University of Stuttgart
Germany
ZIRIUS - Center for Interdisciplinary Risk and Innovation Studies

Adding the Social Perspective to Live Cycle Analysis (LCA) of Energy Transition Scenarios

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Supported by:
Federal Ministry for Economic Affairs and Energy
on the basis of a decision by the German Bundestag

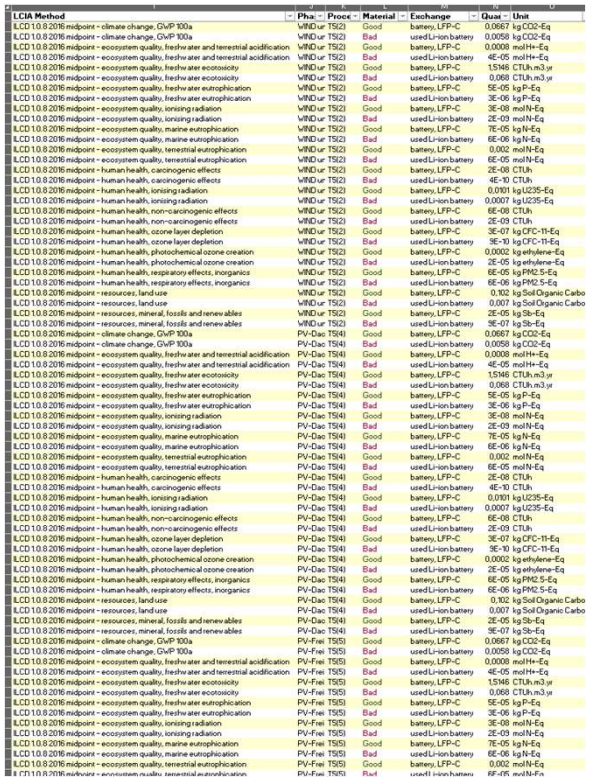
InNOSys - LCA-Analysts and Social-Scientists

The Problem

- LCA (life cycle analysis) data includes +43.000 variables on ecological effects from technologies used in the transition to green energy production. Economic science offers hundreds of variables assessing the financial outcome of green energy production technologies.

→ Data on social impact for sustainable development is scarce and often not compatible for inclusive analysis.

- Our steps in Project InNOSys
  a) Tracing which future & technologies Citizens prefer.
  b) Fill gaps in the sustainability concept with qualitative data on Quality of life, justice between generations and justice of distribution of benefits of energy change



LCIA Method	Pha	Proce	Material	Exchange	Quar	Unit
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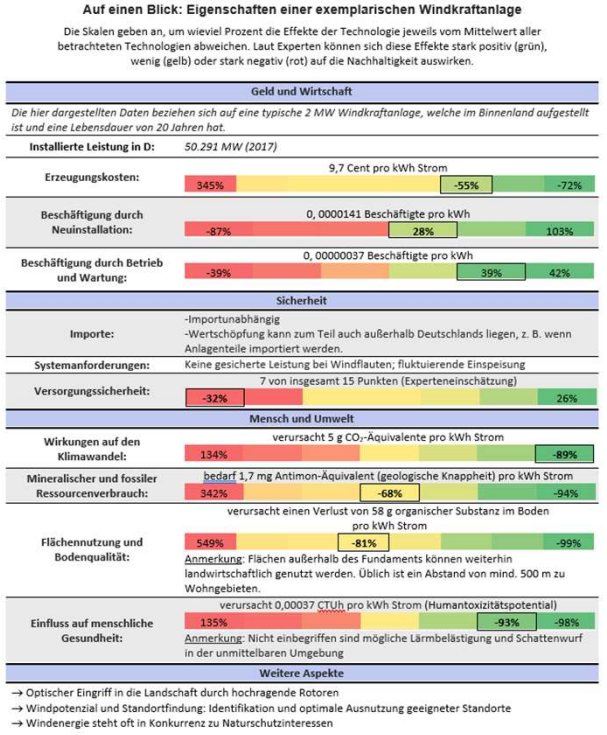
Informing the Citizens

From LCA data to usable knowledge

We took the LCA-data for 7 power (& heat) technologies: wind turbine, photovoltaics (on field / on roof), natural gas, geothermal energy, Power-to-gas, Lithium- battery, heat pump. We translated an normalized it to 8 scales: Costs, employment (installation / maintenance) security of supply, contribution to climate change, usage of resources, land use, damage to ecosystems and damage to human health.

We expressed the numbers on a red to green (related to sustainability) scale with their change if implemented in percentage in comparison to the others.



Auf einen Blick: Eigenschaften einer exemplarischen Windkraftanlage

Die Skalen geben an, um wieviel Prozent die Effekte der Technologie jeweils vom Mittelwert aller betrachteten Technologien abweichen. Laut Experten können sich diese Effekte stark positiv (grün), wenig (gelb) oder stark negativ (rot) auf die Nachhaltigkeit auswirken.

Geld und Wirtschaft	
Die hier dargestellten Daten beziehen sich auf eine typische 2 MW Windkraftanlage, welche im Binnenland aufgestellt ist und eine Lebensdauer von 20 Jahren hat.	
Installierte Leistung in D:	*50.291 MW (2017)*
Erzeugungskosten:	9,7 Cent pro kWh Strom 345% -55% -72%
Beschäftigung durch Neuinstallation:	0, 0000141 Beschäftigte pro kWh -87% 28% 103%
Beschäftigung durch Betrieb und Wartung:	0, 00000037 Beschäftigte pro kWh -39% 39% 42%
Sicherheit	
Importe:	-Importunabhängig -Wertschöpfung kann zum Teil auch außerhalb Deutschlands liegen, z. B. wenn Anlagenteile importiert werden.
Systemanforderungen:	Keine gesicherte Leistung bei Windflauten; fluktuierende Einspeisung
Versorgungssicherheit:	7 von insgesamt 15 Punkten (Experteneinschätzung) -32% 26%
Mensch und Umwelt	
Wirkungen auf den Klimawandel:	verursacht 5 g CO_2-Äquivalente pro kWh Strom 134% -89%
Mineralischer und fossiler Ressourcenverbrauch:	bedarf 1,7 mg Antimon-Äquivalent (geologische Knappheit) pro kWh Strom 342% -68% -94%
Flächennutzung und Bodenqualität:	verursacht einen Verlust von 58 g organischer Substanz im Boden pro kWh Strom 549% -81% -99% Anmerkung: Flächen außerhalb des Fundaments können weiterhin landwirtschaftlich genutzt werden. Üblich ist ein Abstand von mind. 500 m zu Wohngebieten.
Einfluss auf menschliche Gesundheit:	verursacht 0,00037 CTUh pro kWh Strom (Humantoxizitätspotential) 135% -93% -98% Anmerkung: Nicht einbegriffen sind mögliche Lärmbelästigung und Schattenwurf in der unmittelbaren Umgebung
Weitere Aspekte	
→ Optischer Eingriff in die Landschaft durch hochragende Rotoren → Windpotenzial und Standortfindung: Identifikation und optimale Ausnutzung geeigneter Standorte → Windenergie steht oft in Konkurrenz zu Naturschutzinteressen	

Presenting paired-choices

breaking down complex information

- To convey a feeling hat the technologies are not single solutions, we presented always paired-technologies as combined systems.
- To facilitate the decision and present more choices per respondent (n=12), the combined systems were presented as paired-choice experiment with the question to mark the more sustainable system.
- We conducted the experiment with 124 citizens, 60 only got the information and access to the online experiment, 64 got the information, met in 6 focus groups and then access to the online experiment.
- Among these 3 age groups were sampled: students, working people, seniors.

Welches der beiden Paare wäre aus Ihrer Sicht eine insgesamt nachhaltigere Stromversorgung in Deutschland?

Die Prozentzahlen stellen die Abweichungen vom jeweiligen Durchschnitt aller anderen betrachteten Paare dar. Werte sind entweder schlechter (rot/orange) oder besser (gelb/grün) als der Durchschnitt.)

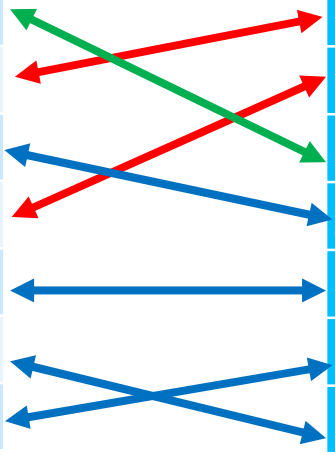
	A: Windkraftanlage + PV-Anlage	B: Gaskraftwerk + Geothermiekraftwerk
Beschäftigung – Installation & Neubau	-7%	-7%
Beschäftigung – Betrieb & Wartung	-24%	+35%
Gestehungskosten	-35%	-21%
Versorgungssicherheit	-19%	+40%
Effekte auf menschliche Gesundheit	-55%	+11%
Wirkung auf den Klimawandel	-84%	+274%
Flächenverbrauch	-91%	-62%
Ressourcenverbrauch	-25%	-81%

Paar A | Paar B

Ranking of Technologies

paired-choice experiment (left) vs. direct ranking (right)

Ranking calculated via Conjoint / paired-choice experiment		
1. Rank	1,41129032	Heat pump
2. Rank	0,66532258	Wind turb.
3. Rank	0,17741935	Geotherm.
4. Rank	-0,15053763	Photovoltaics
5. Rank	-0,74193548	Power-to-gas
6. Rank	-0,75806452	Natural gas
7. Rank	-0,88306452	Li - battery



Direct technology ranking from questionnaire		
1. Rank	5,92741935	Wind turb.
2. Rank	4,73387097	Photovoltaics
3. Rank	4,59677419	Heat pump
4. Rank	3,46774194	Geotherm.
5. Rank	3,33870968	Power-to-gas
6. Rank	3,03225806	Li - battery
7. Rank	2,90322581	Natural gas

→ well-known technologies tend to be favoured beyond the appreciation of their properties in the direct ranking, paired-choice with small energy systems mask single technologies and show attitudes without publicity bias.

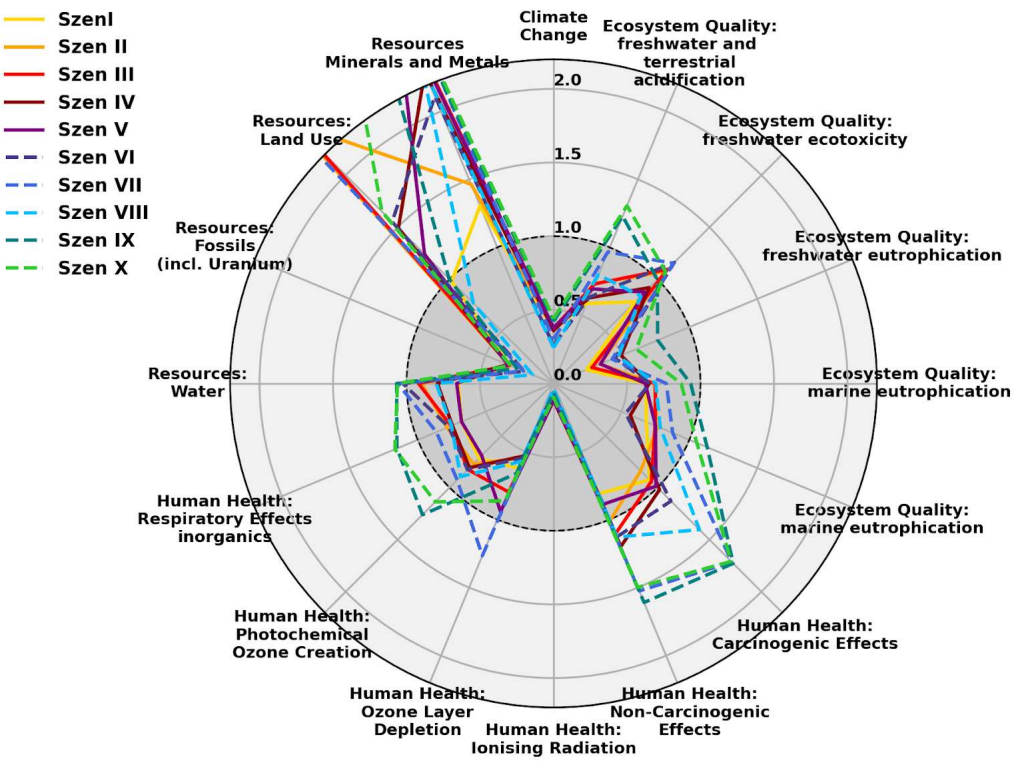
Conjoint Analysis of paired-choices

with mixed logit model

The conjoint analysis then enables us to assess the attitude towards the properties behind every technology.

Overall climate impact is the most important factor followed by resource depletion, health issues and security of supply for assessing sustainability to any energy scenario.

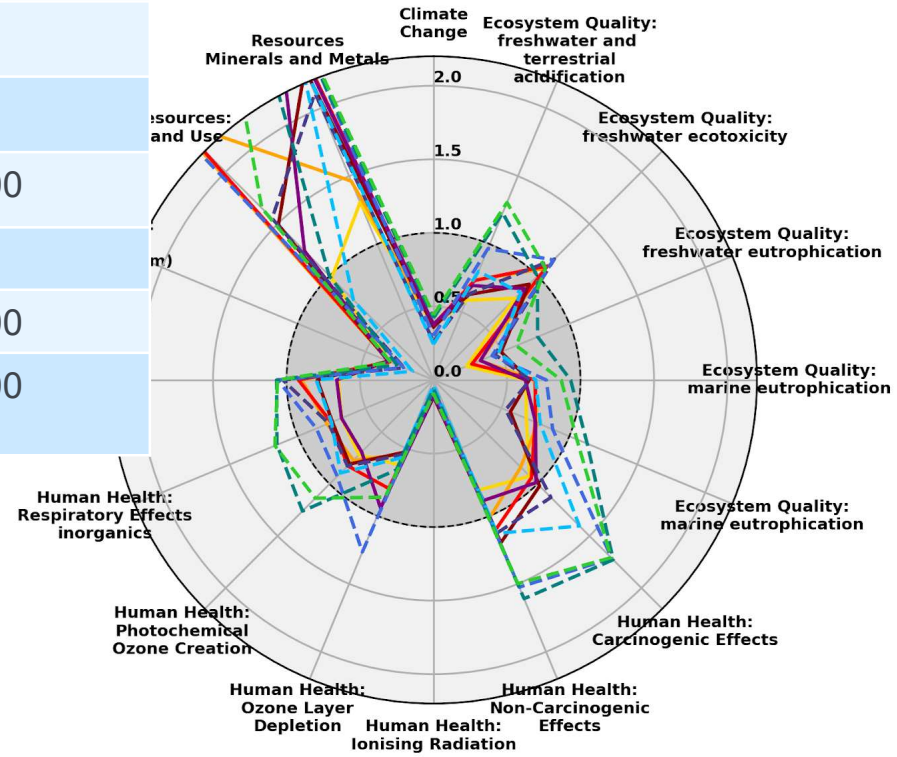
The coefficients now can be reincluded as social sustainability perception into the - soon to be published - results of our LCA collegues.



Source: DLR

Table 1: Results Discrete-Choice Experiment

Factor	β coefficient	significance
costs	0.0138	0.037
Security of supply	0.0229	0.004
Employment	0.0137	0.006
Climate impact	0.0581	< 0.000
Human health impact	0.0252	0.006
Land use	0.0189	< 0.000
Consumption of resources	0.0299	< 0.000



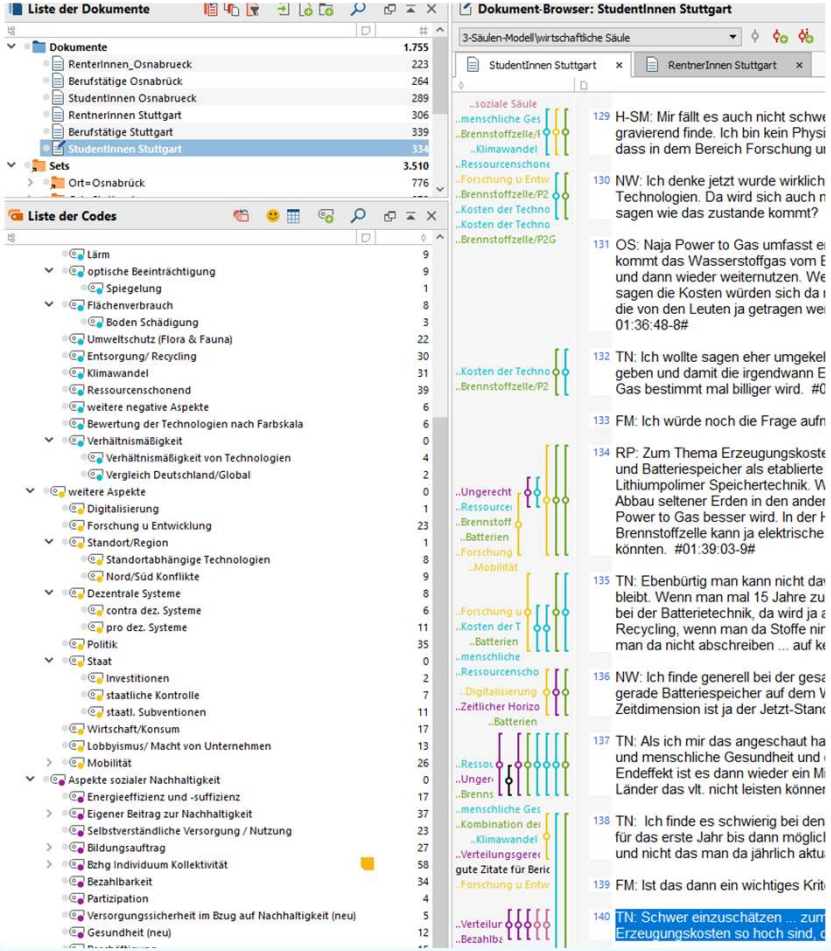
Qualitative analysis of focus groups
using Max QDA

Transferring audio records into transcripts 922 statements in total, about 153 per focus group

A code tree for all different arguments with regards to content / topics discussed / opinions found is created.

3 different social scientists (intercoder realiability) mark the transcripts independently, then discus changes and adjustments to code base and unify code mapping.

Crosschecking of mapping three times.
1.755 coded positions in total, 86 different codes

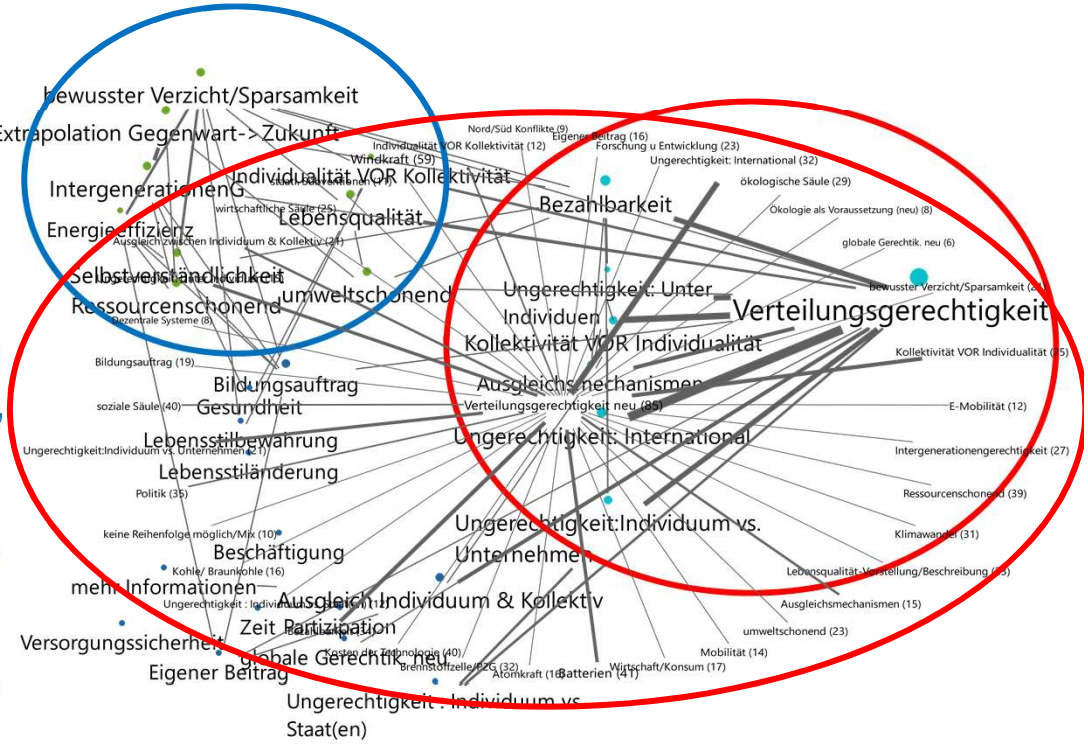


Qualitative analysis of focus groups

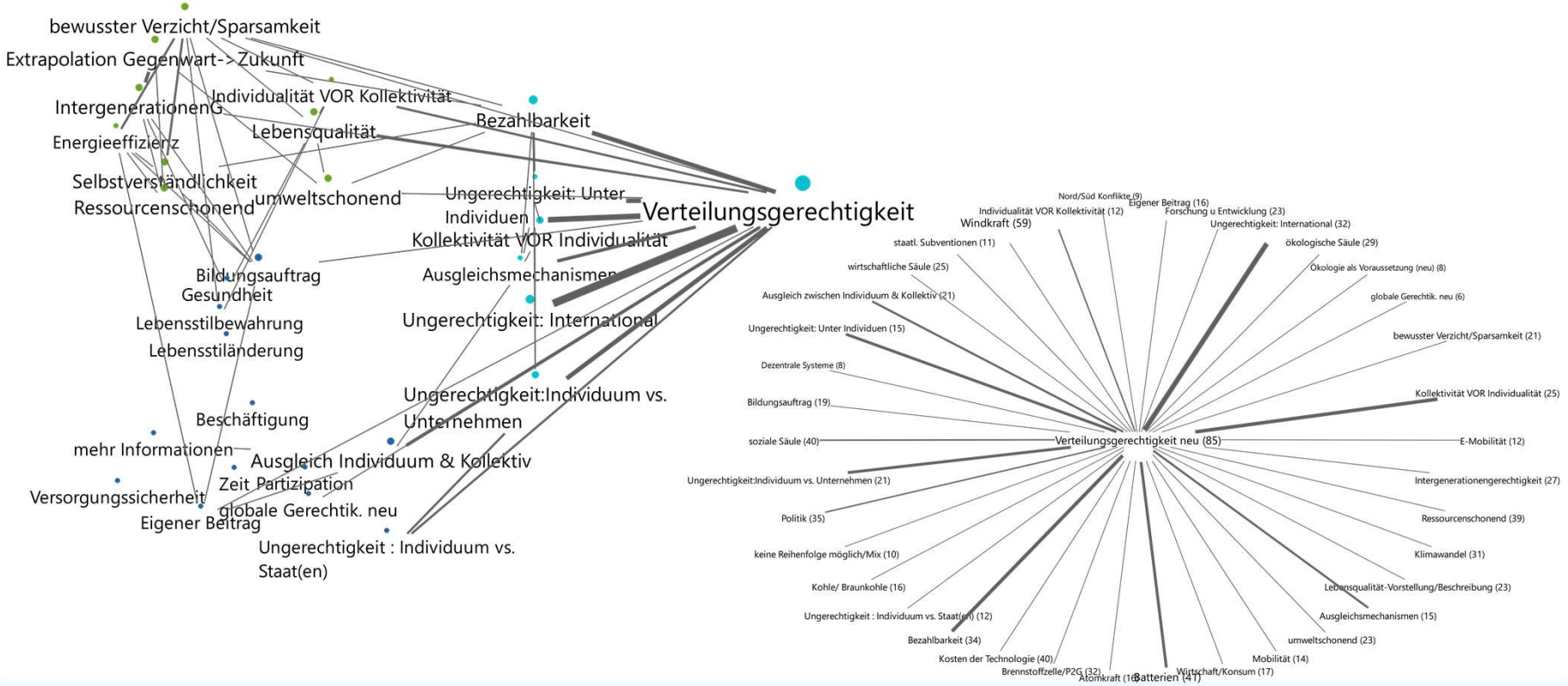
Code clusters

"Distributional justice" is the most talked about topic in the focus groups. It is strongly connected to arguments circling around ecology, injustice among individuals, injustice between individuals and corporations and costs.

The topic "justice between generations" is another argument cluster, mostly among retired participants. The debate between collectivist and individualist perspective is connected to this cluster.



(Lines show at least three connected statements, the more, the thicker)


bewusster Verzicht/Sparsamkeit
Extrapolation Gegenwart-> Zukunft
IntergenerationenG
Individualität VOR Kollektivität
Energieeffizienz
Lebensqualität
Bezahlbarkeit
Selbstverständlichkeit
Ressourcenschonend
umweltschonend
Ungerechtigkeit: Unter Individuen
Verteilungsgerechtigkeit
Kollektivität VOR Individualität
Bildungsauftrag
Gesundheit
Ausgleichsmechanismen
Lebensstilbewahrung
Lebensstiländerung
Ungerechtigkeit: International
Ungerechtigkeit:Individuum vs. Unternehmen
Beschäftigung
mehr Informationen
Ausgleich Individuum & Kollektiv
Zeit Partizipation
Versorgungssicherheit
globale Gerechtik. neu
Eigener Beitrag
Ungerechtigkeit : Individuum vs. Staat(en)
Nord/Süd Konflikte (9)
Eigener Beitrag (16)
Individualität VOR Kollektivität (12)
Forschung u Entwicklung (23)
Windkraft (59)
Ungerechtigkeit: International (32)
staatl. Subventionen (11)
ökologische Säule (29)
wirtschaftliche Säule (25)
Ökologie als Voraussetzung (neu) (8)
Ausgleich zwischen Individuum & Kollektiv (21)
globale Gerechtik. neu (6)
Ungerechtigkeit: Unter Individuen (15)
bewusster Verzicht/Sparsamkeit (21)
Dezentrale Systeme (8)
Kollektivität VOR Individualität (25)
Bildungsauftrag (19)
soziale Säule (40)
Verteilungsgerechtigkeit neu (85)
E-Mobilität (12)
Ungerechtigkeit:Individuum vs. Unternehmen (21)
Intergenerationengerechtigkeit (27)
Politik (35)
Ressourcenschonend (39)
keine Reihenfolge möglich/Mix (10)
Klimawandel (31)
Kohle/ Braunkohle (16)
Lebensqualität-Vorstellung/Beschreibung (23)
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Bezahlbarkeit (34)
umweltschonend (23)
Kosten der Technologie (40)
Mobilität (14)
Brennstoffzelle/P2G (32)
Wirtschaft/Konsum (17)
Atomkraft (16)
Batterien (41)

Qualitative analysis of focus groups

subsample comparison

Rank		Retired	n	Working	n	Studying	n
1	Codes	Distributional justice	23	Distributional justice	32	Distributional justice	30
2		Individuum vs. collective	23	Future perspective	19	Individuum vs. collective	22
3		Saving environment	20	Saving environment	16	Quality of life	16
4		Own contribution	14	(Energy) costs	14	(Energy) costs	14
5		Education	14	Individuum vs. collective	13	Own contribution	12
6		Quality of life	13	Own contribution	11	Saving environment	11
7		Future perspective	11	Inter-generation justice	11	Employment	10

Overall many similarities.

Students focus more on costs and employment due to lack of security.

Middle aged participants often focus on options for future development among the scenarios.

Seniors tend to favour educational programs on energy saving & climate awareness.

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Thank you!

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