InNOSys – Integrated Sustainability Assessment and Optimization of Energy Systems

Summary and Conclusions

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DLR

Overview

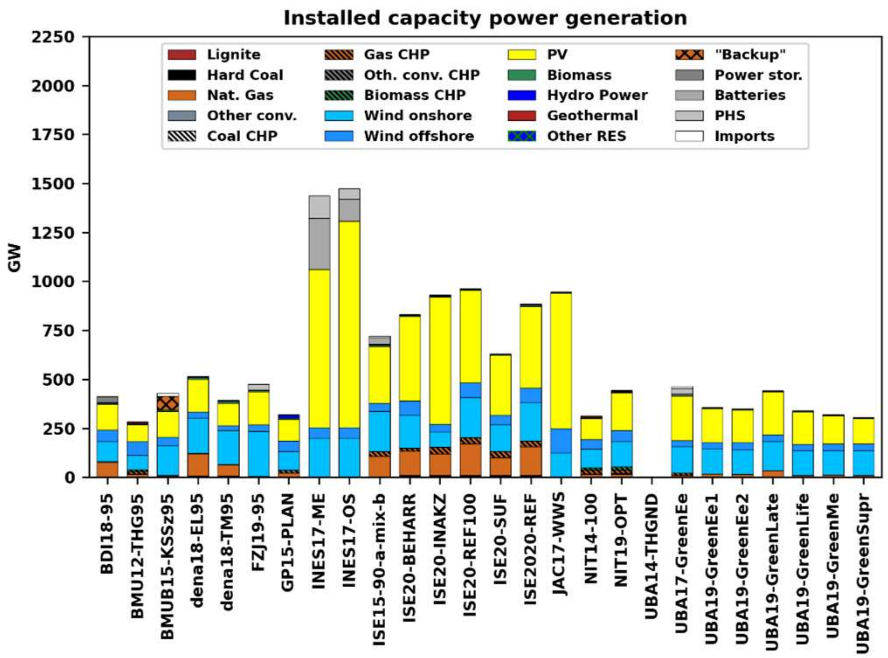
- **Methods**: What have we learned from a methodological point of view? Which challenges did (and still do) we have to face?
- **Results**: What have we learned from a content point of view?
- **Central Conclusions**

Methods – Indicator selection

Categorie	Sub-Categorie	Indicator	unit	calculated with	used in MCDA	used in DSE	method/ reference
ecological	Climate Change	Climate change	kg CO2 eq	FRITS	CUM	X	ILCD 2.0 2018
	Ecosystem Quality	Freshwater & terrestrial acidification	mol H+ eq	FRITS			ILCD 2.0 2018
		Freshwater ecotoxicity	CTUe	FRITS			ILCD 2.0 2018
		Freshwater eutrophication	kg P eq	FRITS			ILCD 2.0 2018
		Marine eutrophication	kg N eq	FRITS			ILCD 2.0 2018
		Terrestrial eutrophication	mol N eq	FRITS			ILCD 2.0 2018
	Human health	Carcinogenic effects	CTUh	FRITS	CUM	AGG	ILCD 2.0 2018
		Non- Carcinogenic effects	CTUh	FRITS	CUM	AGG	ILCD 2.0 2018
		Ionising radiation	kg U235 eq	FRITS	CUM	AGG	ILCD 2.0 2018
		Ozone layer depletion	kg CFC-11 eq	FRITS	CUM	AGG	ILCD 2.0 2018
		Photochemical ozone creation	kg NMVOC eq	FRITS	CUM	AGG	ILCD 2.0 2018
		Respiratory effects, inorganics	disease incidence	FRITS	CUM	AGG	ILCD 2.0 2018
	Resources	Fossils	MJ	FRITS	CUM	AGG	ILCD 2.0 2018
		Dissipated Water	m3 water eq	FRITS			ILCD 2.0 2018
		Land use	points	FRITS	CUM	AGG	ILCD 2.0 2018
		Minerals and metals	kg Sb eq	FRITS	CUM	AGG	ILCD 2.0 2018 (modified)
socio-economic		System costs	Bn €	MESAP	CUM	X	
		GDP	Bn €	PANTA RHEI			
		structural change	1000	PANTA RHEI			
		regional inequality	-	PANTA RHEI			
	Employment	people in employment	1000	PANTA RHEI		X	
		unemployment rate	-	PANTA RHEI	X		
socio-technical		Resilience/security of supply	-	OTHER	X	(X)	Stirling Index Power Generation Capacities; for DCE: Resilience based on expert judgements

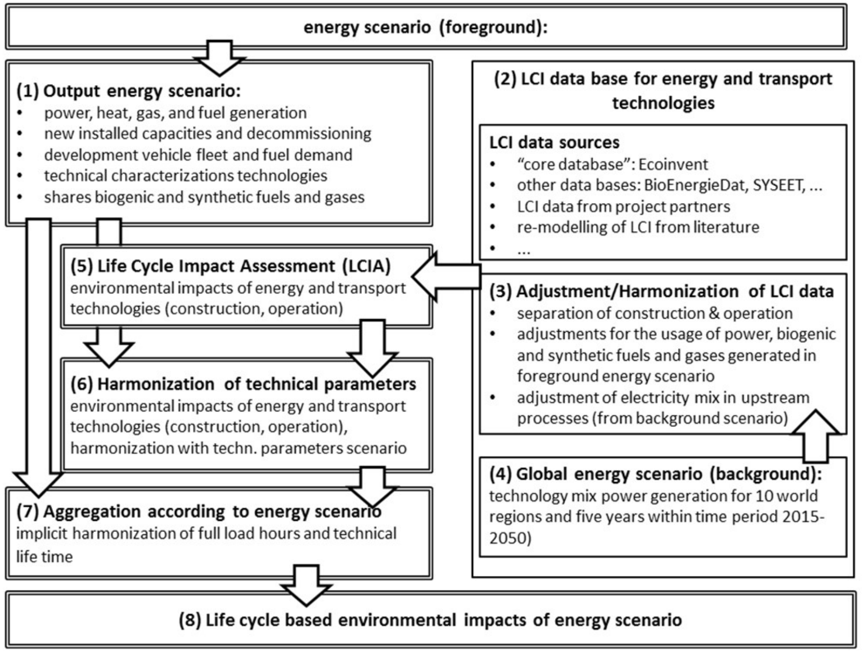
- Indicator selection requires intensive cooperation already at beginning of the project
- Conflicting goals: Comprehensive description of all relevant consequences vs. manageability and comprehensibility for stakeholders and MCDA
- Explicit consideration of social indicators not yet satisfactorily resolved.
- Systemic indicators (e.g. resilience): only first steps achieved

Methods – Scenario selection and re-modeling



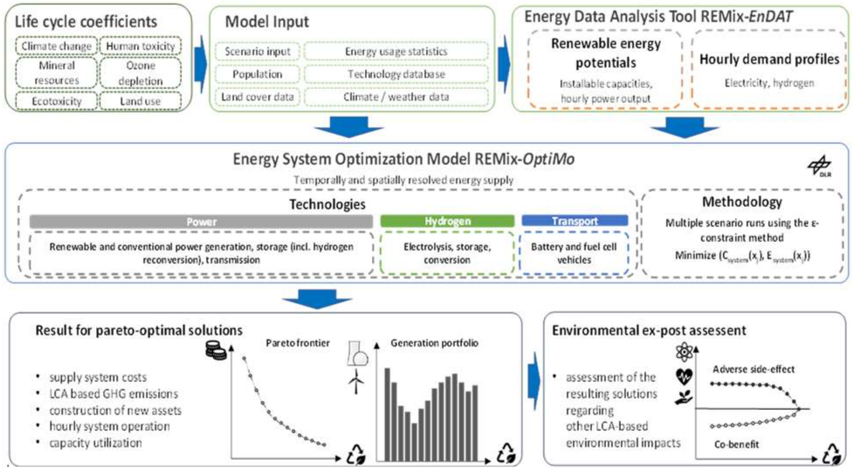
- Published scenarios differ strongly in terms of storylines, boundary conditions, etc.
- Harmonized re-modeling of scenarios allows unbiased comparison of impacts for different transformation strategies
- Shortcomings:
  - Focus on Germany
  - Re-modeling of entire scenarios allows no systematic assessment of sector-level strategies

Methods – Life cycle based environmental impacts



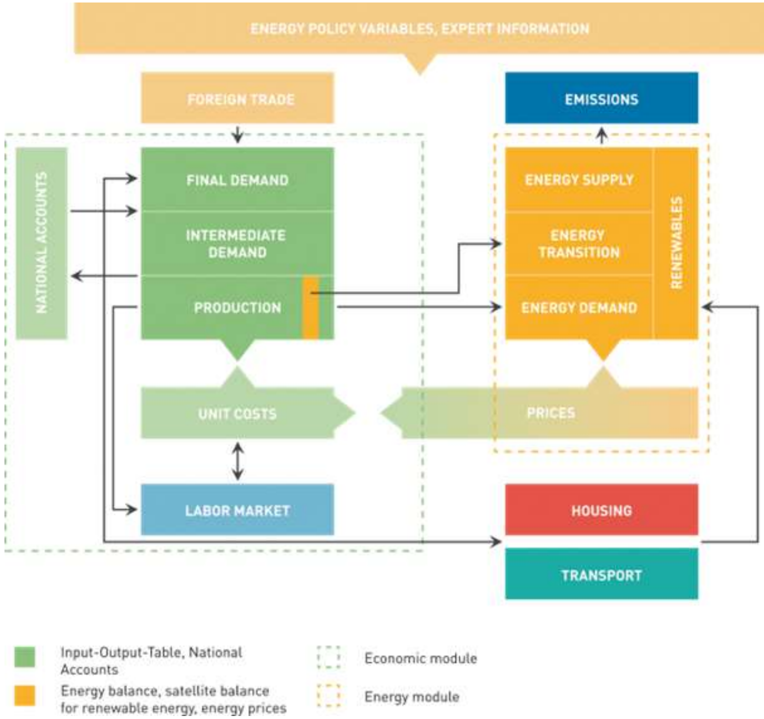
- FRITS: **Fr**amework for the assessment of life cycle environmental **i**mpacts of **t**ransformation **s**cenarios
- Challenges:
  - LCI data availability, quality and representativeness
  - Prospectivity also in background data base
  - Volume of data → analysis and visualization

Methods – Multi-objective optimization



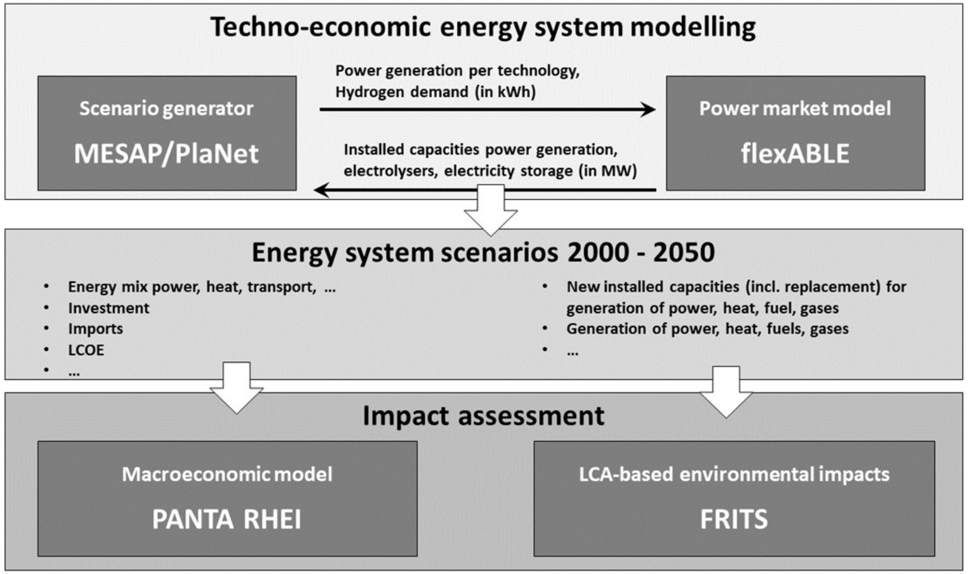
- Allows systematic analysis of trade-offs between pairs of indicators and consequences for energy (power) system
- Challenges (up to now):
  - Large effort to implement LCI data in optimization model REMix
  - Long computation times
  - Multi-objective optimization only possible for pairs of indicators
  - Limited to infrastructure expansion and dispatch of power system

Methods: Macroeconomic modeling



- Allows assessment of macroeconomic impacts of transformation strategies
- Coupling with energy system model requires harmonisation of technologies and data
- Challenge prospectivity: Long time horizon and fundamental changes in analyzed energy systems
  → numerous exogenous assumptions required during assessment of macroeconomic impacts

Methods: Integrated impact assessment in general



- Focus on supply side strategies neglects impacts from changes in demand → "true" impacts of transformation might be different
- Different system boundaries ESMs / FRITS and macroeconomic model PANTA RHEI hamper comparison of relative differences between ecological and economic indicators
- No assessment of uncertainties of impacts possible (yet)

Methods: Discrete Choice Experiments

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

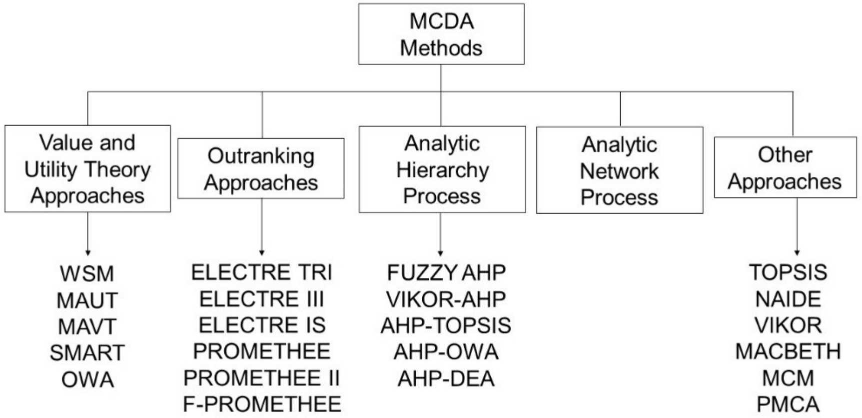
Die Prozentzahlen stellen die Abweichungen vom jeweiligen Durchschnitt aller anderen betrachteten Paare dar. Werte sind entweder schlechter (rot/orange) oder besser (gelb/grün) als der Durchschnitt.)

	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

- New approach of applying discrete choice experiments (DCEs) to scenarios is promising, but
- Challenges:
  - Complexity and abstractness of scenarios
  - Develop condensed representation of the future appropriate for DCEs
  - Appropriate choice of indicators

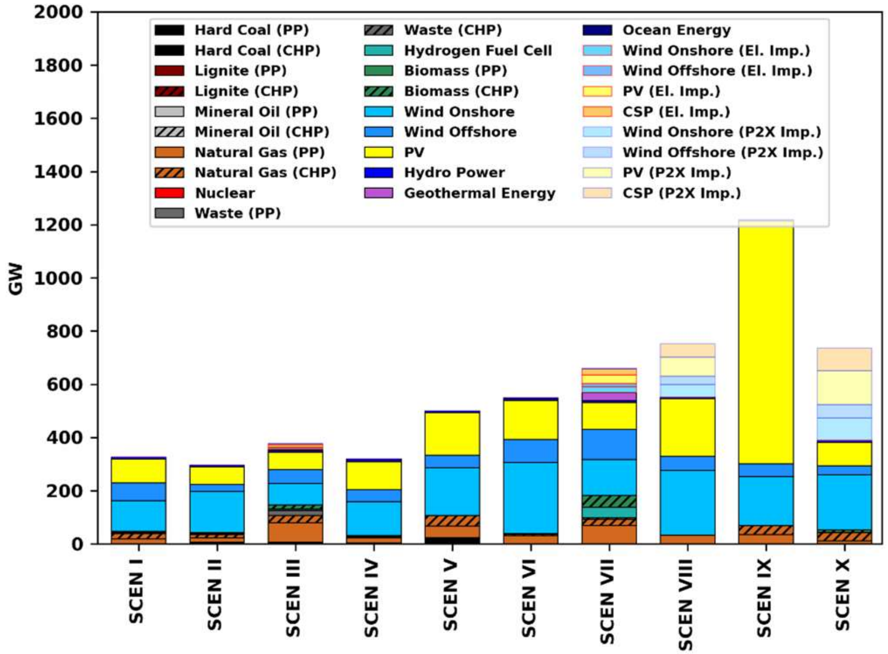
Methods: MCDA



[Greco et al., 2016]

- Use of different MCDA methods → robust statements possible
- Challenges:
  - Some MCDA methods require further procedures and parameters not available from models and focus groups → own settings by modelers necessary
  - Indicator weights crucial → should involve broader variety of stakeholders

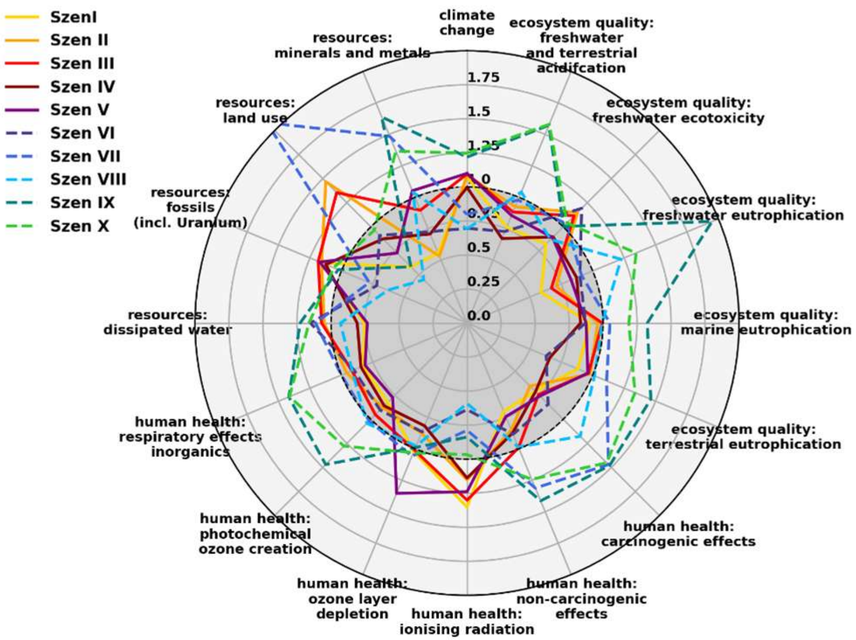
Important Findings: Transformation strategies



- Even after harmonisation of useful energy demand and transport services: Surprising little consensus on how a climate friendly energy system should look like
- In particular true for scenarios with GHG emission reduction of ca. 95%

→ Need for multidimensional impact assessment of transformation strategies and discussion of results with stakeholders

Important Findings: LC-based environmental impacts



- Impacts from **upstream processes** become more and more important
- **No clear tendency** for ambitious climate protection strategies to have lower environmental impacts than moderate strategies
- **Resource-type impacts** may significantly increase compared to today
- Impacts related to **road transport** tend to dominate overall impacts

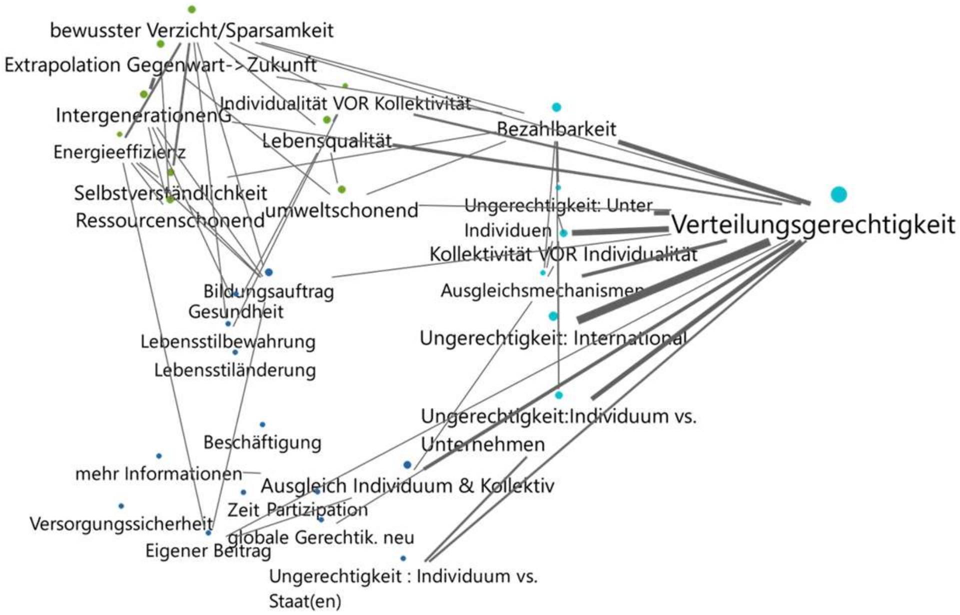
Important Findings: Macroeconomic impacts

Scenario	GDP	Total investment	Employment	Unemployment-rate indicator
	Real, Bn $Euro_{2015}$		1 000	Percent
	Average of the years 2030 to 2050			
Scen I	3751.9	820.7	43879.5	4.39
Scen II	3748.8	815.5	43869.9	4.41
Scen III	3755.8	825.4	43888.1	4.37
Scen IV	3749.0	817.3	43889.8	4.37
Scen V	3757.0	836.3	43936.3	4.27
Scen VI	3775.1	842.8	43982.8	4.17
Scen VII	3788.4	862.8	44009.1	4.11
Scen VIII	3762.2	834.2	43946.5	4.25
Scen IX	3783.7	870.3	44047.7	4.03
Scen X	3743.9	822.1	43875.0	4.40

- Differences between macroeonomic impacts of selected scenarios relative small
- Tendency for more favorable economic impacts in scenarios with high (national) investment in new technologies

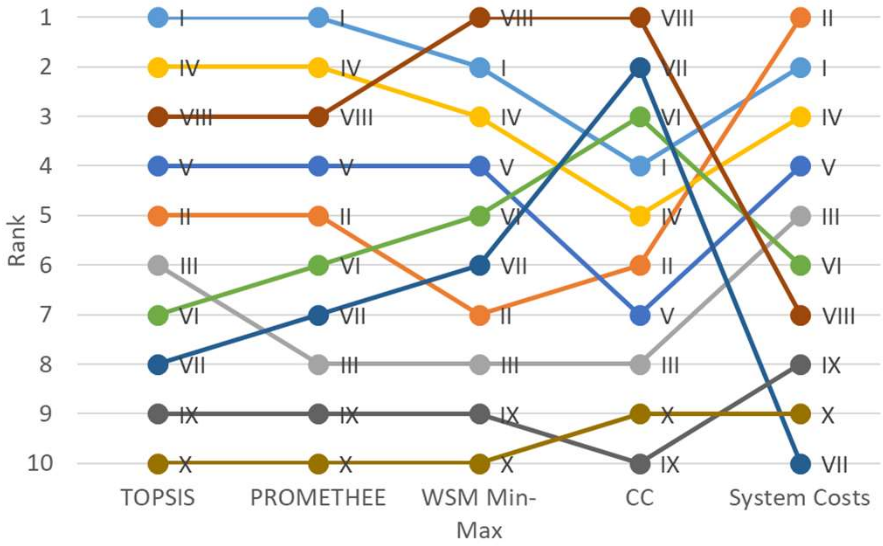
→ From macroeconomic perspective not decisive which (moderate or ambitious) (supply) side strategy is chosen!

Important Findings: Discrete Choice Experiments (DCE) and Focus Groups



- DCE used to determine stakeholders‘ preferences → weighting for MCDA
- Costs do not play a central role for most stakeholders
- More important: climate protection and distributive justice / fair burden sharing within the society
- Stakeholders‘ life situation more important for preferences than education

Important Findings: MCDA



- Ranking of scenarios depends to some extend on MCDA method
- No clear trend that more climate protection is more sustainable in general
- No leading indicator that dominates MCDA results
- Difficult to trace back MCDA results to individual scenario features

Central Conclusions I:

- Wide range of discussed transformation paths for Germany in the literature, all claiming to describe an “optimal” or “sensible” scenario
- Ambitious climate protection (95% GHG reduction) is not automatically “more sustainable” than moderate climate protection (80% GHG reduction)
- No “leading indicator” in MCDA results
- Distributional justice as highly relevant topic in focus groups blind spot of ESMs and macroeconomic models

→ **Classic „techno-economic“ scenario development falls short when aiming at a development of “sustainable” transformation paths**

→ **Multidimensional impact assessment required!**

Central Conclusions II:

- **Transport** sector is becoming the **driving force for environmental impacts** → necessity to develop sustainable strategies for transport sector (technologies and user behavior)
- **Increasing resource requirements** (minerals, metals, land, …) are the biggest (environmental) drawback of climate friendly transformation strategies
- Climate-friendly transformation generally has strong positive impacts on the macroeconomy. From **macroeconomic perspective not decisive which pathway is chosen**.

Central Conclusions III:

Methodological challenges:

- Availability, quality and representativeness of LCI data must be improved
- Prospectivity: Expected transformation of upstream processes must be better considered in LCI data
- Certain relevant social and technical indicators can so far only be determined roughly or not at all
- Models should be improved in order to adequately represent the expected fundamental structural changes in the energy system over the next decades.

If you are interested in more details of the analyses or in a future cooperation, please do not hesitate to contact us:

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For **more information** (presentations, publications, data) please visit our website: https://www.innosys-projekt.de/de

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Thank you very much for your attention!

DLR Deutsches Zentrum für Luft- und Raumfahrt
German Aerospace Center

GWS SPECIALISTS IN EMPIRICAL ECONOMIC RESEARCH

INATECH DEPARTMENT OF SUSTAINABLE SYSTEMS ENGINEERING

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INEC INSTITUTE FOR INDUSTRIAL ECOLOGY PFORZHEIM

ITAS Institute for Technology Assessment and Systems Analysis

zirius Center for Interdisciplinary Risk and Innovation Studies

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