JÜLICH
FORSCHUNGSZENTRUM

GERMANY'S "YES" TO RENEWABLES: JUST A QUESTION OF REACHING CO2-REDUCTION TARGETS?

Stefan Vögele[1], Dirk Rübbelke[2], Philip Mayer[2], Wilhelm Kuckshinrichs[1]

[1] Forschungszentrum Jülich GmbH, Institute of Energy and Climate Research – Systems Analysis and Technology Evaluation (IEK-STE), Germany

[2] TU Bergakademie Freiberg, Germany

Outline

1. Motivation/Objective
2. Method
3. Results
4. Conclusions

1. Motivation/Objective

Germany: Quantitative target of the energy transition and status quo

	2015	2020	2030	2040	2050
Greenhouse gas emissions					
Greenhouse gas emissions (compared with 1990)	-27%	at least -40%	at least -55%	at least -70%	-80% to -95%
….					

Source: BMWi (2015)

➔ **Analysis of pros and cons to support decisions to go for renewables**

1. Motivation/Objective

- Pros and cons of renewables ➔ focusing on sustainability indicators?
- Renewables as part of a energy/electricity system ➔ assessment of complex systems with different players
- Overall assessment? Cost-Benefit Analysis?

1. Motivation/Objective

Objective

Overall assessment of intensive use of renewables in the German electricity system by comparing different scenarios

Steps

- Selection of indicators
- Specification of values for the indicators by taking the entire system into consideration
- Overall assessment

2. Method: Selection of Indicators

Economy	Ecology	Society
Net present value of the elec. system	direct CO_2	Pecept.-Trust
Average levelized cost of electricity	SO_2	Pecept.-Economics
Wholesale prices	NOx	Pecept.-Environment
Annual producer surplus	Cumulated energy demand	Pecept.-Social & Ethics
Consumer surplus	Coal demand	Pecept.-Technological-feasibility
Expenditure on import of fuels	Global warming Potential	Pecept.-Health
Sensitivity to changes in fuel prices	Eutrophication Potential	Pecept.-NIMBY
Sensitivity to changes in CO_2 certificates prices	Acidification Potential	Impact on energy system
		Uncertainties the impacts are linked with

2. Method: Measurement of the Indicators

Steps:

- defining system boundaries (incl. scenario specification)
- assessment of the values for each indicator on technology level
- adjustment of the values by using a dispatch model for the European electric market (installed capacity/electricity production as weighting factors)

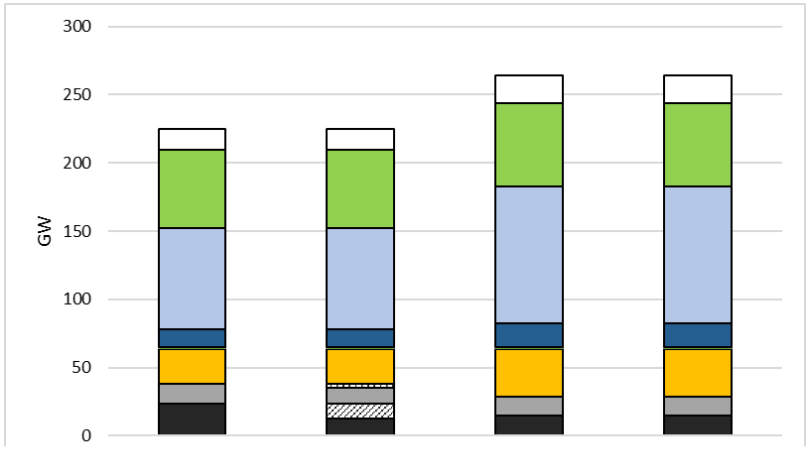
2. Method: Multi-Criteria Assessment

- normalization of results: enables a methodologically reliable comparison of indicators with different units
- weighting of indicators: defines the relative importance of indicators based on a normative foundation

Indicator weights in categories	Number of indicators	Variant 1: Equal weight	Variant 2: Econ. only	Variant 3: Ecol. only	Variant 4: Soc. only
Economy	8	1/25	1/8	0	0
Environment	8	1/25	0	1/8	0
Social	9	1/25	0	0	1/9
Total	25	1	1	1	1

- aggregation: final assessment by aggregation to a composite indicator

2. Method: Scenario Specification



Technology / Perception Category	Coal	CCS	Natural Gas	Nuclear	Wind ON	Wind OFF	PV	Solar Heat	Biomass	Efficiency
1.Trust										
2. National Economics										
3. Individual Economics										
4. Environment										
5. Social & Ethics										
6. Techn. Feasibility										
7. Health										
8. NIMBY										
9.Potential of Desaster										

Legend: -1 = contra 0 = ambivalent 1 = pro n/a = no answer

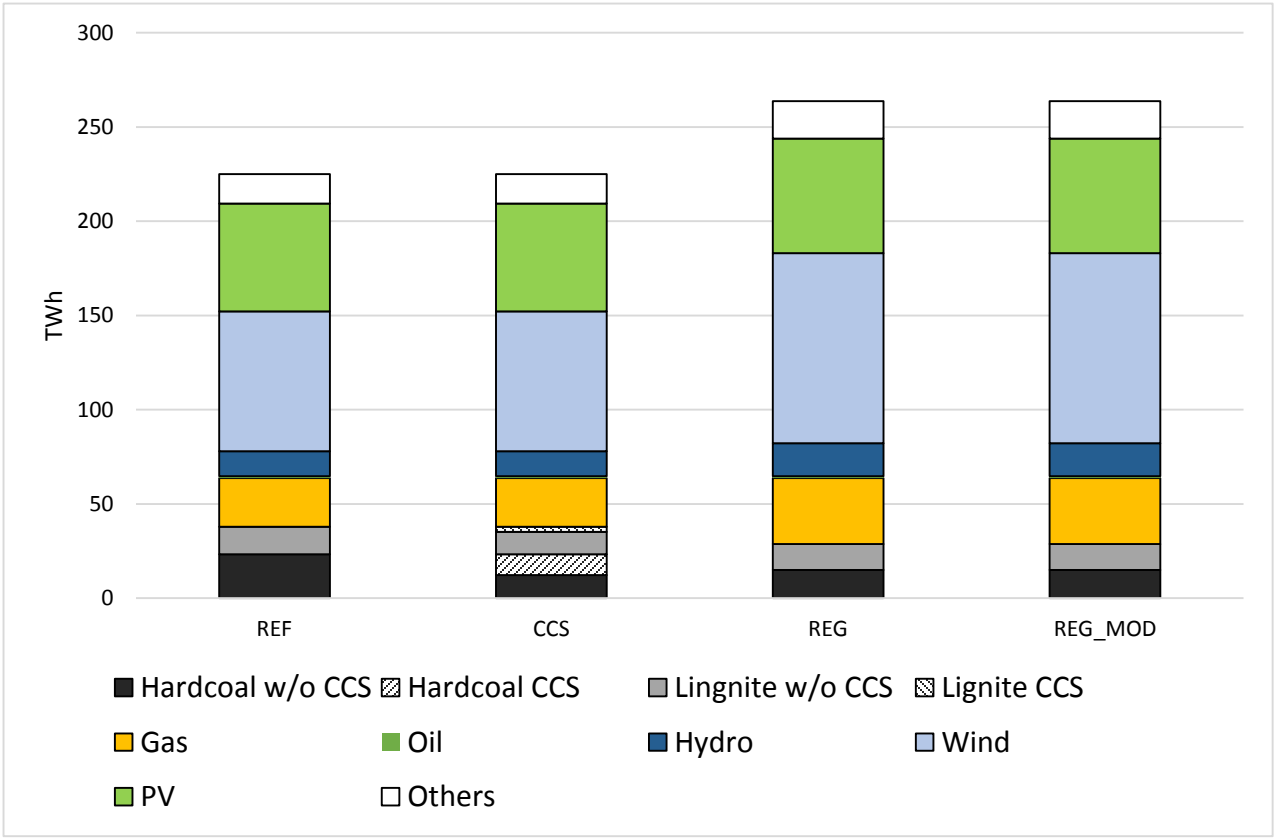
Source: Own compilation based on (Scheer et al. 2014)

		REF	CCS	REG	REG_mod
Fuel costs					
Hard coal	Euro/GJ	3.48			2.21
Lignite	Euro/GJ	0.44			0.44
Natural gas	Euro/GJ	10.28			7.91
Oil	Euro/GJ	23.2			16.73
CO_2 prices	€/ton	31			93
Technology specific cost					
Coal-fired power plants	Capital cost	Euro/kW	1500-1700		
	O&M (w/o fuel cost)	Euro/MWh	4		
	Capital cost	Euro/kW	2500-2700		
	O&M (w/o fuel cost)	Euro/MWh	6		
	Capital cost	Euro/kW	750		
	O&M (w/o fuel cost)	Euro/MWh	3		
	Capital cost	Euro/kW	2500		
	O&M (w/o fuel cost)	Euro/MWh	7		
	Capital cost	Euro/kW	1400		
	O&M (w/o fuel cost)	Euro/MWh	0		

based on ENTSO-E (2016)

- Data from Life Cycle Analysis
- Data from World Energy Council („World Energy Issues Monitor“)

3. Results: Electricity Production



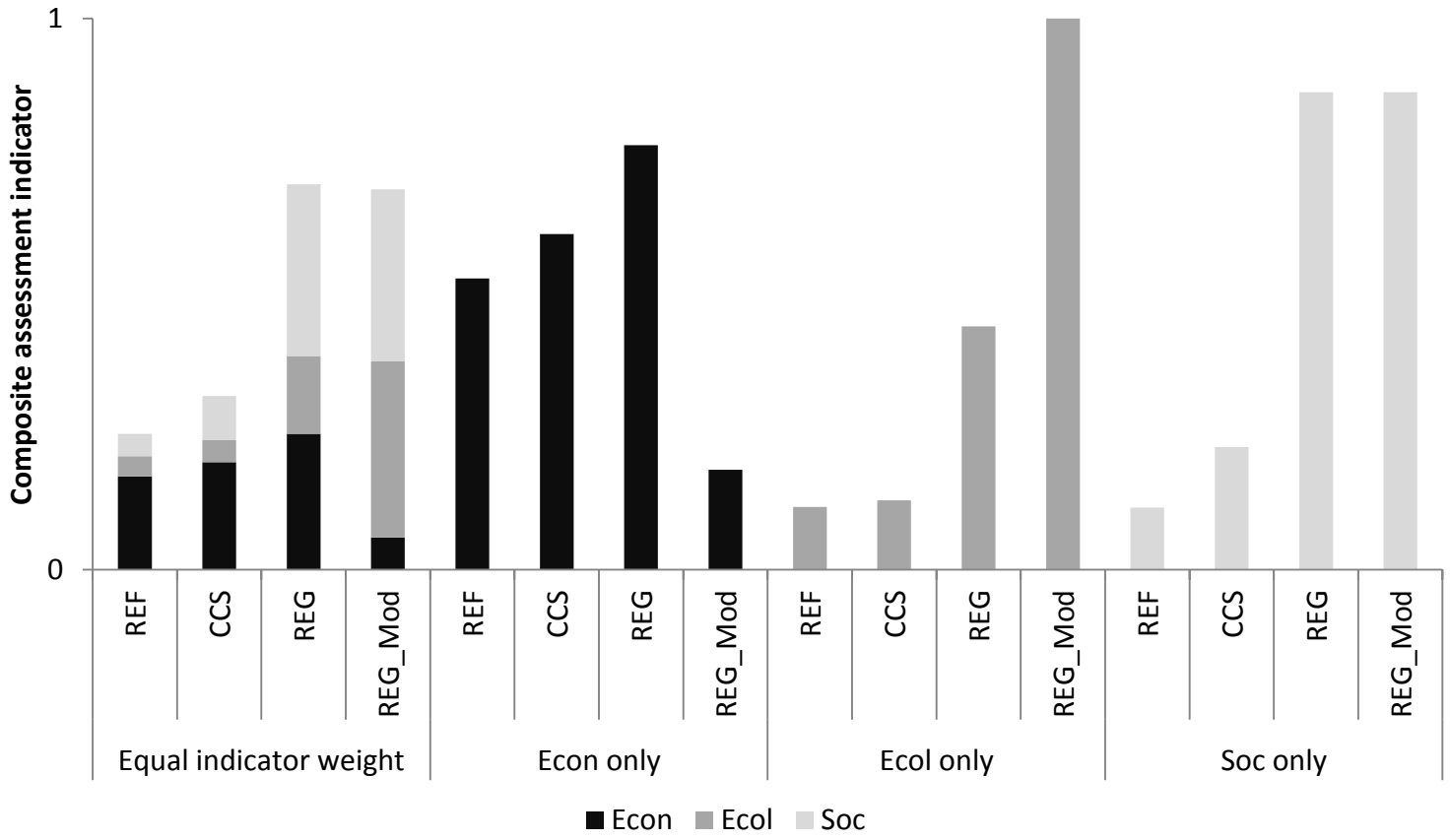
Source: Own calcculation

3. Results: Performance Matrix

		Indicators	REF	CCS	REG	REG_mod
Economy	A1	Net. Present Value	best			worst
	A2	average LCOE	best			worst
	A3	Wholesale price			best	worst
	A4	Producer surplus			worst	best
	A5	Consumer surplus			best	worst
	A6	Exp. on imported fuels			best	worst
	A7	Sensitivity to fuel prices		worst	best	
	A8	CO_2 certificate prices			best	worst
Ecology	B1	direct CO_2	worst			best
	B2	SO_2	worst			best
	B3	NOx		worst		best
	B4	Cumulated energy demand		worst		best
	B5	Coal demand		worst		best
	B6	Global warming Potential	worst			best
	B7	Eutrophication Potential		worst		best
	B8	Acidification Potential		worst		best
Society	C1	Pecept.-Trust	worst	worst	best	best
	C2	Pecept.-Economics	worst	worst	best	best
	C3	Pecept.-Environment	worst	best		
	C4	Pecept.-Social & Ethics	worst	worst	best	best
	C5	Pecept.-Technological-feasibility	worst	worst	best	best
	C6	Pecept.-Health	worst	best		
	C7	Pecept.-NIMBY	worst	worst	best	best
	C8	Impact on energy system		worst	best	best
	C9	Uncertainties the impacts are linked with	best	worst		

best value
worst value

3. Results: Overall Assessment



Source: Own calcculation

4. Conclusions

- Extension of indicator set helps since stakeholders are not only interested in sustainability indicators
- Even if economic indictors are prioritized, scenarios with renewables have more advantages than others
- Next steps: Further extension of indicator set, modification of system boundaries

Thank you for your attention!

Contact: s.voegele@fz-juelich.de