>				<b>Ese of transportation (g12)</b>
<b>a4</b>	0.115	High (4)	High (4)	7637	236	Low (2)	Very low (1)	High (4)	41	Very low (1)
<b>a5</b>	0.143	Very high (5)	Medium (3)	4852	635	High (4)	Low (2)	Low (1)	15	Very high (5)
<b>a6</b>	0.0891	Medium (3)	Very high (5)	4088	159	Very high (5)	High (4)	High (4)	64	Low (2)

# Use case

## Preference modelling

### Interactive workshop:

“Setting up a common base for environmental, techno-economic and socio-economic assessment to unlock the potential applications for hybrid ES systems”

6<sup>th</sup> of December 2023, Vienna



## Experiment settings

### 1. Individual preferences (plenum)

HELDA

1.1 Plenum: criteria reflection

1.2 Plenum: weighting of criteria

### 2. Group preferences (5 groups)

Posters (direct weights)+ deck of cards (DCM)+ HELDA

2.1 Group work: weighting of criteria

2.2 Group work: criteria reflection



1<sup>st</sup> application of HELDA

# Use case

## Problem analysis: results

### 1.1 Plenum: criteria reflection

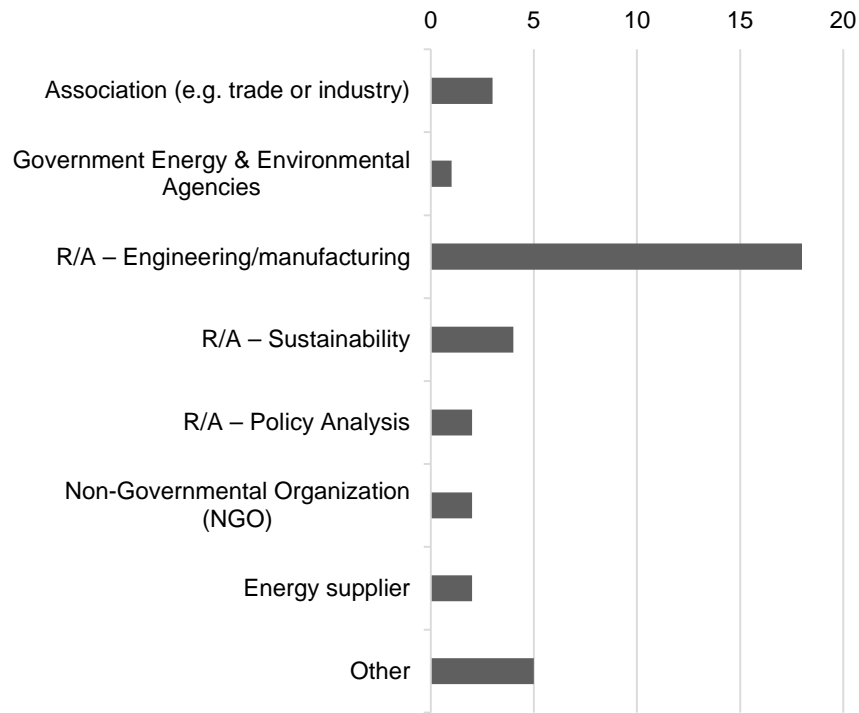


Fig 1. Distribution of stakeholders per category (n=37)

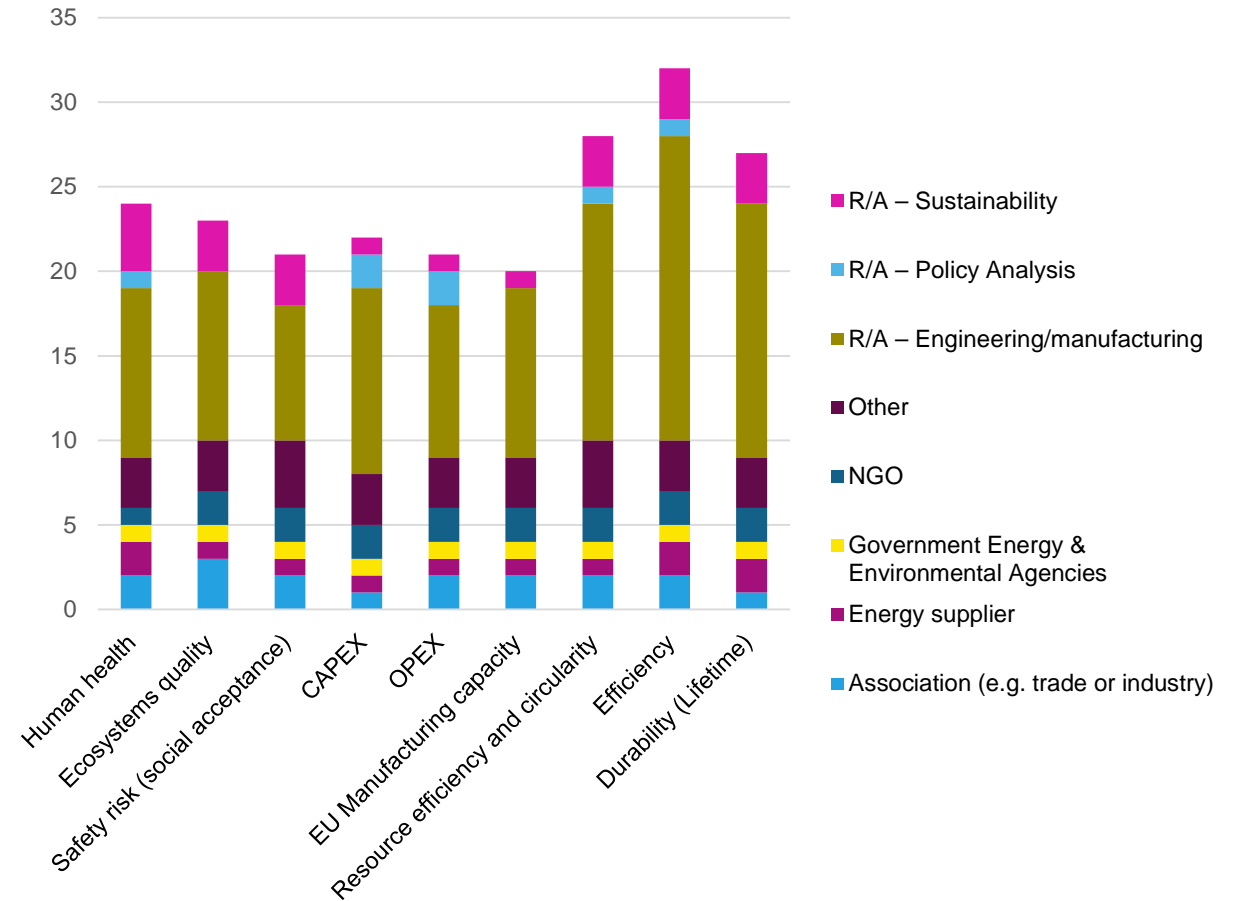


Fig 2. Total votes of criteria by stakeholders.

# Use case

## Problem analysis: results

### 1.2 Plenum: weighting

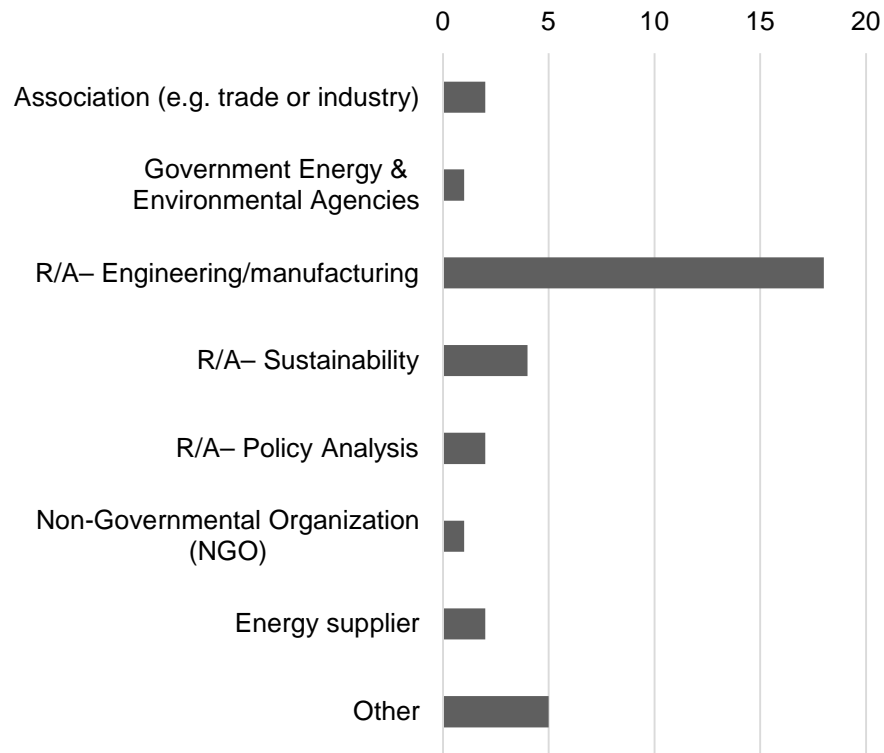


Fig 3. Distribution of stakeholders per category (n=37)

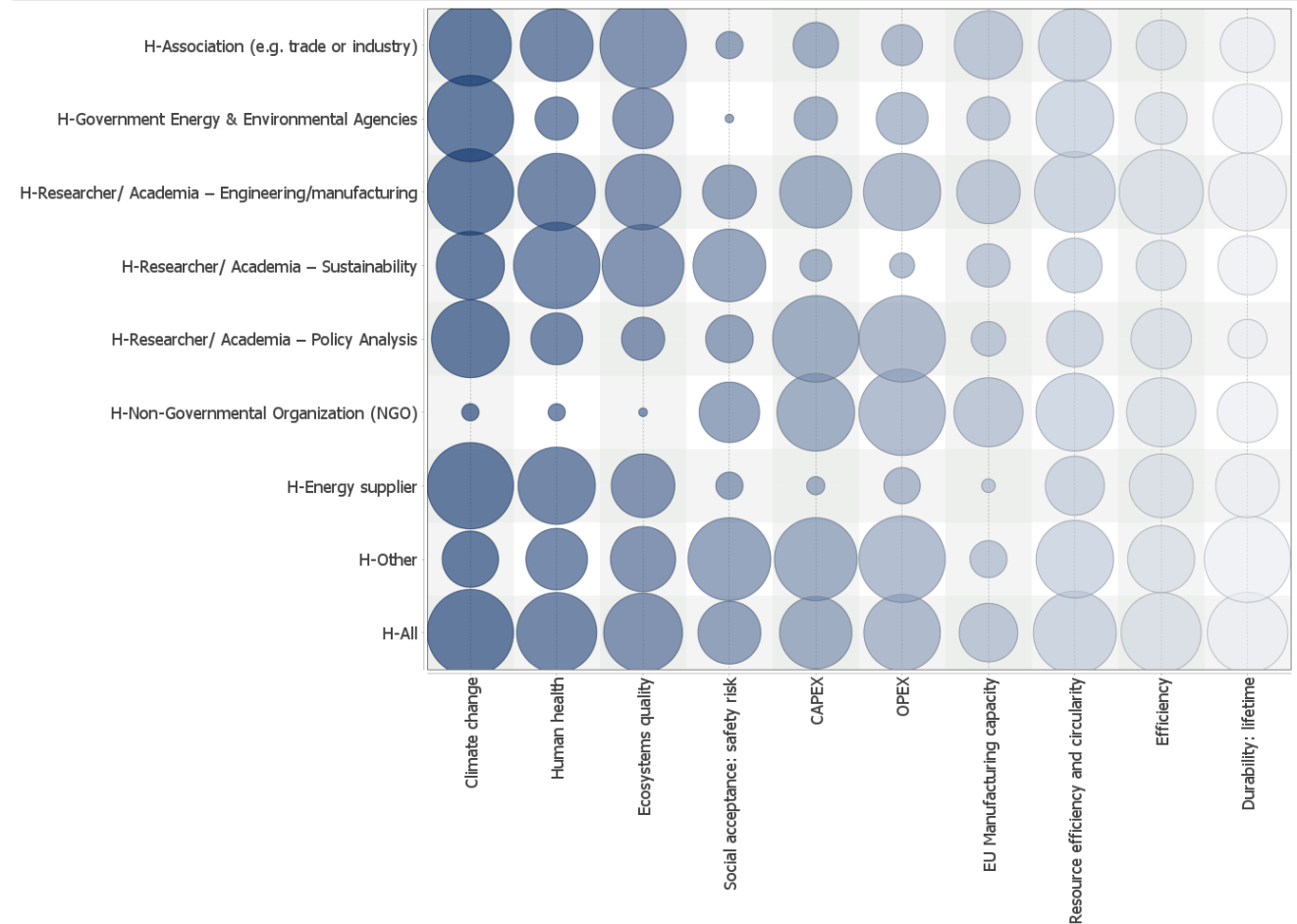


Fig 4. Weighting sets analysis



# Use case

## Problem analysis: results

### 2.1 Group preferences: weighting of criteria

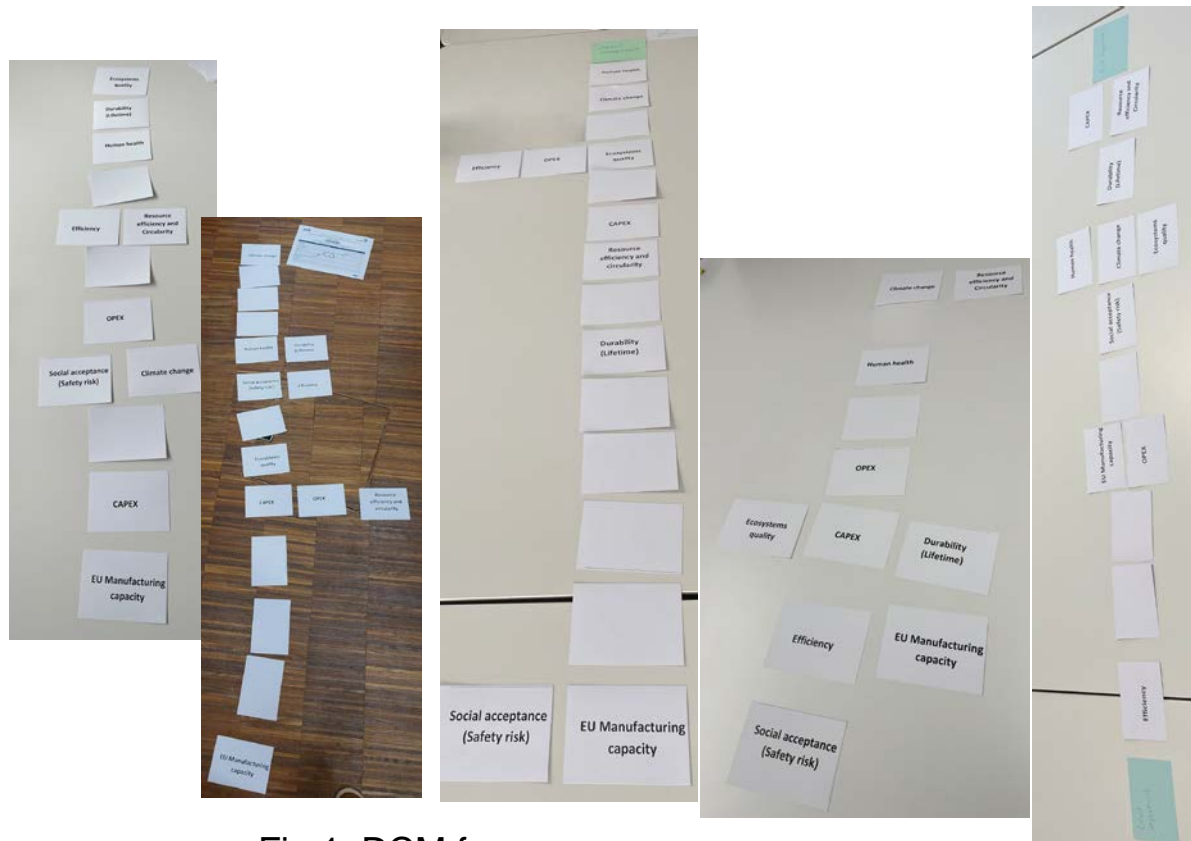


Fig 1. DCM for every group

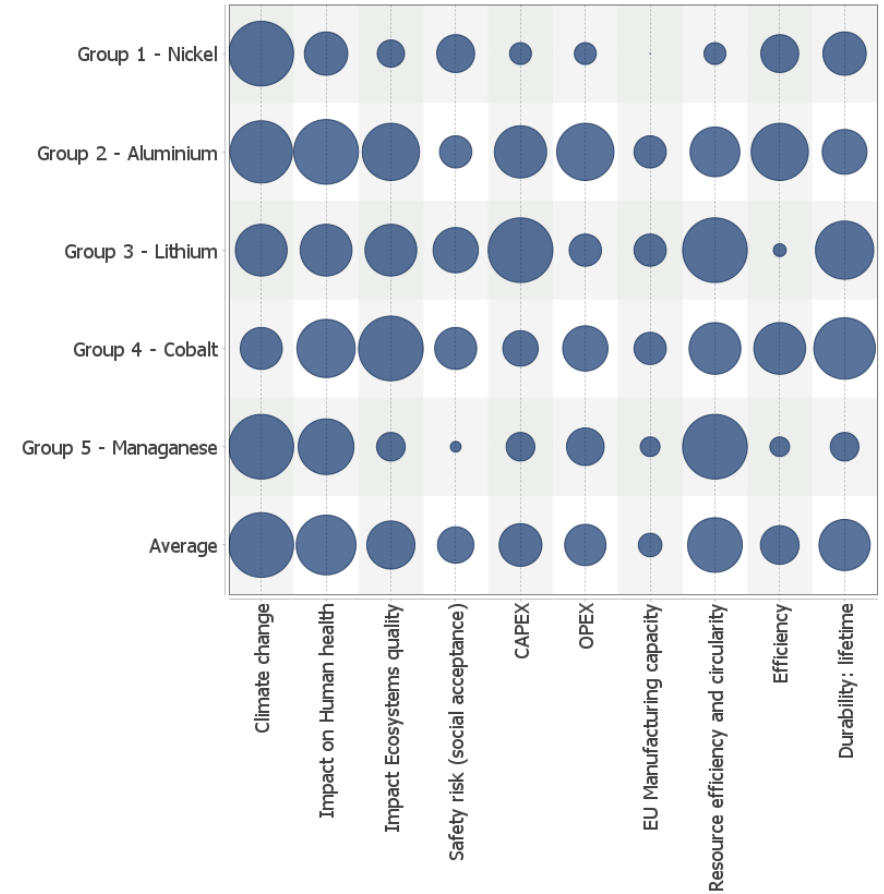
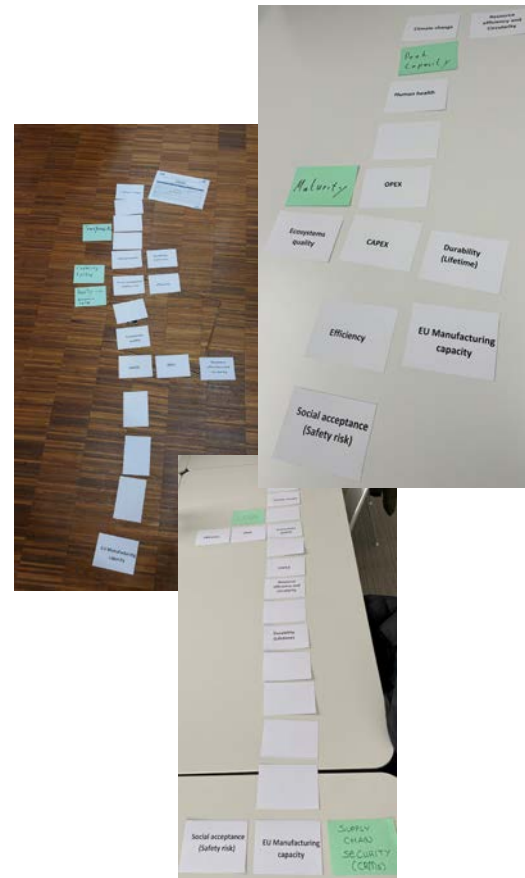
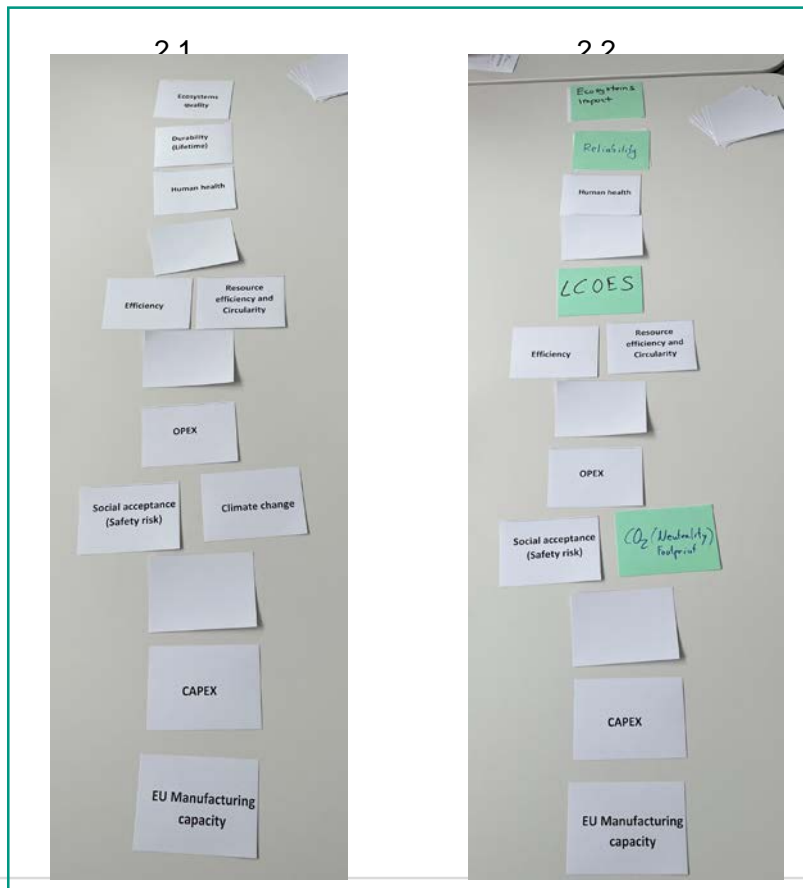


Fig 2. Weighting sets analysis by groups with DCM.

# Use case

## Problem analysis: results

### 2.2 Group preferences: criteria reflection



### Criteria added

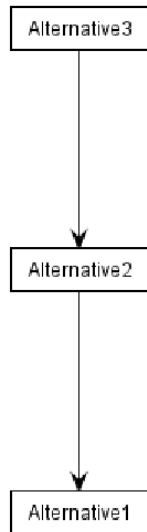
- LCOS
- Reliability
- Maturity
- Peak capacity
- Number of suppliers of raw materials
- Novelty
- Capacity factor
- Transferability
- Supply chain security

# Use case

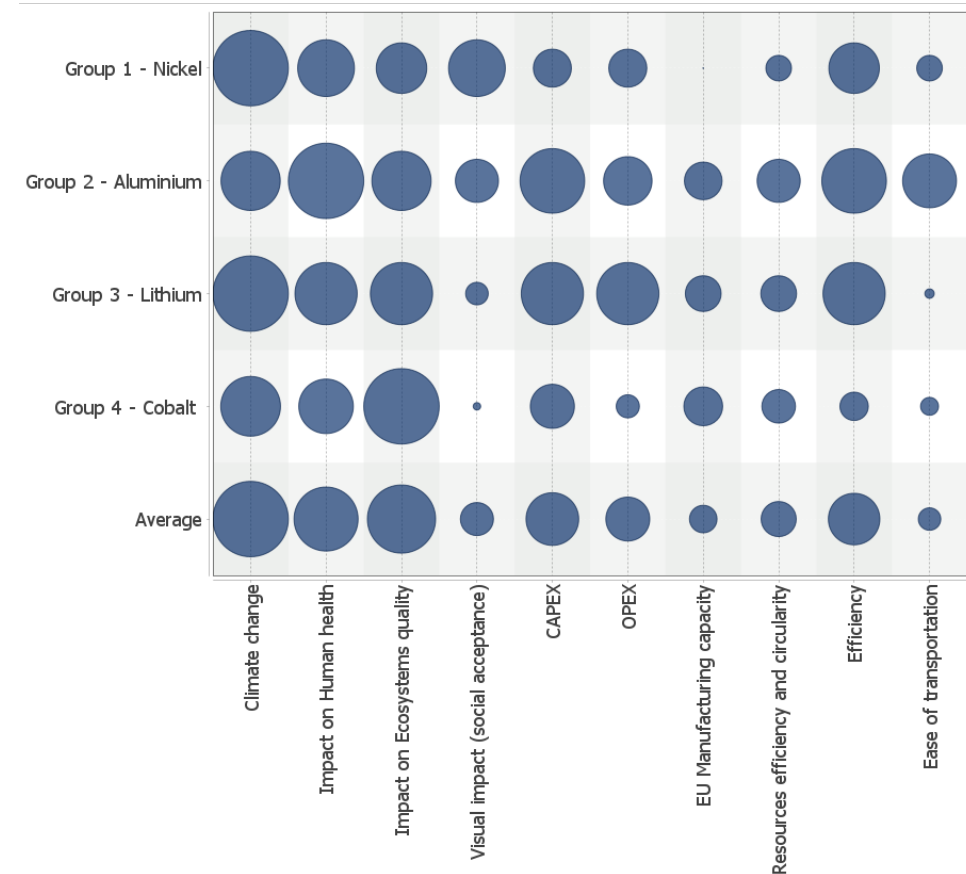
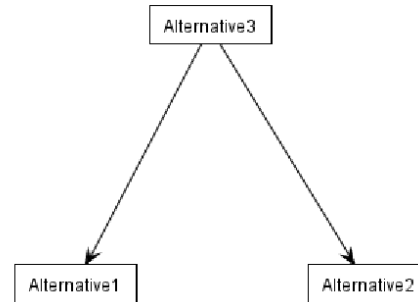
## Problem analysis: results

### Indicative ranking: Long-term ES

Group 1  
Group 2



Group 4  
Group 3



# Outlook

Further testing of the methodology

Sensitivity analysis, e.g.

- Discriminating thresholds
- Input data
  
- Uncertainty analysis, e.g.
  - Weight intervals within groups
  - Weighting methods



Thank you! 😊