Special session: Revealing Trajectories Towards a Sustainable Energy Future

Identifying Robust Development Trajectories for the Icelandic Energy System using Multi-Criteria Decision Analysis

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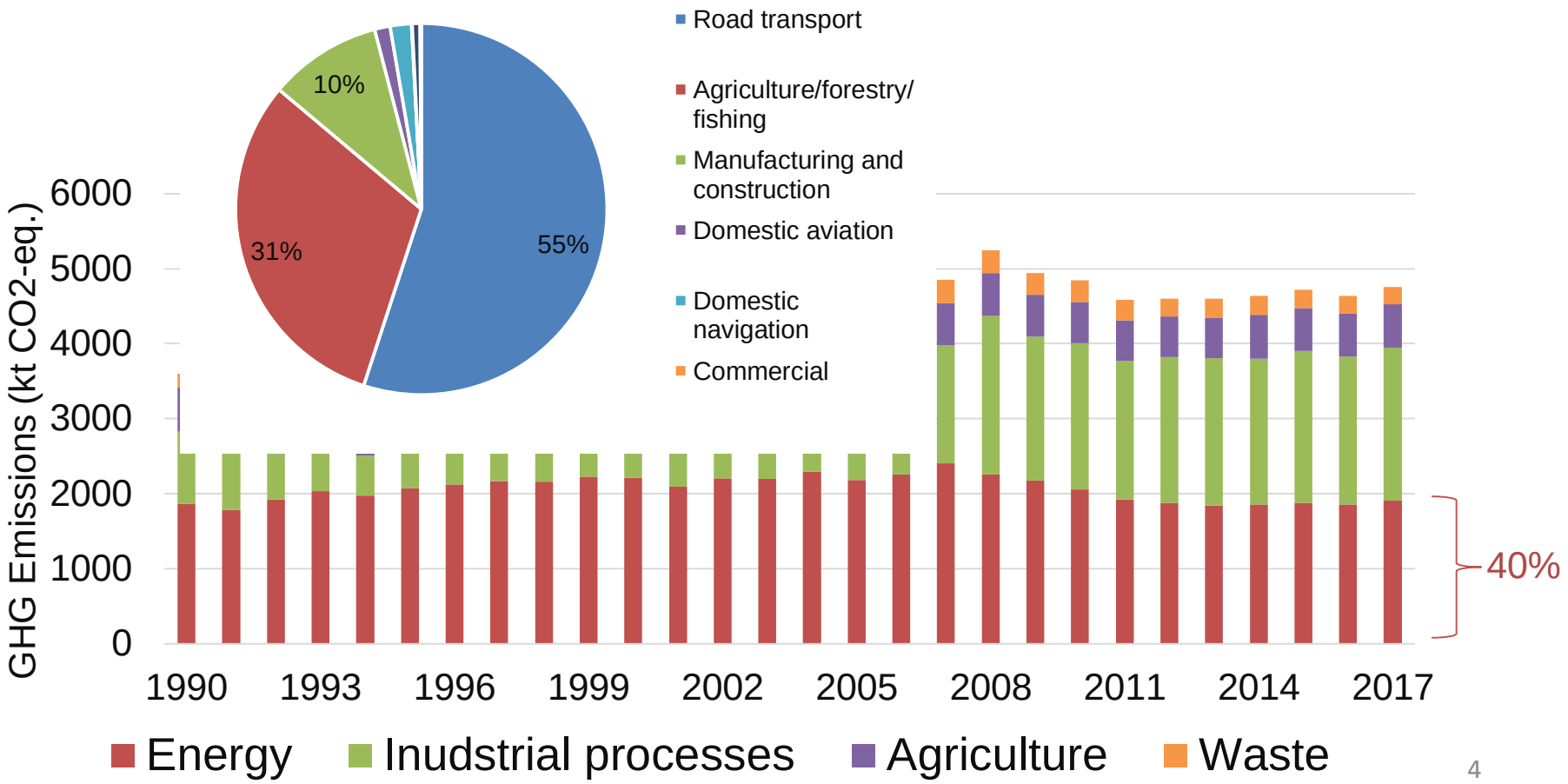
Main Objectives

1) develop/validate the participatory Multi-Criteria Decision Analysis framework for energy trajectories,
2) to integrate energy sustainability indicators with the MCDA framework to assess energy trajectories

Process of Multi-Criteria Decision Analysis

1. Problem Identification

GHG Emissions by sectors without LULUFC



Source: statistics Iceland

2. Problem Structuring

Stakeholders

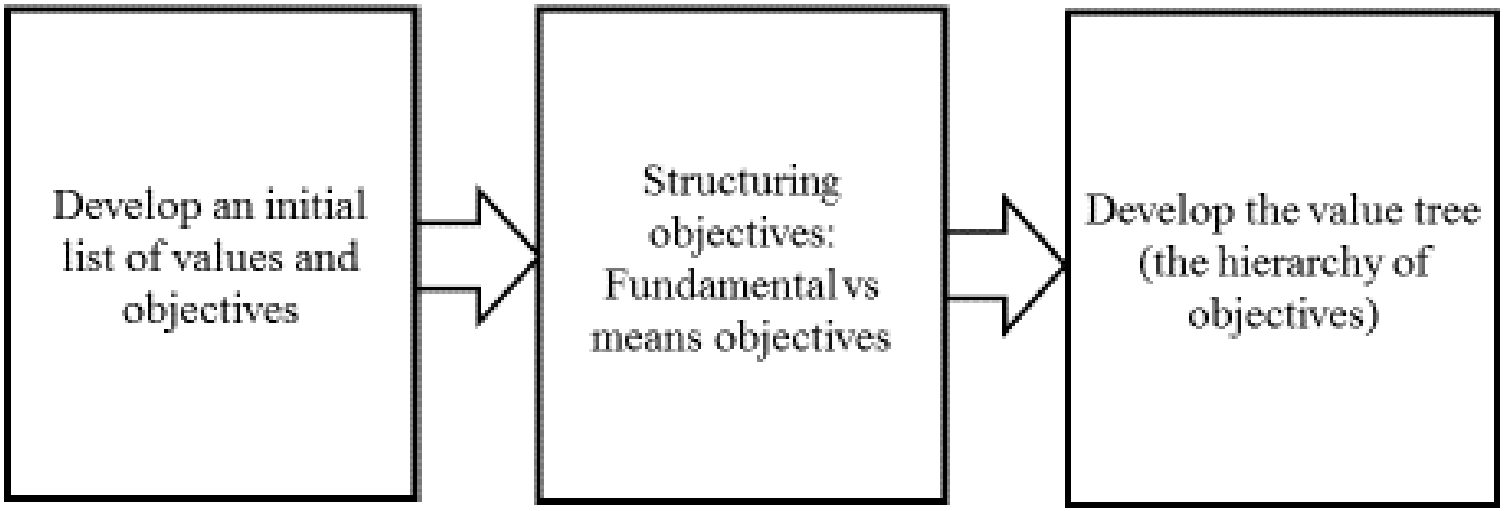
- Stakeholder Analysis
  a) Identification of stakeholders

Decision-makers (National and Regional level), ***Energy Producers***, ***Fuel Importers***, ***Distribution and Transmission companies***, ***Industrial Users***, ***Public and Small Business Users, NGOs, Professional Interest*** (Consulting engineering firms and Universities), and ***Landowners***.

2. Problem Structuring

Values/Objectives

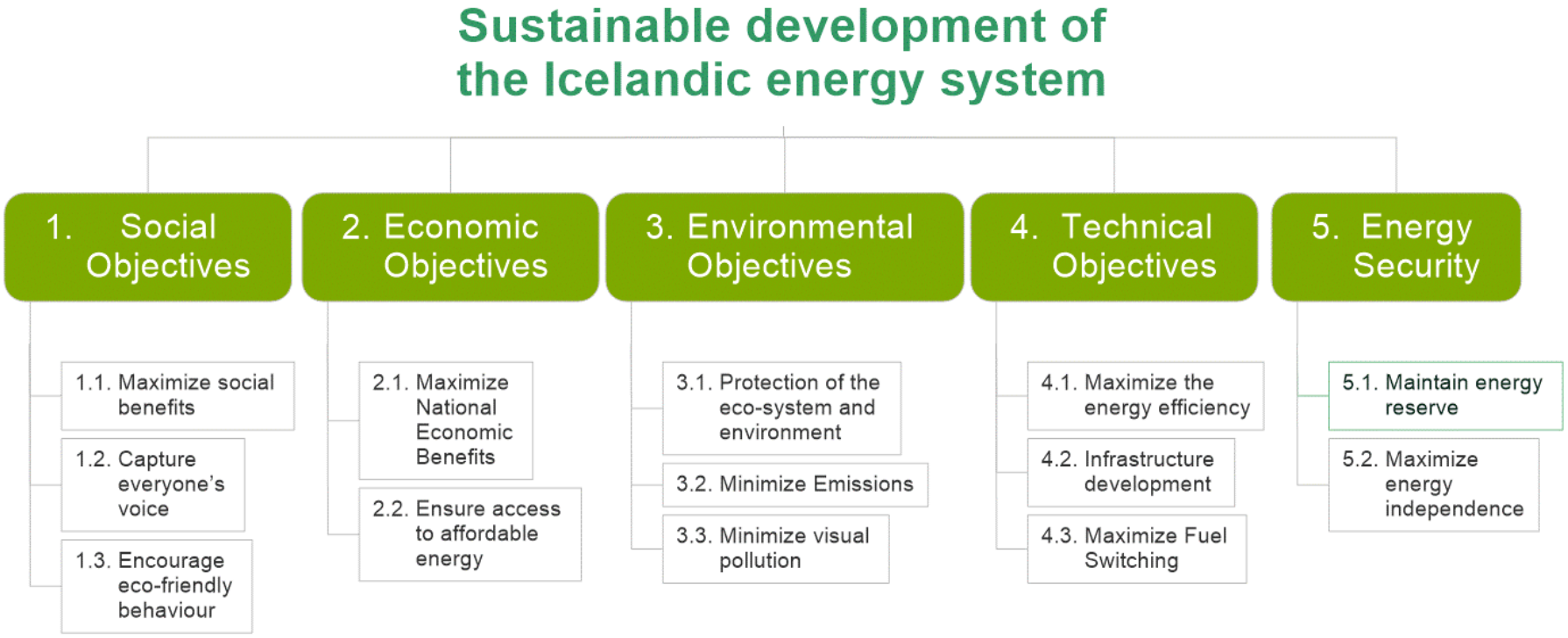
Value-Focused Thinking Approach (Keeney, 1992)



Adjusted based on Keeney, (1992); Sheng et al., (2005)

2. Problem Structuring

Hierarchy of fundamental-means objectives



3. Decision Model

Developing Scenarios

- **Economy**
  - Recent trend: GDP Growth: 2.5% until 2030 and 2% after 2030 (OS-2018-07)
  - High growth driven by tourism GDP Growth: 3% until 2030 and 2.5% after 2030 (OS-2016-02),
  - High growth driven by large industries: GDP annual Growth of 2.8% (OS-2018-07)
- **Abatement efforts**
  - Base: Current fuel & vehicle usage tax, Equal VAT rates + current excise duty
  - Premium: New tax proposal assumptions on fuels and vehicles + VAT exemption for light & heavy BEVs after 2020
  - Banning: New tax proposal assumptions on fuels and vehicles + Ban on the new sales of ICE and HEV from 2030
- **Efficiency trends in energy use**
  - Recent trends,
  - Higher efficiency: improvement in vehicle efficiency and industries (1.5% per year) (OS-2018-07)

3. Decision Model

Defining Criteria and Linking indicators

Criteria code	Sustainable energy development criteria	Indicators
C-1	Social Impacts	• Job Creation • The share of alternative fuel vehicles • Government Tax Revenue – Expenditure (Subsidies, investment, …)
C-2	Economic Development	• Household expenditure on electricity and transport • Energy Intensity of the economy • Total impact area of power plants
C-3	Environmental Impacts	• GHG emissions from the transport sector • Dynamic reserve / production ratio
C-4	Energy Security	• Diversity in supply – energy sources • Proportion of domestic energy sources in total primary energy supply • Share of alternative fuels in road transportation
C-5	Technical Aspect	• Total number of fast-charging spots and other eco-friendly multi-fuel stations • Total final energy consumption in transportation per capita

3. Model Building

Eliciting Values

TOPSIS

"**T**echnique of **O**rder **P**reference **S**imilarity to the **I**deal **S**olution"

The fundamental idea:
The best solution has shortest distance to the ideal solution and furthest distance from the anti-ideal solution

First developed by Hwang and Yoon (1981)

4. Challenging thinking

Synthesizing information

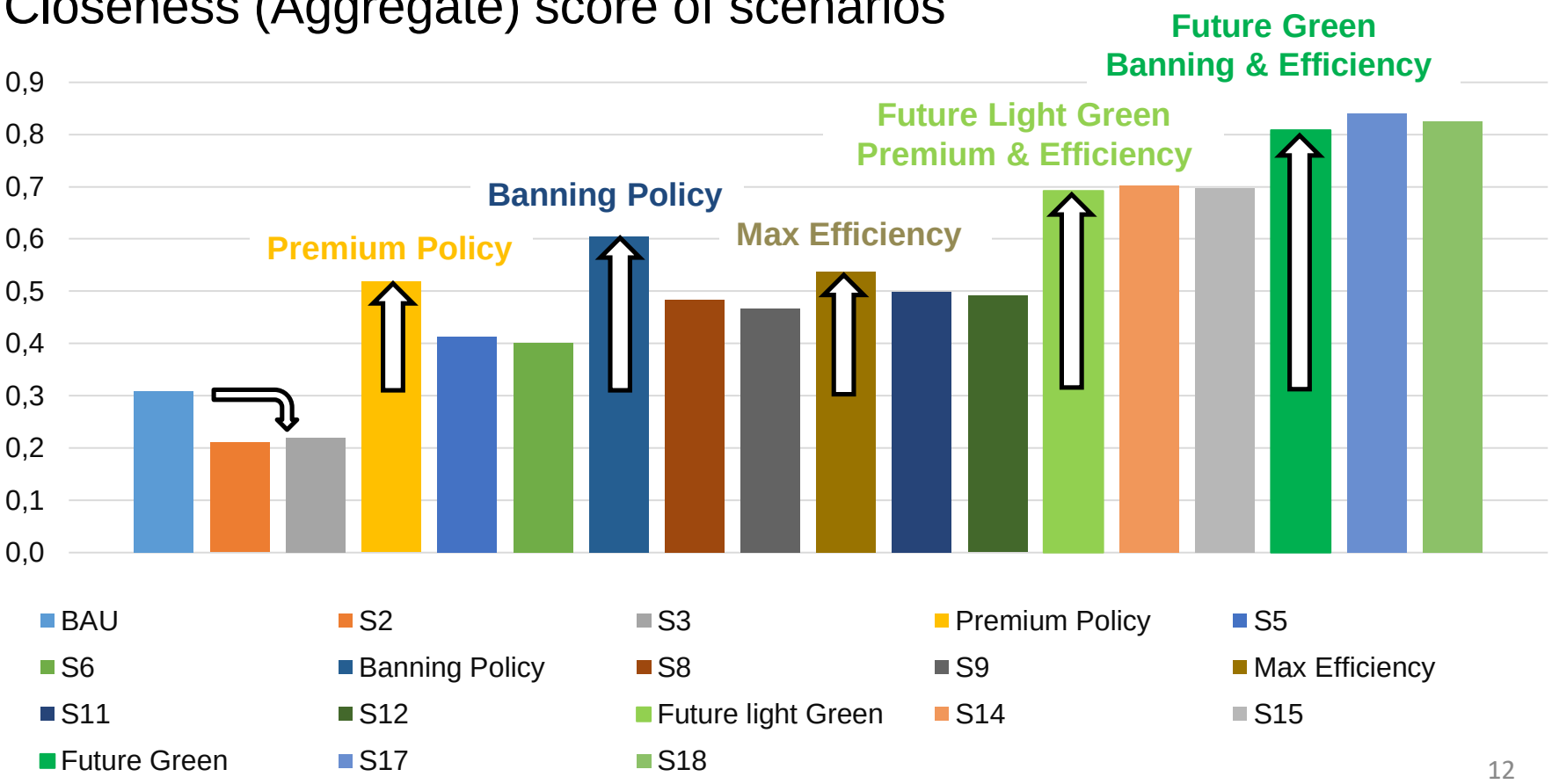
Weights of criteria for different stakeholder groups

	C1: Social Impacts	C2: Economic Development	C3: Environmental Impacts	C4: Energy Security	C5: Technical Aspect
Industrial Users	**36%**	18%	**24%**	**10%**	13%
Energy Producers	13%	**24%**	18%	**36%**	**10%**
Decision Makers	13%	18%	**36%**	**24%**	**10%**
Professional Interest	18%	**10%**	**24%**	**36%**	13%
Public	13%	18%	**36%**	**24%**	**10%**
D&T	**10%**	18%	13%	**36%**	**24%**
NGO	**36%**	18%	**24%**	13%	**10%**

4. Challenging thinking

Synthesizing information

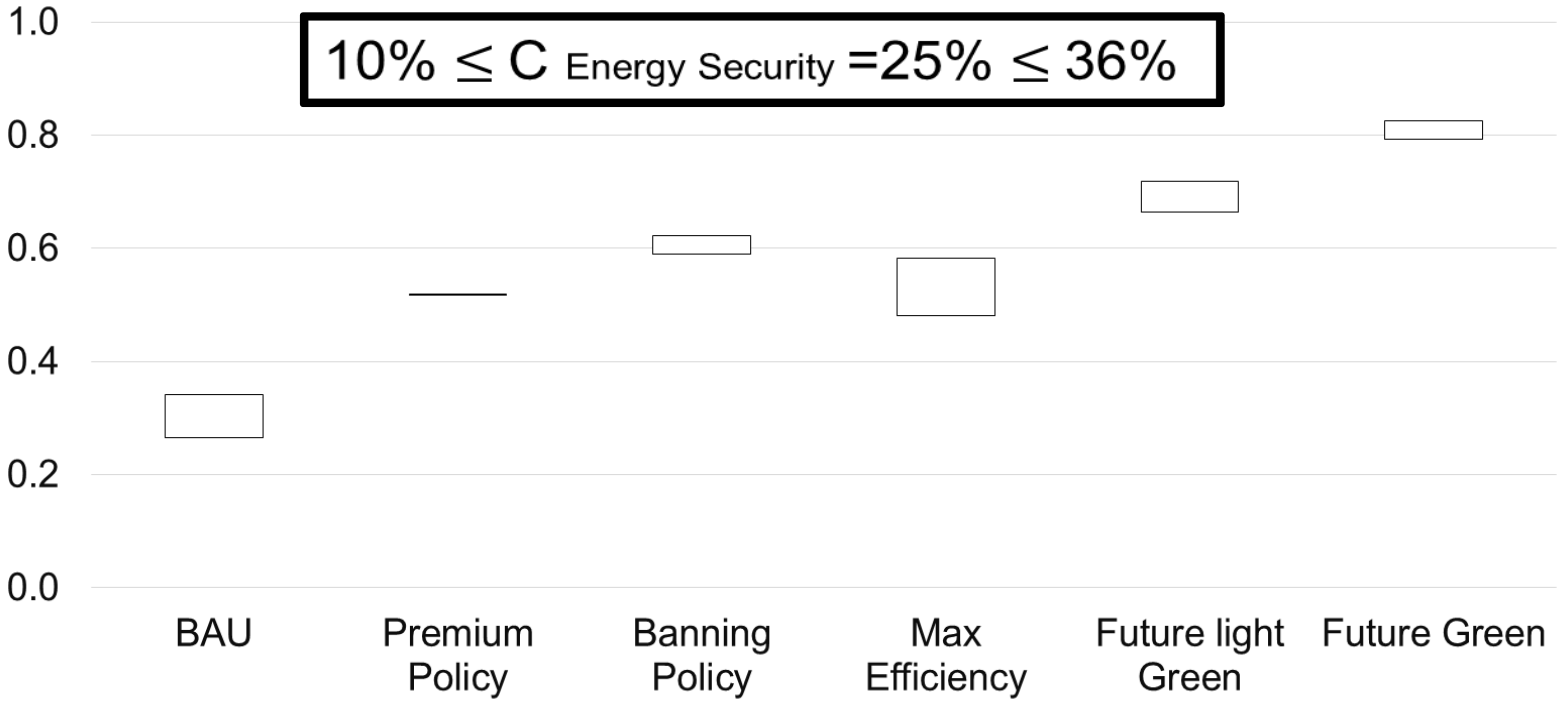
Closeness (Aggregate) score of scenarios



4. Challenging thinking

Sensitivity Analysis

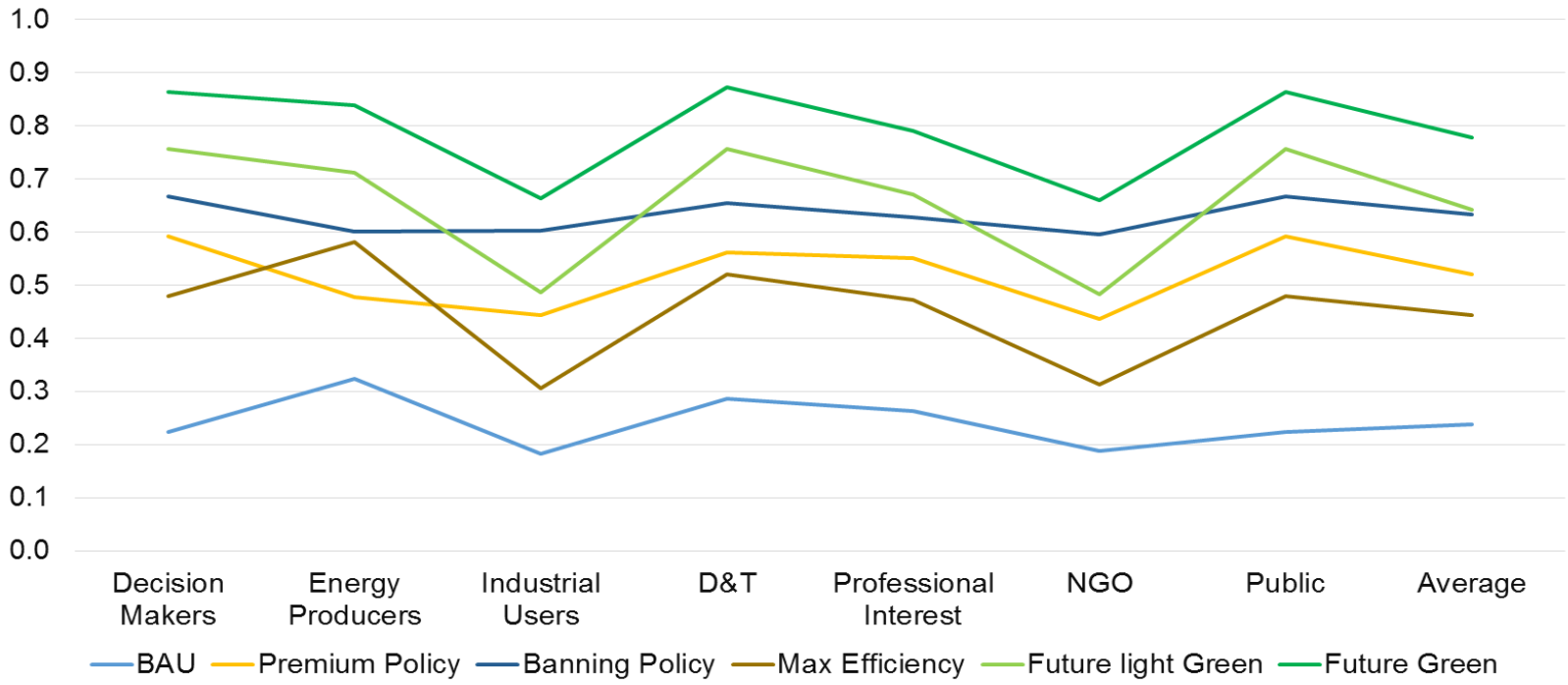
- Uncertainty in the weights



4. Challenging thinking

Analyzing Robustness

- Consensus among stakeholder groups



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5. Developing an Action Plan (ongoing)

- Comparing the performance scores of scenarios in five criteria of (Social Impacts, Economic development, Environmental Impacts, Energy Security and Technical Aspects), **the Future Green trajectory combining the Banning policy and Energy Efficiency** looks promising.
- As a result of the sensitivity analysis, **the Future Green trajectory** can be recommended as a robust trajectory.

Thank you for your attention

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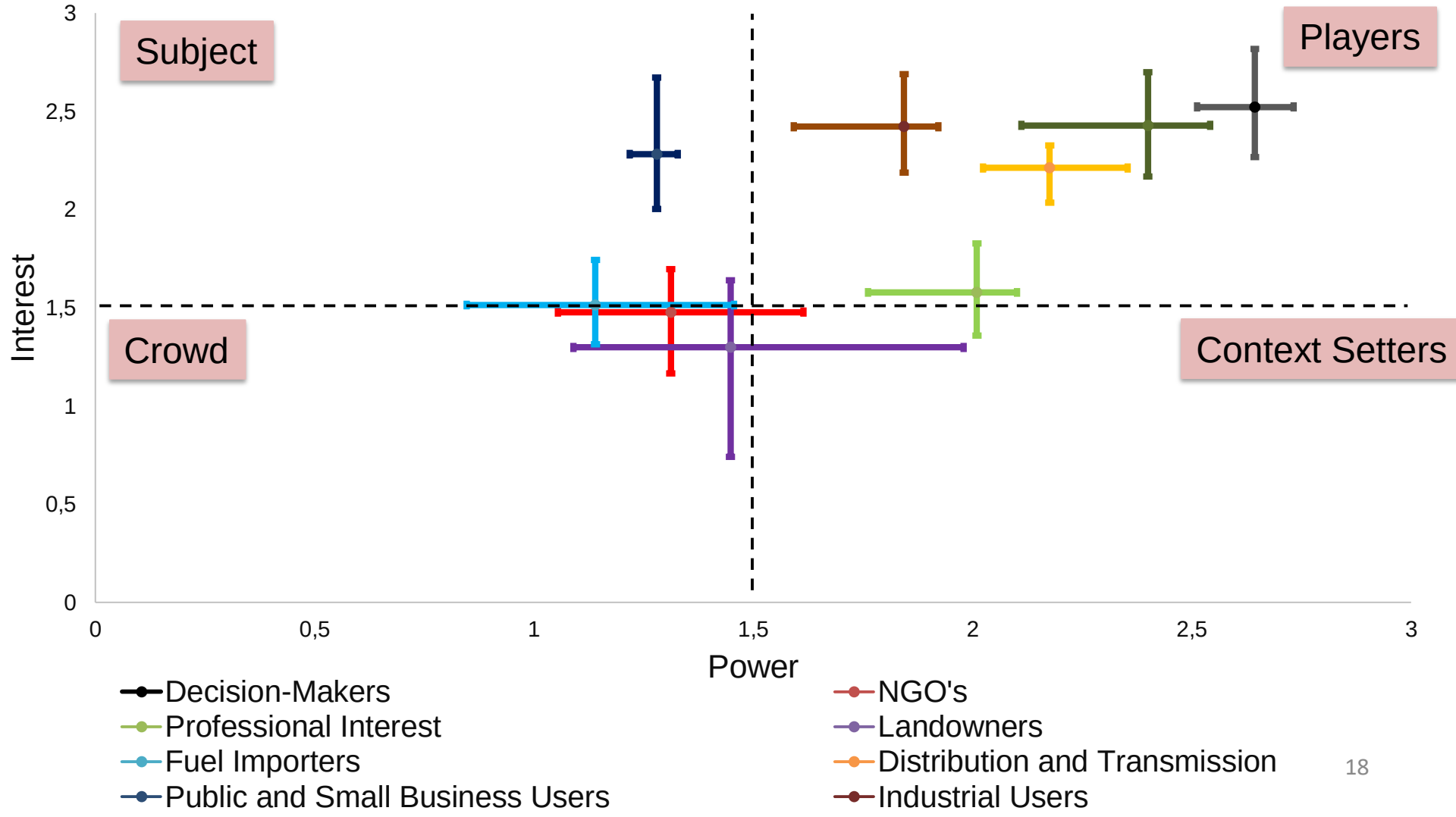
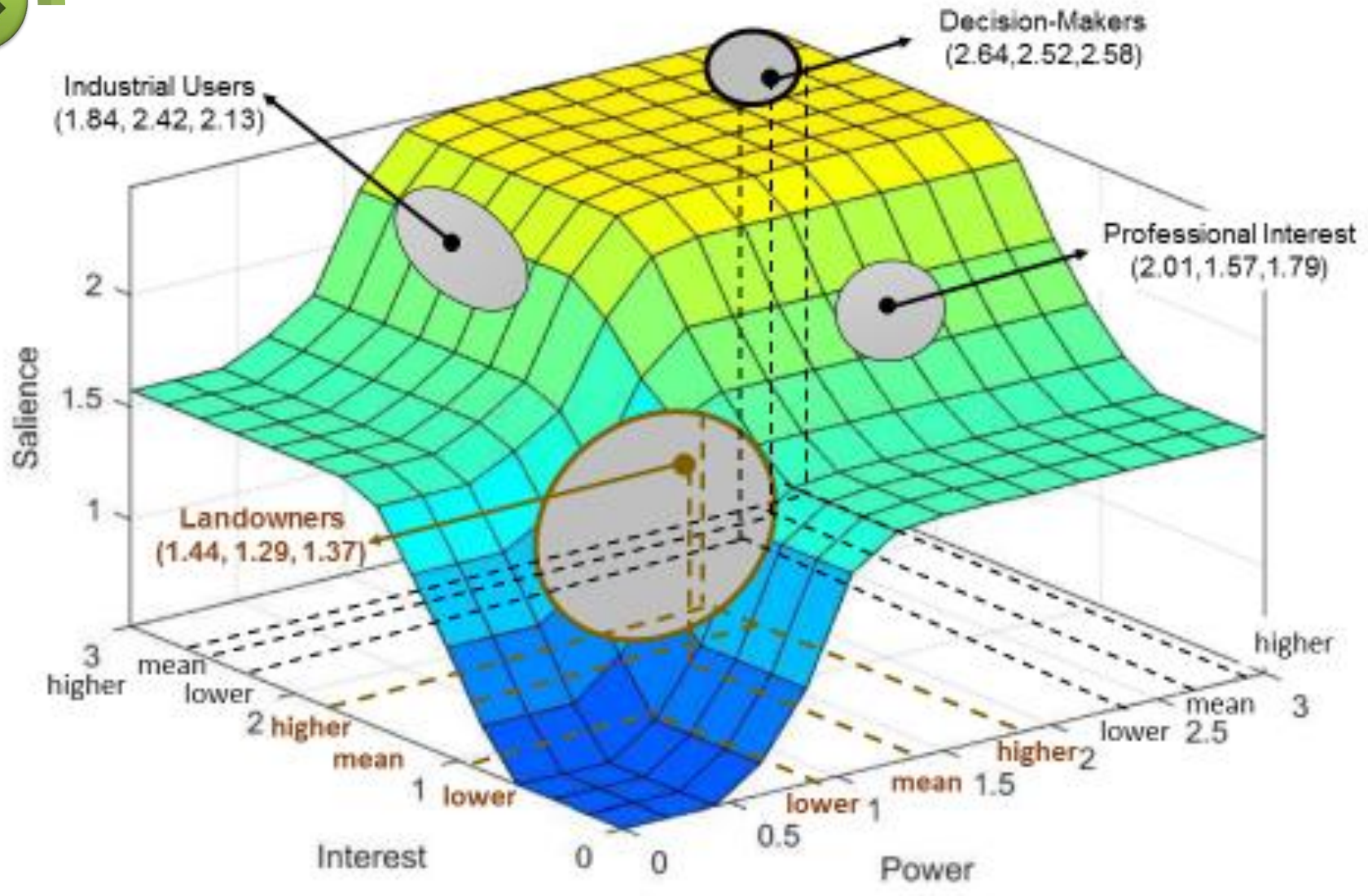
2. Problem Structuring

Stakeholders

- Stakeholder Analysis
  a) Identification of stakeholders
  b) Stakeholder mapping
     - Utilizing the Power-Interest Matrix (Eden and Ackerman, 1998)
     - Using Fuzzy logic (Zadeh, 1965)

Stakeholder mapping




Decision-Makers
(2.64,2.52,2.58)
Industrial Users
(1.84, 2.42, 2.13)
Professional Interest
(2.01,1.57,1.79)
Landowners
(1.44, 1.29, 1.37)
Salience
2
1.5
1
Interest
3
higher
mean
lower
2
higher
mean
1
lower
0
0
0.5
lower
1
mean
1.5
higher
2
Power
lower
mean
2.5
higher
3

Questionnaire

10 Questions to rank/rate decision criteria

* 1. Please assign rank-order to the five criteria for sustainable energy trajectories in Iceland according to their importance. Most important criterion should be assigned with Rank-1 and the second most important criterion with Rank-2 and so on.

Criteria code	Sustainable energy development criteria	Sub-criteria	Rank
C-1	Social Impacts	• Social Benefit • Consumer Behavior	
C-2	Economic Development	• Government Expenditure/Revenue • Affordable Energy Price • Economically efficient energy system	
C-3	Environmental Impacts	• Wilderness Protection and Visual Pollution • Net Emissions	
C-4	Energy Security	• Energy Reserve • The diversity of energy sources • Energy independence	
C-5	Technical Aspect	• Fuel Switching • Infrastructure Development • Energy Efficiency	

≡ C-1: Social Impacts

≡ C-2: Economic Development

≡ C-3: Environmental Impacts

≡ C-4: Energy Security

≡ C-5: Technical Aspect

3. Model Building

Defining Criteria

Criteria code	Sustainable energy development criteria	Sub-criteria
C-1	Social Impacts	• Social Benefit • Consumer Behavior • Government Expenditure/Revenue
C-2	Economic Development	• Affordable Energy Price • Economically efficient energy system
C-3	Environmental Impacts	• Wilderness Protection and Visual Pollution • Net Emissions
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C-5	Technical Aspect	• Fuel Switching • Infrastructure Development • Energy Efficiency

4. Challenging thinking

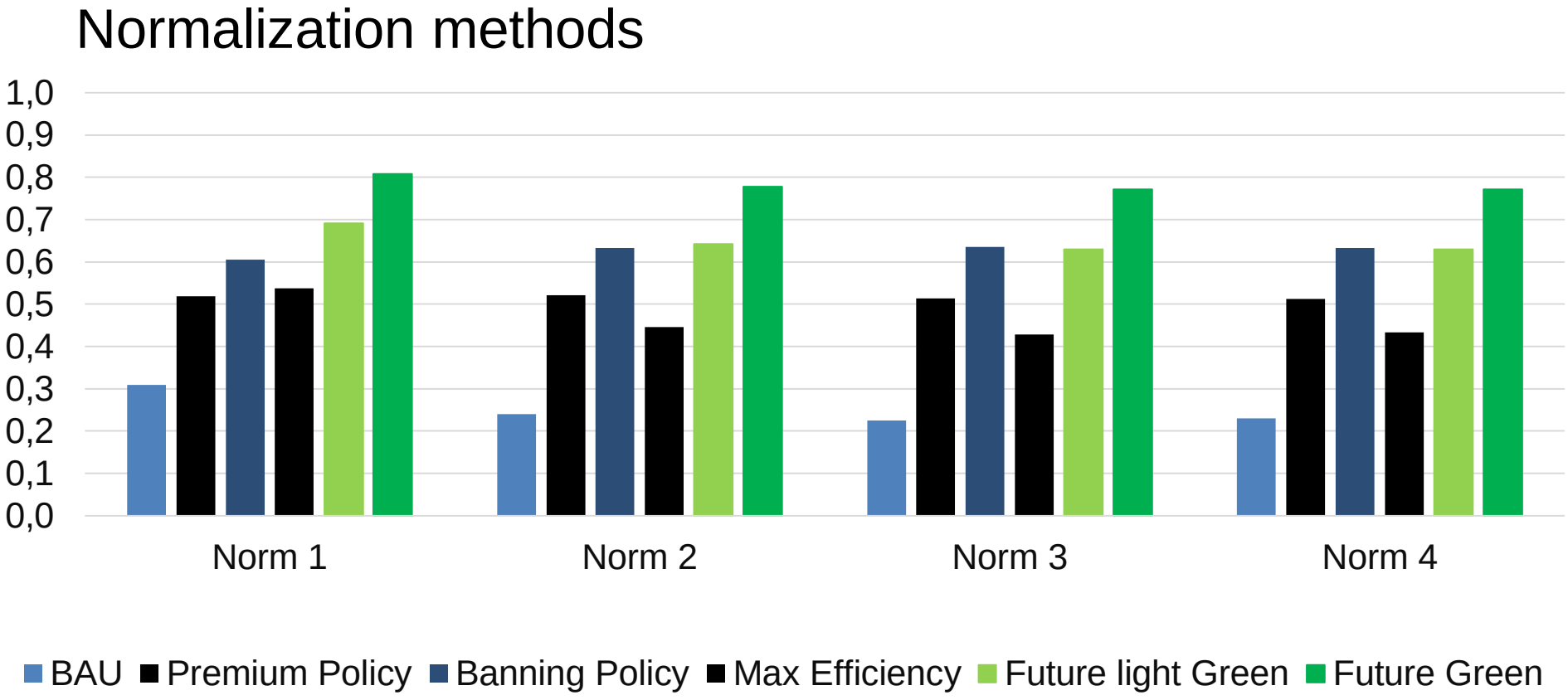
Synthesizing information

Performance score of scenarios across five criteria

	Social Impacts	Economic Development	Environmental Impacts	Energy Security	Technical Aspect
BAU	0.87	0.30	0.08	0.60	0.47
S2	0.37	0.24	0.01	0.69	0.45
S3	0.37	0.23	0.00	0.71	0.45
Premium Policy	0.43	0.31	0.17	0.60	0.62
S5	0.44	0.24	0.10	0.69	0.60
S6	0.44	0.23	0.09	0.71	0.60
Banning Policy	0.53	0.33	0.17	0.60	0.63
S8	0.53	0.27	0.11	0.69	0.61
S9	0.53	0.26	0.10	0.71	0.61
Max Efficiency	0.38	0.40	0.23	0.49	0.52
S11	0.38	0.36	0.15	0.53	0.51
S12	0.39	0.35	0.14	0.54	0.51
Future light Green	0.45	0.40	0.31	0.49	0.66
S14	0.46	0.37	0.22	0.53	0.64
S15	0.46	0.36	0.22	0.54	0.64
Future Green	0.57	0.43	0.32	0.49	0.69
S17	0.57	0.39	0.24	0.53	0.68
S18	0.58	0.38	0.24	0.54	0.68

4. Challenging thinking

Sensitivity Analysis



4. Challenging thinking

Sensitivity Analysis

- Uncertainty in the weights

$$10\% \leq C_{\text{Energy Security}} = 25\% \leq 36\%$$