Karlsruhe Institute of Technology

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Scenarios for Energy Transition Acceleration
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Methodology for the evaluation of social, environmental, and energy indicators beyond energy system models

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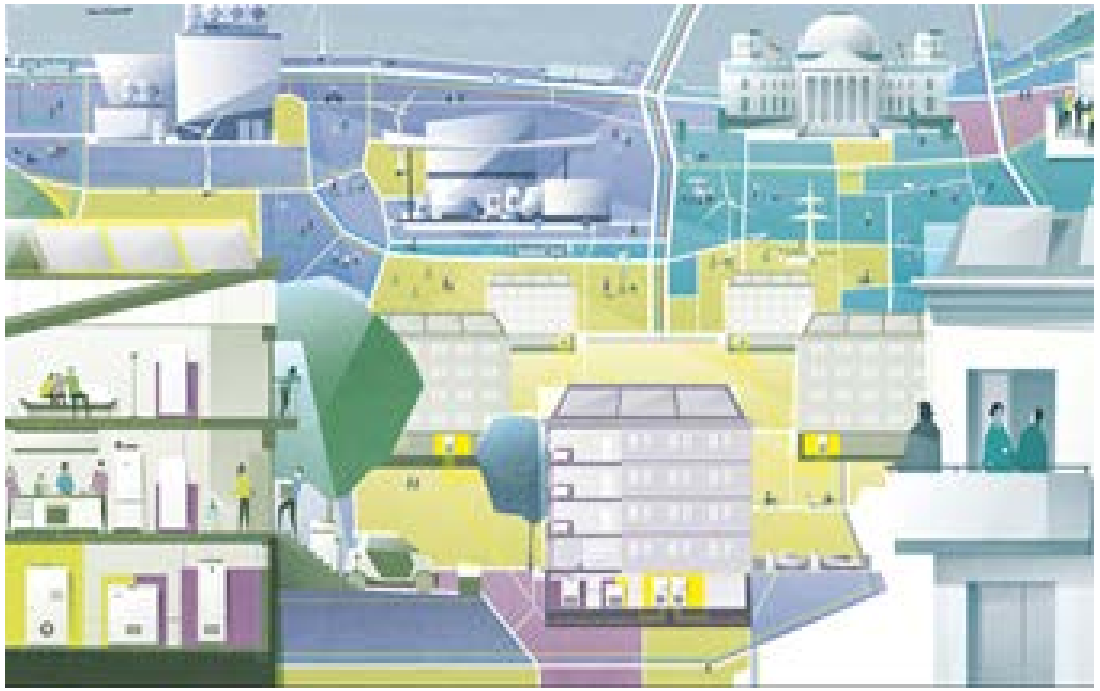
Motivation – Assessment of future energy systems

- Energy systems
  - are socio-(economic-)technical systems
  - shall contribute essentially to a sustainable transformation of economies and societies

- Socio-technical systems assume the embeddedness of technical systems in societal developments

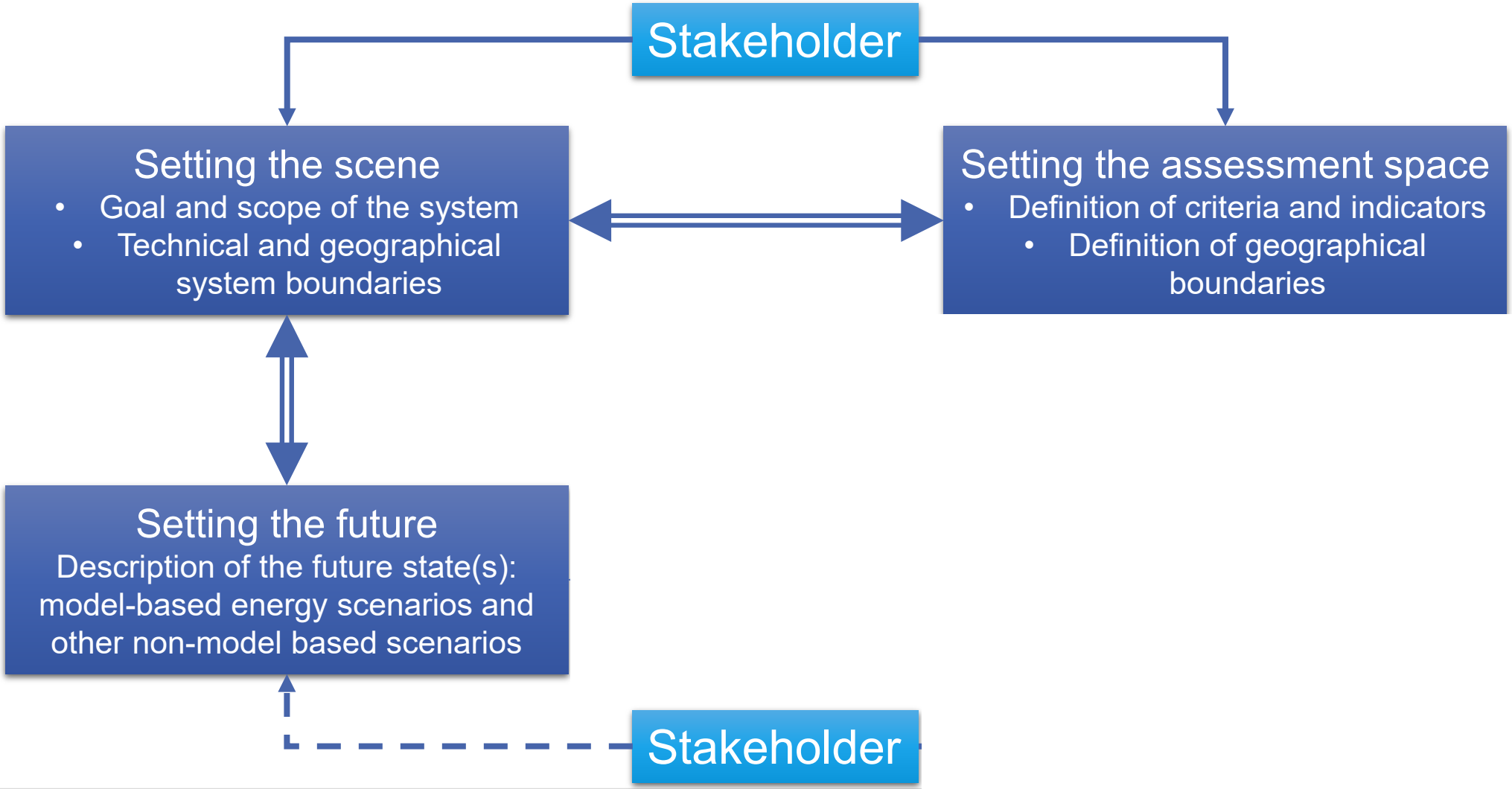
- Energy system models
  - focus on dynamics of technologies and costs
  - setting societal dynamics “constant”



https://www.kopernikus-projekte.de/vision

- How to identify relevant indicators?
- How to estimate the indicator values?

Identifying relevant indicators

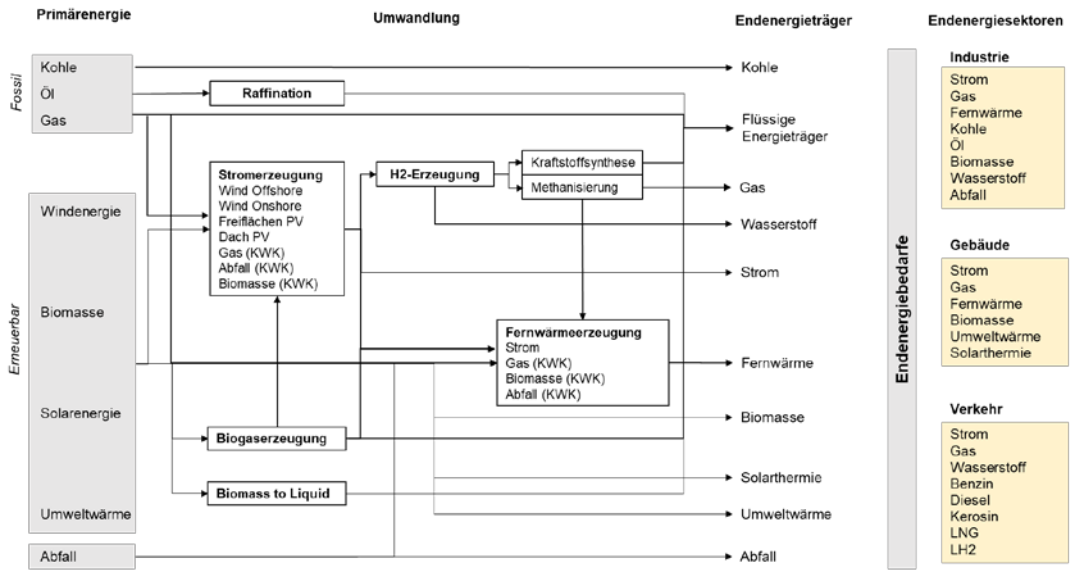


Setting the scene – The case of Steinburg

Goal and scope of the system:

Providing energy to a region and outside, considering

- the socio-technical characteristics of the energy system, i.e. the interrelation with the
  - technical system
  - economic system
  - societal system
  - environment
- the contribution to a sustainable transformation of the economy



Setting the assessment space – Identifying relevant indicators

- What are the most important criteria and indicators which characterize a sustainable future energy system?

- Possible sources:
  - Sustainable Development Goals (SDG)
  - Literature
  - Stakeholders

Case of Steinburg

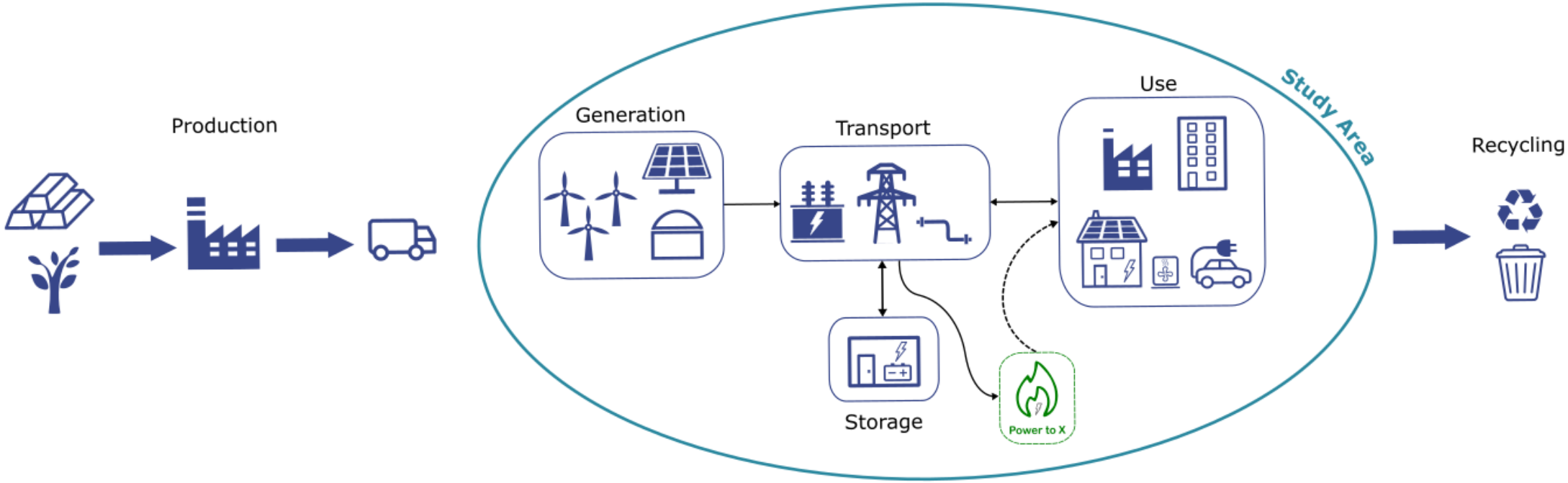
- Identifying relevant topics
  - Health
  - Climate, environment and resources
  - Basic services and economy
  - Society
- For each topic criteria has to be identified
- For each criteria indicators has to be defined

Setting the assessment space – Criteria and indicators

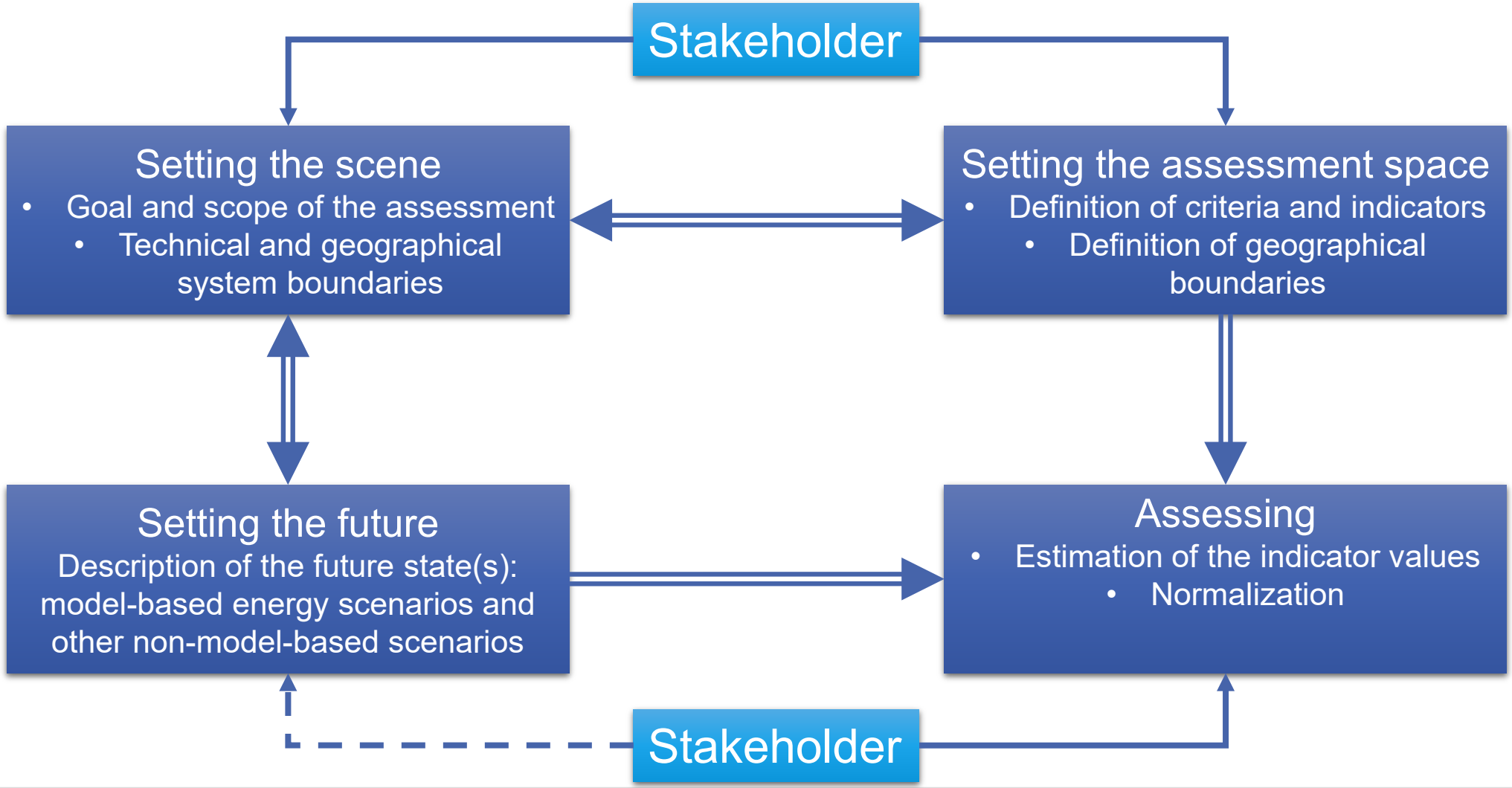
		Criterion	Indicator
Health	1	Air pollutant emissions	*kg PM2.5*
	2	Other emissions (Noise & light)	*Weighted: number of wind turbines; noisy vehicle kilometres*
Climate, Environ., Resources	3	Global warming potential	*t CO_2 eq.*
	4	Land use by energy system	*ha direct land use*
	5	Resource demand (Metal and minerals)	*kg Sb eq.*
	6	Resource demand (Energy)	*MJ eq. cumulative fossil energy expenditure*
	7	Eutrophication	*kg PO eq.*
	8	Acidification	*kg SO_2 eq.*
Basic services, Economy	9	Employment	*full-time equivalents (power sector)*
	10	Regional value added	*€ gross value added*
	12	Energy import dependency	*% import ratio*
	13	Conflict of use with food production	*ha land use for energy crops*
Society	11	Energy poverty	*€*
	14	Fairness (Final energy demand of private households)	*kWh / person*
	15	Procedural participation	*qualitative*
	16	Financial participation opportunities	*semiquantitative*
	17	Landscape	*ha indirect land use*

Setting the assessment space – Geographical boundaries

- Geographical boundaries of the system and of criteria / indicators may differ => “burden shifting”
- Life cycle approach may be a suitable approach



Estimating indicator values



Assessing – Estimating indicator values

- ESM is the anchor
  - Energy mix
  - Energy provision and demands
  - Installed capacities

		Criterion	Method
Health	1	**Air pollutant emissions**	*Connecting ESM with LCA*
	2	**Other emissions (Noise & light)**	*ESM & average size of future wind pp and PV*
Climate, Environ., Resources	3	**Global warming potential**	*Connecting ESM with LCA*
	4	**Land use by energy system**	*Connecting ESM with LCA*
	5	**Resource demand (Metal and minerals)**	*Connecting ESM with LCA*
	6	**Resource demand (Energy)**	*Connecting ESM with LCA*
	7	**Eutrophication**	*Connecting ESM with LCA*
	8	**Acidification**	*Connecting ESM with LCA*

Assessing – Estimating indicator values

		Criterion	Method
Basic services, Economy	9	**Employment**	*ESM & regional IOT & sectoral employment table*
	10	**Regional value added**	*ESM & regional IOT*
	12	**Energy import dependency**	*ESM => regional energy balance*
	13	**Conflict of use with food production**	*Connecting ESM with LCA*
Society	11	**Energy poverty**	*ESM & energy efficiency of household living & energy prices*
	14	**Fairness (Final energy demand of private households)**	*ESM & regional population estimation*
	15	**Procedural participation**	*Valuation of the need to include society in the decisions of installing new power plants*
	16	**Financial participation opportunities**	*Assessment of (current) participation opportunities in relation to the future mix of RES in the region*
	17	**Landscape**	*ESM & average indirect land use*

Results – Financial participation

	Fulfillment sustainability*	Onshore wind energy		Roof PV		Ground-mounted PV		Biogas	
		Importance 2050**	Result	Importance 2050**	Result	Importance 2050**	Result	Importance 2050**	Result
Citizen energy companies	1,75	2	3,5	1	1,75	2	3,5	0	0
Prosuming	1,00	0	0	2	2	0	0	1	1
Debt participation in third-party projects	0,75	1	0,75	1	0,75	1	0,75	1	0,75
Levies to local authorities	1,75	2	3,5	0	0	2	3,5	0	0
Local discounted rates	1,75	2	3,5	0	1,75	2	3,5	1	1,75
Lease income	0,50	2	1	1	0,5	2	1	1	0,5
Trade tax	2,00	2	4	0	0	2	4	1	2
Community foundations or community projects for the common good	2,50	1	2,5	0	0	1	2,5	0	0
Valuation summary			18,75		6,75		18,75		6

*Fulfilment of sustainability: average of values between 1 and 3 (higher = fulfilment of sustainability criteria rather given).
**Importance 2050: 0 = not given or hardly given; 1 = partly given / possible / constant; 2 = increasingly given / obligatory

Valuation figures are then multiply with installed generation capacities

Results – Procedural participation

Scenario A	Scenario B	Scenario C	Scenario D
Oriented to the current participation options. Extensive changes are not expected.	This ambitious goal is linked to the desire and need for greater involvement of society. For this reason, both the legal requirements and the informal opportunities for participation are being expanded.	On the one hand, integration into the European target system reduces the pressure for domestic expansion and thus, compared to scenario B, also the need for participatory involvement opportunities. However, the opportunities for participation are more comprehensive than in scenario A.	Scenario D implies in principle a stronger regional expansion of renewable energies and thus the increased need for on-site participation opportunities.
0	1	**0.5**	**1**

Results

		Scenario A	Scenario B	Scenario C	Scenario D
Air pollutant emissions	kg 2.5PM	29,023	22,093	19,044	23,025
Other emissions (Noise & light)	Dimensionless	0.31	0.35	0.19	0.14
Global warming potential	t CO_2 -eq.	319,247	221,410	209,376	247,914
Land use by energy system	ha	286.6	470.4	476,2	322,6
Resource demand (Metal and minerals)	kg Sb-eq.	36,435	39,803	30,466	45,847
Resource demand (Energy)	TJ-eq.	3,286	2,514	2,389	2,825
Eutrophication	kg PO_4 -eq.	10,895,187	9,196,615	12,947,656	12,940,304
Acidification	kg SO_2 -eq.	8,284,187	6,940,514	8,909,150	9,096,258
Employment	Full-time equivalent	222	324	278	233
Regional value added	€ million	1,575	2,746	2,424	2,969
Energy import dependency	Import ratio	7.9 %	4.4 %	3.7 %	11.6 %
Conflict of use with food production	ha	3,394	3,074	3,436	2,270
Energy poverty	Dimensionless	0.23	0.31	0.25	0.20
Fairness (Final energy dem. of priv. households)	kWh/person	7,592	6,454	7,380	7,380
Procedural participation	Score	0	1	0.5	1
Financial participation opportunities	Dimensionless	15,299	29,013	26,390	30,199
Landscape	ha	3,970	5,909	5,540	6,782

Note: Scenario A, B, C, and D stand for different scenarios

- A = reference, least ambitious (-85% greenhouse gas emissions in 2050 compared to 1990)
- B = most ambitious (<< +2.0 °C)
- C = less ambitious, centralized energy system (< +2.0 °C)
- D = less ambitious, decentralized energy system (< +2.0 °C)

Assessing – Estimating indicator values

- Different units make even a preliminary assessment of the energy futures hard

- A possible approach:
  - to calculate the relative distances for each indicator value per criterion in a range between 0 and 1
  - but, the relative difference between the best and worst performance is not recognized

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Assessing – Normalized results

	Criterion	Scores			
		A	B	C	D
1	Particulate matter	0,00	0,89	0,95	1,00
2	Noise & light emissions	1,00	0,79	0,46	0,00
3	Greenhouse gas emissions	0,00	1,00	0,84	0,87
4	Land use	0,95	0,17	0,00	1,00
5	Resource consumption	0,50	1,00	0,65	0,00
6	Cumulative fossil energy expenditure	0,00	1,00	0,81	0,95
7	Eutrophication	0,00	0,90	0,79	1,00
8	Acidification	0,00	1,00	0,51	0,37
9	Employment effects	0,00	1,00	0,55	0,11
10	Regional value added	0,00	0,84	0,61	1,00
12	Energy import dependency	0,47	0,91	1,00	0,00
11	Energy poverty	0,35	1,00	0,52	0,00
13	Conflict of use with food production	0,04	0,31	0,00	1,00
14	Final energy consumption of private households	0,00	1,00	0,19	0,19
15	Procedural participation	0,00	1,00	0,50	1,00
16	Financial participation	0,00	0,95	0,73	1,00
17	Landscape	1,00	0,31	0,44	0,00

Notes:

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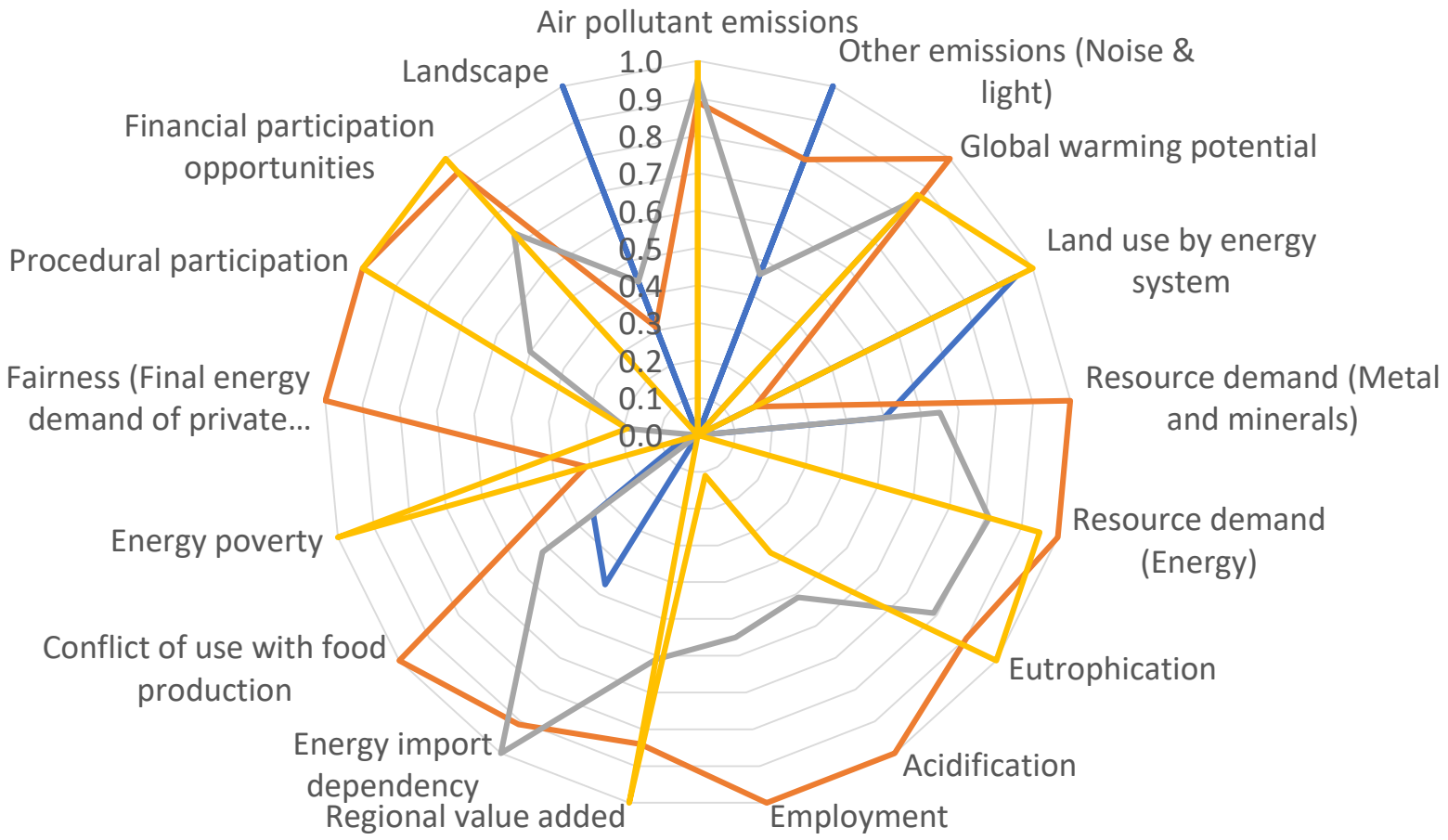
- Figure 1 indicates the best performance
- Figure 0 indicates the worst performance
- Figures between 0 and 1 indicates the distance to the best performance

Assessing – Normalized results



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Conclusions

- Sound methods
  - to identify indicators and
  - to estimate the indicators

  are available
- Number of methods is sufficient

- Challenges are
  - combination of “quantified” and “qualified” estimations of indicator values
  - definition of coherent system boundaries (system vs. indicators)
  - appropriate normalization procedures
  - (appropriate methods to implement preferences for criteria)

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