Behavioural Aspects of Decision Making in Energy Systems – A Selection of Current Topics

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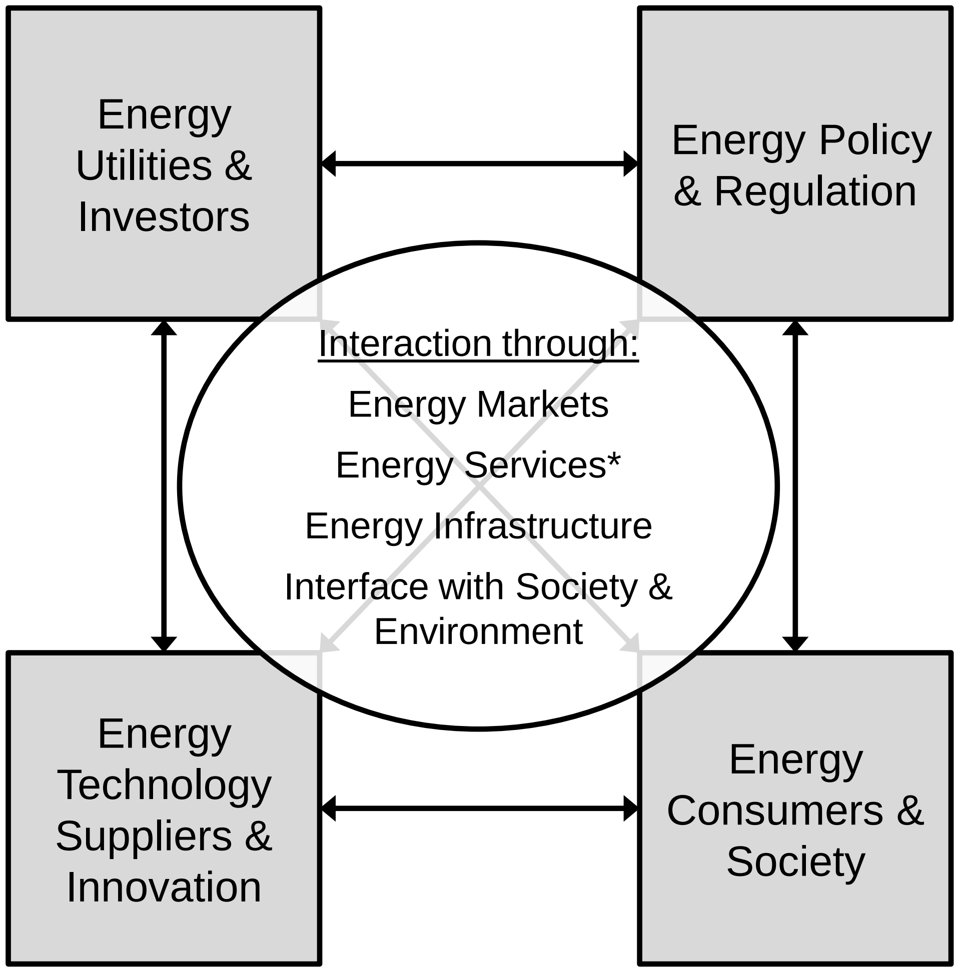
Background: Categories of Players in Energy Systems

Decisions of
- Power plant investors and operators (utilities)
- Grid investors and operators
- Decisions of service providers / intermediaries (e.g., offer of different tariffs)

Political decisions on
- RES feed-in scheme
- Grid usage charges (e.g., capacity pricing)
- CO_2 trading scheme
- Feed-in tariff design



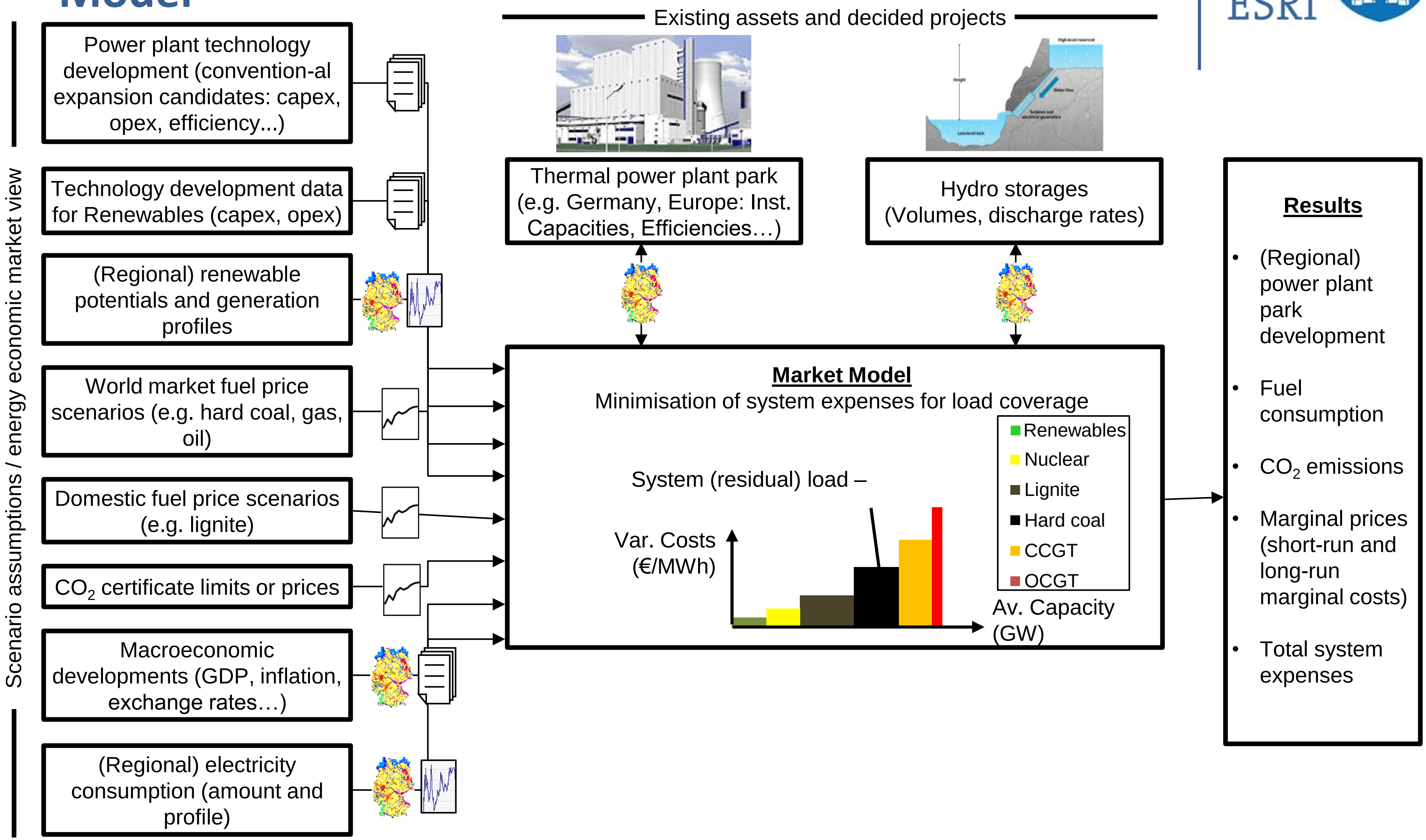
Decisions and developments concerning
- RES technologies
- ICT (smart meters...)
- (Battery) storages
- Power-to-Heat
- Power-to-Gas
- Grid techn. (HVDC)

Decisions on
- Investment and consumption behaviour (residential and industrial consumers)

Preferences & Acceptance
- Technology
- Tariffs

* Focussing on the relationship between service provider and customer based on the principle of ‘value co-creation’

Background: Input and Output of an Energy Systems Model



Background and Agenda

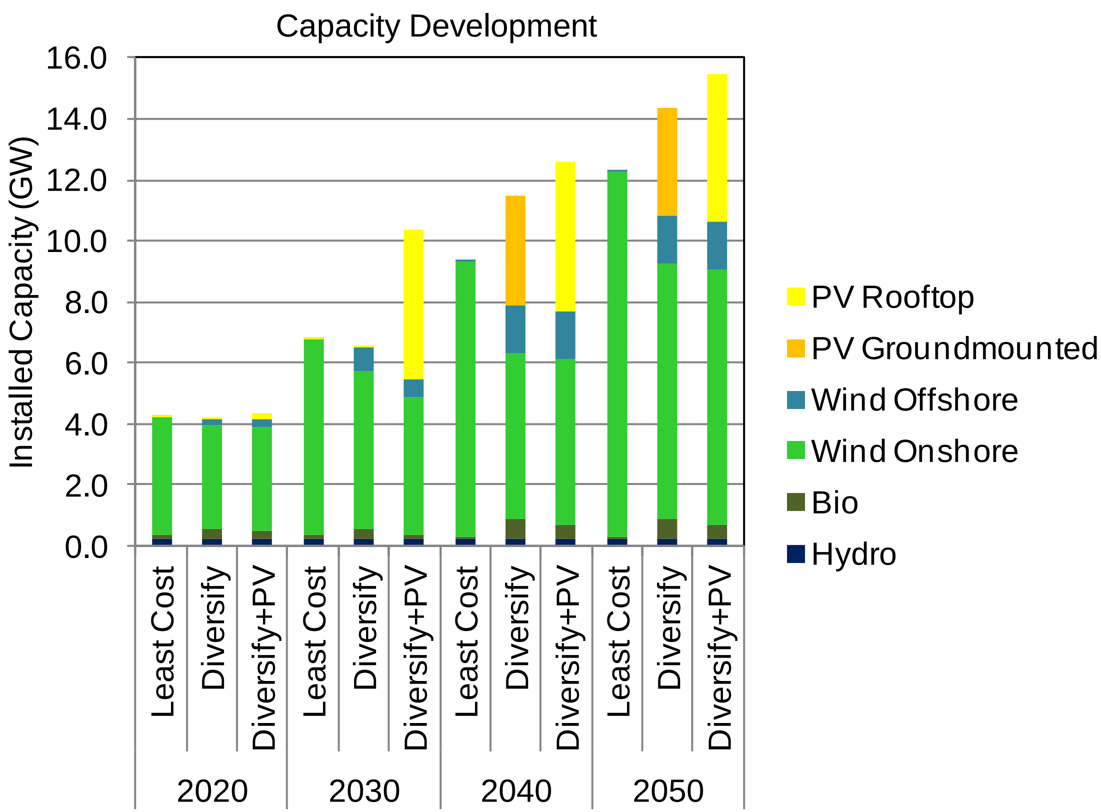
- Least-cost optimisation models are of limited use for energy systems analysis
  - Technology acceptance by the public
  - Technology adoption by consumers
    - Adoption regardless of economics
    - No adoption regardless of economics
  - Assumption of “central planner”
  - Combinations of the above
  - …

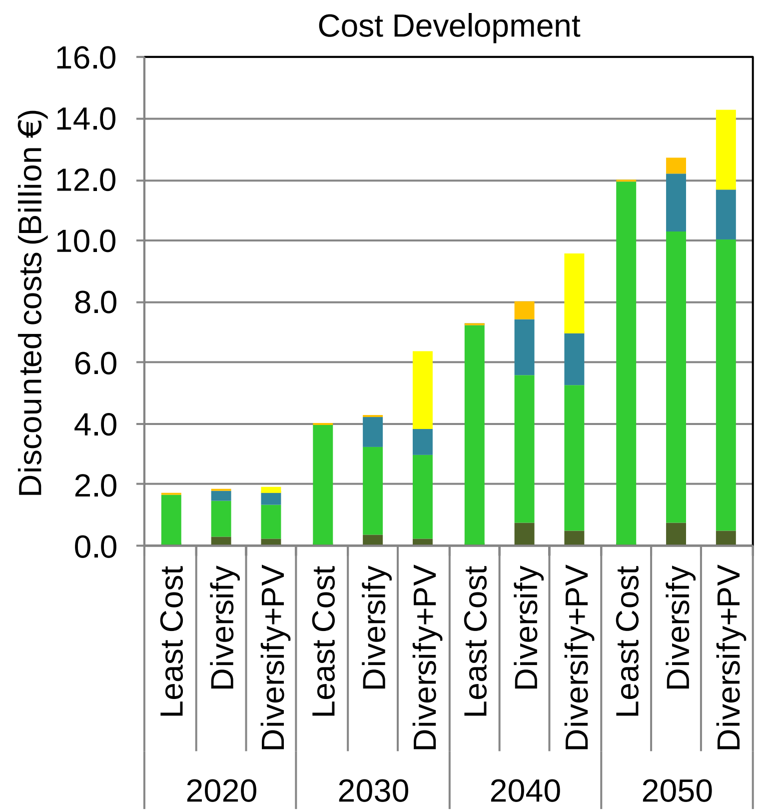
- Agenda
  - Illustration for Irish case study: focus on acceptance
  - Combination of energy systems modelling and MCDA
  - Conclusions and discussion

Irish case study: Renewable allocation planning until 2050 under given targets

- Electricity generation from renewable energy sources (RES-E) in Ireland
  - 27.3% in 2015 (wind onshore alone accounting for 22.8%, i.e. >80% of all RES-E)
  - 2020 target: 40%
  - 2030 target under negotiation
- Energy white paper (DCENR 2015): diversification of renewable energy sources (e.g. solar PV, wind offshore, bioenergy)
- Objectives: quantify costs associated with different diversification scenarios and understand when which technologies would/should be expanded from a cost minimisation perspective
- Considered diversification scenarios
  - Least Cost: Pure cost minimal solution
  - Diversify: assumes a predefined minimum level of diversification of RES-E sources, a minimum of 15% of the RES-E generation must come from sources other than wind onshore by 2030 increasing to 30% by 2050
  - Diversify+PV: in addition to the Diversify scenario, this scenario assumes a predefined minimum level of rooftop PV, a minimum of 5% of the RES-E generation must come from rooftop PV by 2030 increasing to 10% by 2050

Development of RES-E capacity and discounted costs in Ireland until 2050

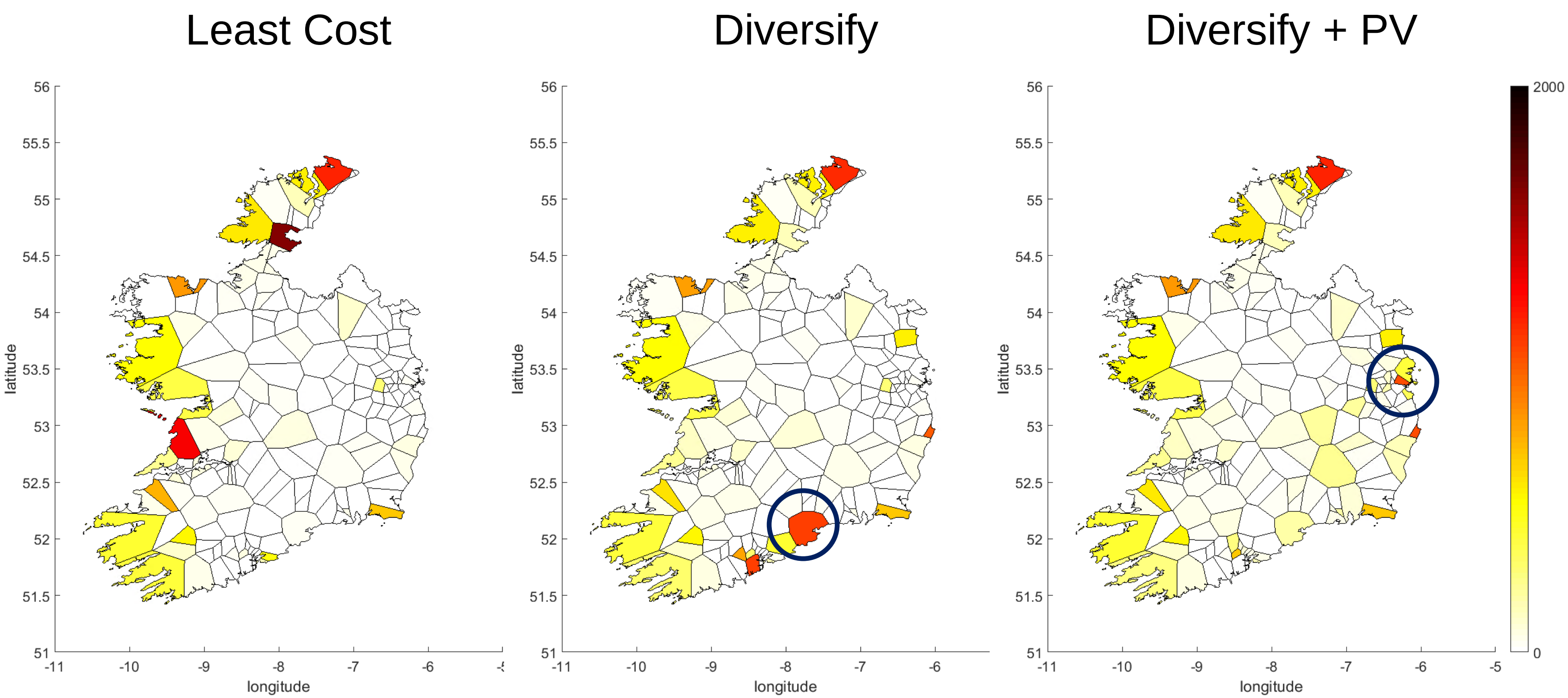




- Least Cost: Wind onshore only
- Moderate discounted cost increase for Diversify scenario (compared to Least Cost): 7-9% in 2030
- Strong increase for Diversify+PV scenario (compared to Least Cost): 60-70% in 2030

Source: Slednev, V., Ruppert, M., Fichtner, W. & Bertsch, V. (2017) Highly resolved optimal renewable allocation planning in power systems under consideration of dynamic grid topology. MPRA Paper No. 79706 (https://mpra.ub.uni-muenchen.de/79706/).

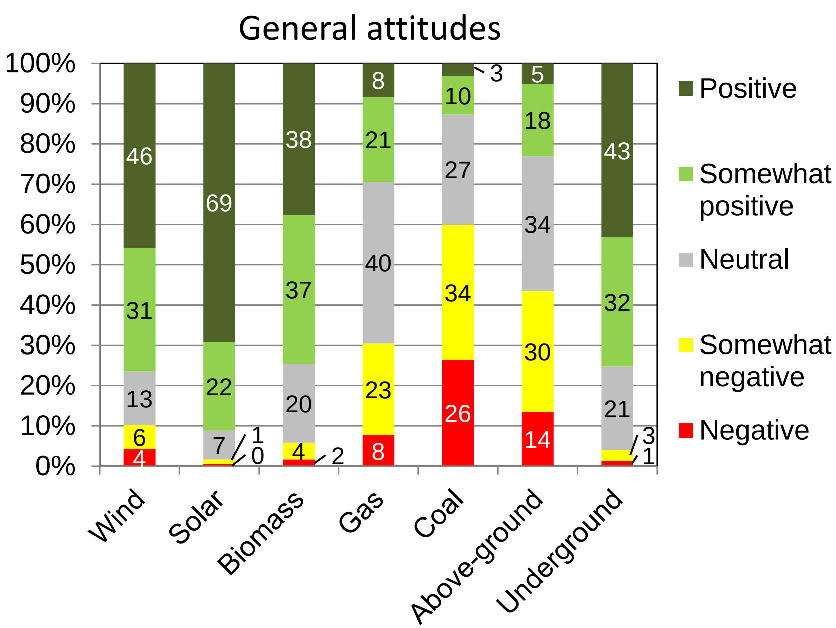
Regional distribution of RES-E capacities in 2050

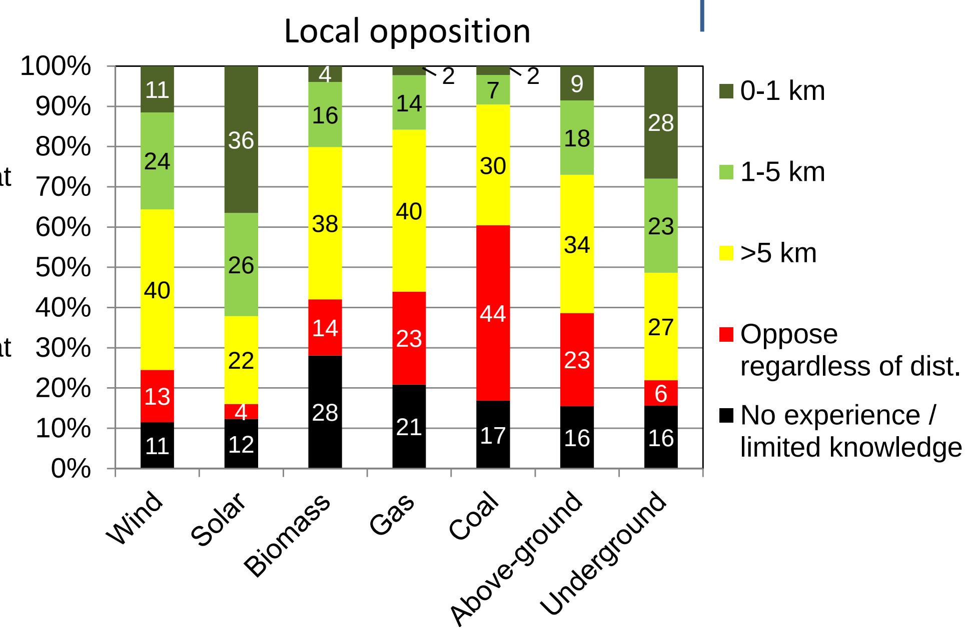


- Least Cost: Capacity hotspots in the west and north, with a single region reaching >1,500 MW installed RES-E capacity
- Effect is softened in both Diversify scenarios as offshore wind and solar show a different spatial concentration

Source: Slednev, V., Ruppert, M., Fichtner, W. & Bertsch, V. (2017) Highly resolved optimal renewable allocation planning in power systems under consideration of dynamic grid topology. MPRA Paper No. 79706 (https://mpra.ub.uni-muenchen.de/79706/).

However, despite generally positive opinions of RES-E technologies, local opposition can still abound





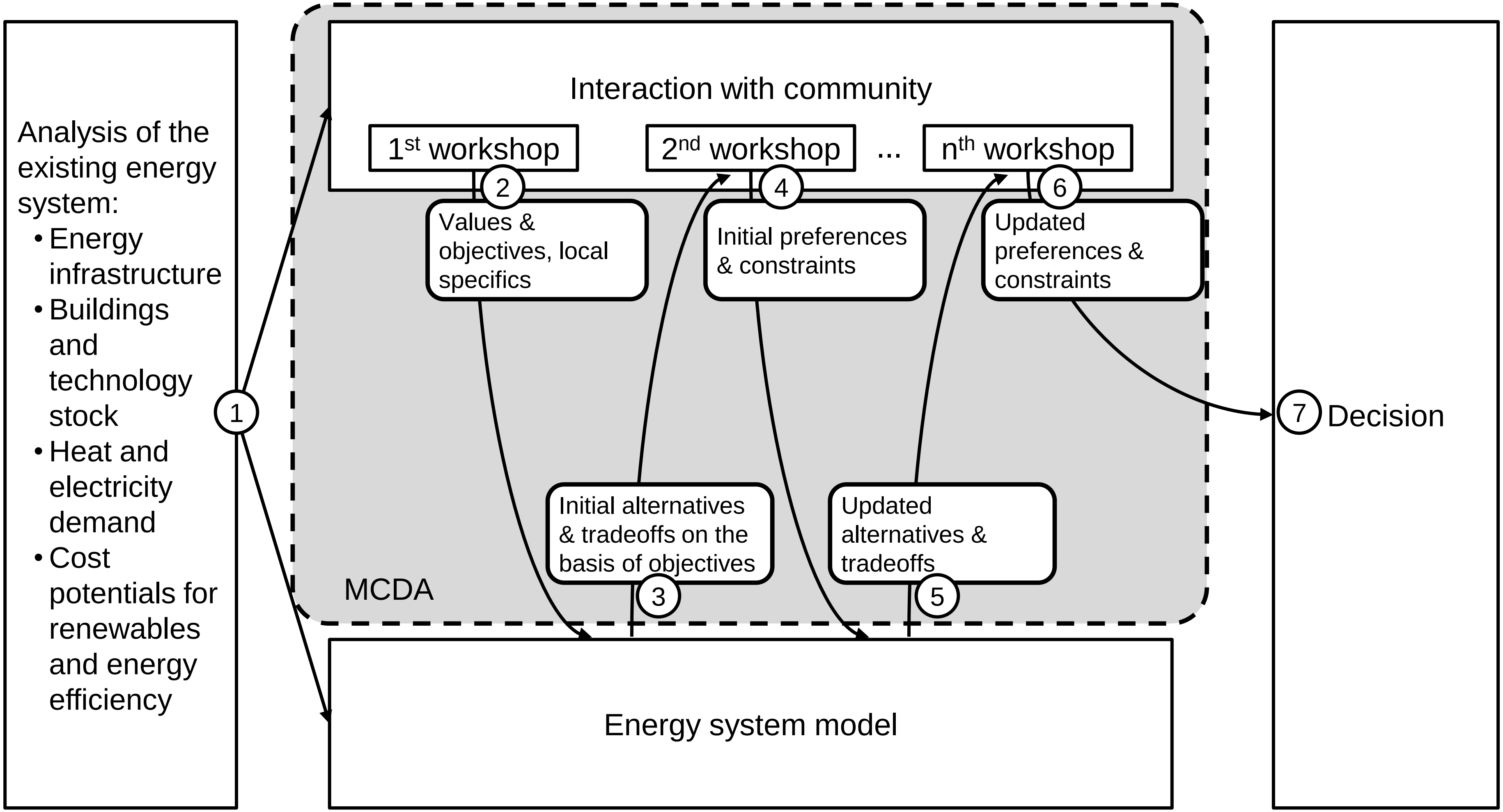
- For example, nationally-representative survey showed that 77 % of people were generally positively disposed towards wind powered generation but only 36 % of respondents indicated that they would be happy to have a wind farm constructed within five kilometres of their place of residence
- Consideration of acceptance, emissions etc. beyond costs => weights needed
- Moreover, rooftop PV investments are decided by consumers following their “investment logic” rather than a central cost minimisation

Source: Bertsch, V., Hyland, M. & Mahony, M. (2017) What drives people's opinions of electricity infrastructure? Empirical evidence from Ireland, Energy Policy, 106, pp. 472-497.

Possible ways forward

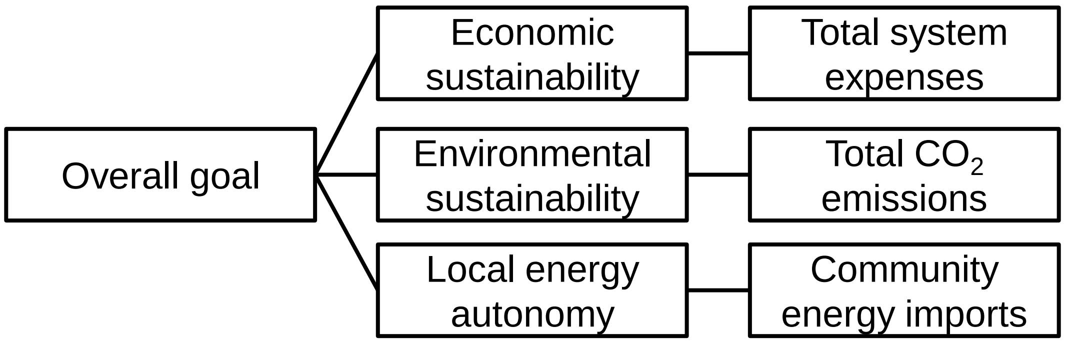
- Combination of energy systems modelling and MCDA
  - Local level study
    - Decision maker: Local community
    - Time horizon: 2030
    - Focus: What are the preferences of a local community in terms of a local energy strategy and how does a multi-criteria ranking of alternatives differ from a mere cost minimisation ranking?
  - National level study
    - Decision maker: Government / Regulator
    - Time horizon: 2030
    - Focus : What is the impact of different combinations of grid expansion and RES-E curtailment options on the long-term system development, costs, emissions and public acceptance?
- Integration of consumer utility maximisation (rather than cost minimisation) into energy systems modelling framework
- Behavioural analysis of consumer adoption of technologies and transformation of insights into technology-specific hurdle rates
- …

Local level study: Developing energy concepts for and with a rural community in South Germany



Source: McKenna, R., Bertsch, V., Mainzer, K. & Fichtner, W. (2016) Combining local preferences with multi-criteria decision analysis and linear optimisation to develop feasible energy concepts in small communities, Working Paper Series in Production and Energy, No. 16

A total of 3 criteria and 8 alternatives were developed in a stakeholder workshop with the community

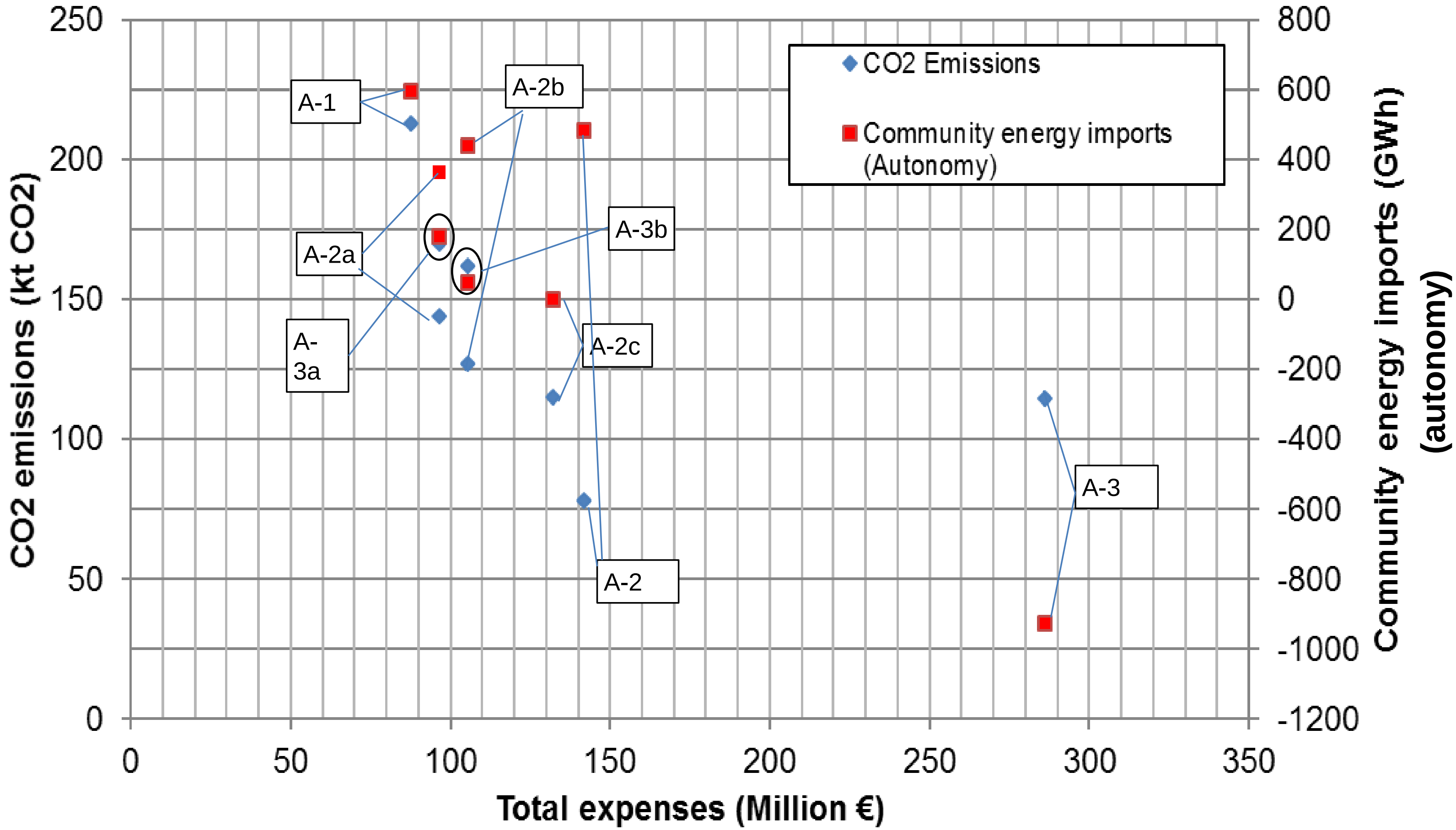


Criterion	Weight Interval	Normal-ised Mean
Economic sustainability	0.40-0.60	0.52
Environmental sustainability	0.15-0.30	0.24
Local energy autonomy	0.10-0.35	0.24

Alter-native no.	Alternative name	Total costs	CO_2 emissions	Community net imports (autonomy)
1	Costs first	Minimise	Free	Free
2	Emissions first	Free	Minimise	Free
2a	Emissions focus with strong cost constraints	110% of min.	Minimise	Free
2b	Emissions focus with weak cost constraints	120% of min.	Minimise	Free
2c	Emissions focus with cost and import constraints	150% of min.	Minimise	Zero
3	Imports first	Free	Free	Minimise
3a	Imports focus with strong cost constraints	110% of min.	Free	Minimise
3b	Imports focus with weak cost constraints	120% of min.	Free	Minimise

Source: McKenna, R., Bertsch, V., Mainzer, K. & Fichtner, W. (2016) Combining local preferences with multi-criteria decision analysis and linear optimisation to develop feasible energy concepts in small communities, Working Paper Series in Production and Energy, No. 16

Quantification of tradeoffs between the 8 alternatives

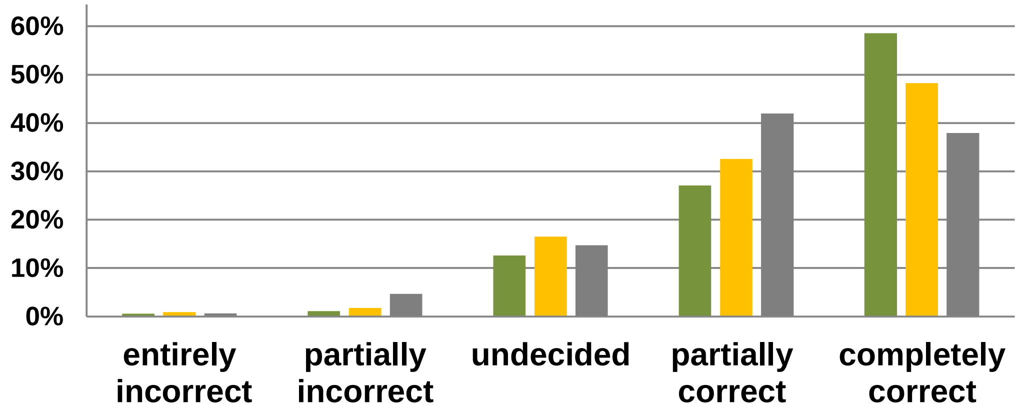


- Derived willingness to pay for local emission abatement: 130-400 € / t CO_2
- Current market price (ETS): 1 t CO_2 < 10 € => Valuation of "the local"

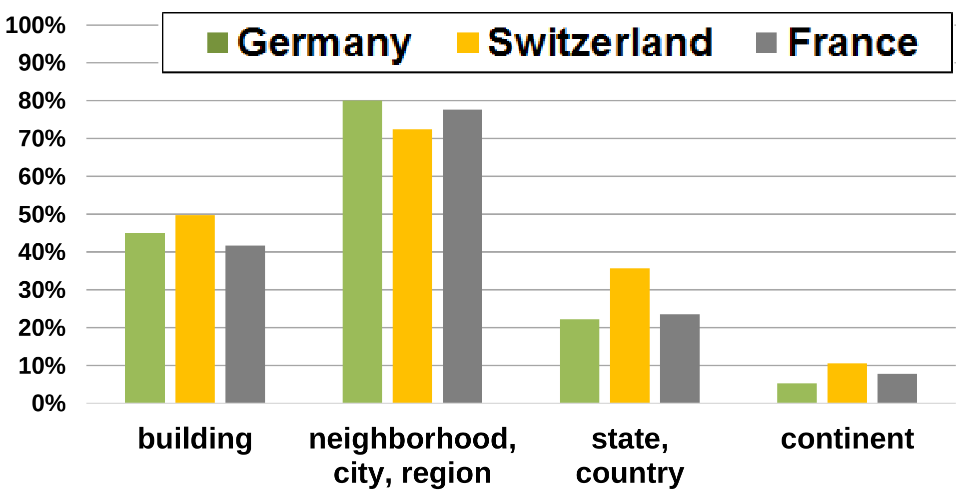
Source: McKenna, R., Bertsch, V., Mainzer, K. & Fichtner, W. (2016) Combining local preferences with multi-criteria decision analysis and linear optimisation to develop feasible energy concepts in small communities, Working Paper Series in Production and Energy, No. 16

Why energy autonomy?

"I generally support initiatives in my neighborhood, which lead to higher energy autonomy."



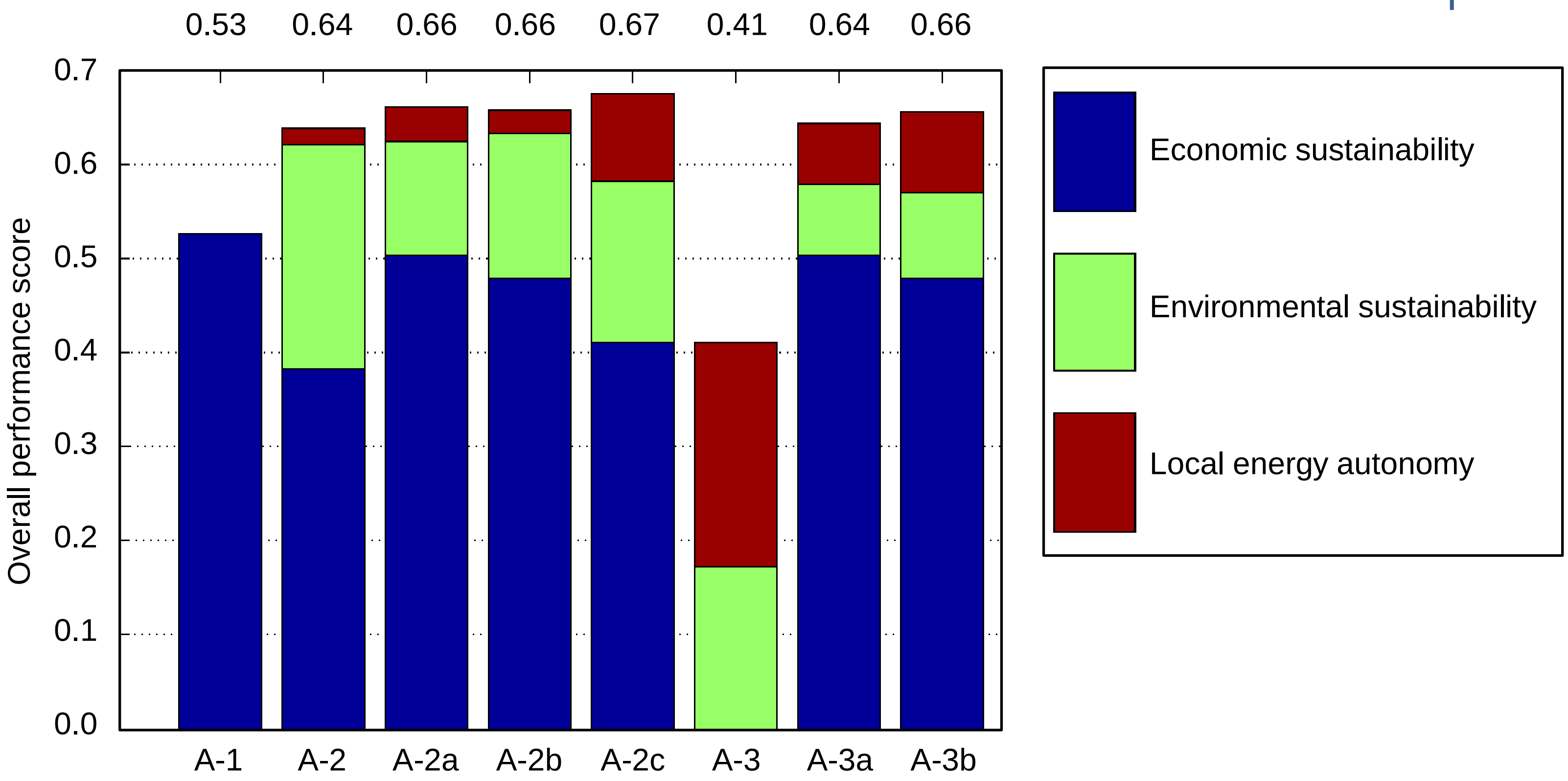
"On which level do you think energy autonomy makes sense?"



1. **Autonomy emerged in workshop discussion**
2. **Further results from related survey-based research**
   - **High general approval** of energy autonomy
   - **Level of knowledge** however relatively **low** (58% did not know the term "energy autonomy")
   - **Approval in Germany** is **significantly higher** than in Switzerland and France
   - **Preference for** autonomy on the **local and regional level** (building, city, region)

Source: Schumacher, K., Krones, F., McKenna, R. & Schultmann, F. (2017) Social acceptance of renewable energies: a comparative, survey-based analysis in Germany, France, and Switzerland, 1st International Conference on Energy Research & Social Science

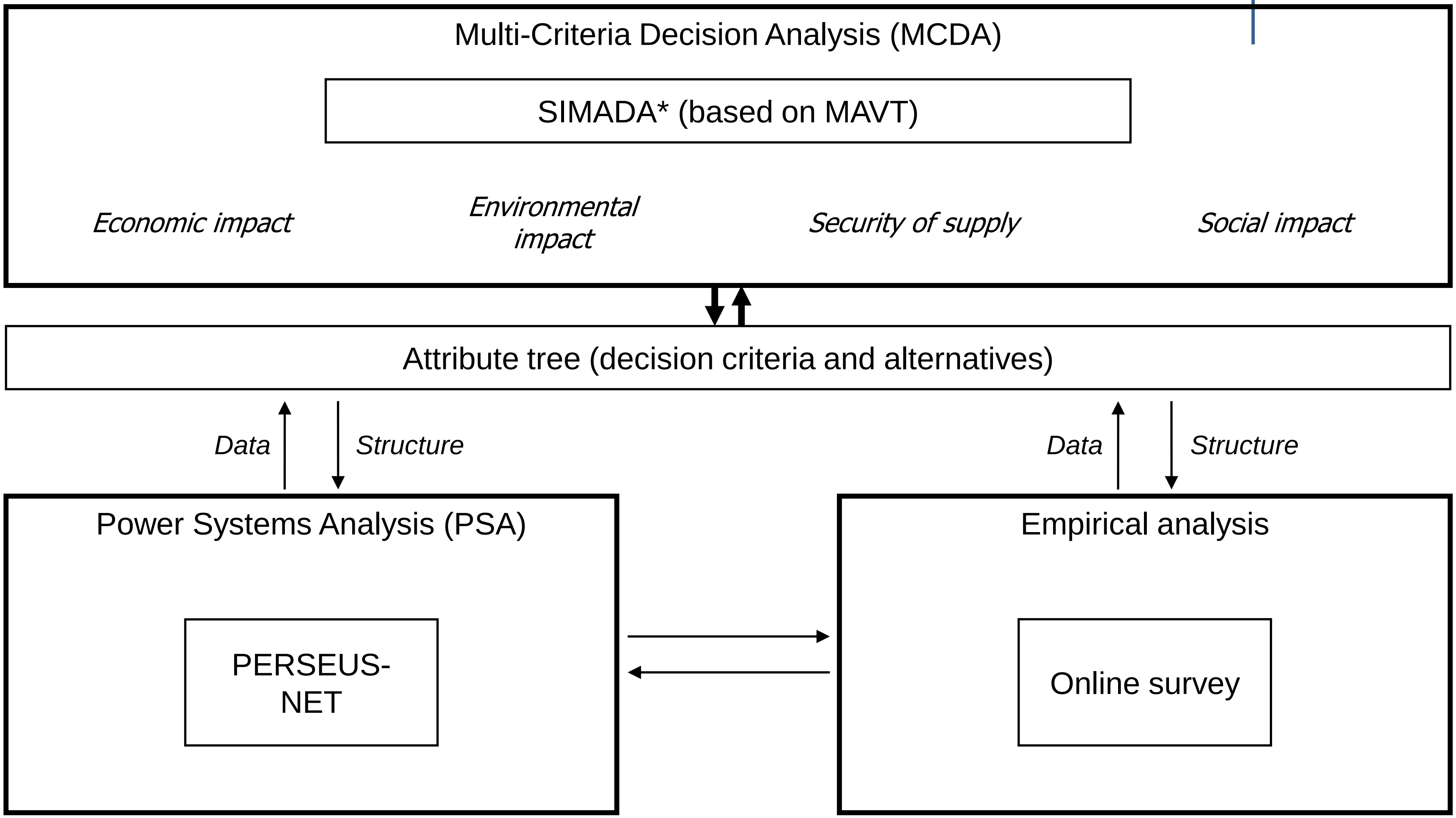
Selected results for the local level study



- Despite the strong weighting of costs, the minimum cost scenario is rarely the "best"

Source: McKenna, R., Bertsch, V., Mainzer, K. & Fichtner, W. (2016) Combining local preferences with multi-criteria decision analysis and linear optimisation to develop feasible energy concepts in small communities, Working Paper Series in Production and Energy, No. 16

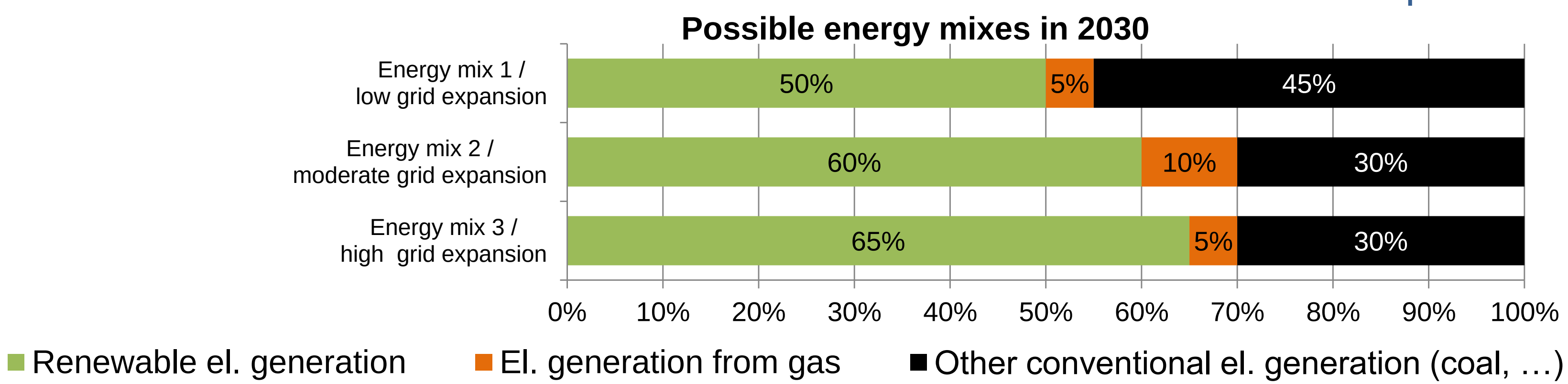
National level study: Overall approach combining power systems modelling, empirical analysis and multi-criteria evaluation



** 'SImulation-based Multi-Attribute Decision Analysis', for details see: Bertsch (2008)*

Source: Bertsch, V. & Fichtner, W. (2016) A participatory multi-criteria approach for power generation and transmission planning, Annals of Operations Research, 245(1), pp. 177-207.

The elicitation of the public acceptance was based on a nationally-representative online survey (n=1000)



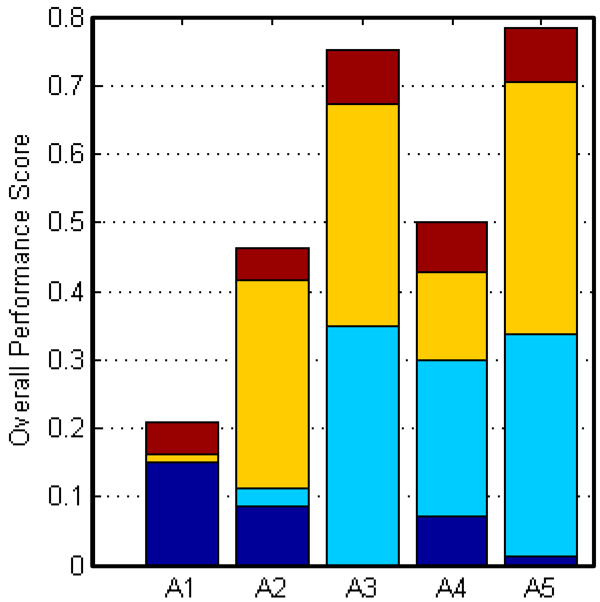
- Use of power systems model to calculate 2030 energy mixes for different combinations of grid expansion and RES-E curtailment
- Respondents were presented with the resulting energy mixes
- Respondents' acceptance of energy mixes for the year 2030 is the higher the more electricity is generated by renewables, regardless of the required grid expansion
  - 60% indicated a higher acceptance for mix 2 than for mix 1 (25% neutral)
  - 60% indicated a higher acceptance for mix 3 than for mix 1 (20% neutral)
  - 45% indicated a higher acceptance for mix 3 than for mix 2 (25% neutral)

Source: Bertsch, V., Hall, M., Weinhardt, C. & Fichtner, W. (2016) Public acceptance and preferences related to renewable energy and grid expansion policy: Empirical insights for Germany, Energy, 114, pp. 465-477.

Selected results for the national level study

Aggregation

Stacked-bar charts illustrate the results of the analysis and the contributions of the different criteria/objectives to the overall results



Objectives

- Security of Supply
- Economic Competitiveness
- Public Acceptance
- Environmental Sustainability

- Alternatives 5 and 3 most preferred followed by Alternative 4
  - Alternative 5: Highest security of supply
  - Alternative 3: Highest env. sustainability
  - Alternative 4: Most balanced alternative, does not score highest for an objective
- Alternative 1 shows best performance in economic terms (highest degree of freedom in power systems modelling)
- Consideration of consumer behaviour/acceptance leads to considerably different ranking

Source: Bertsch, V. & Fichtner, W. (2016) A participatory multi-criteria approach for power generation and transmission planning, Annals of Operations Research, 245(1), pp. 177-207.

Conclusions and discussion

- Conclusions
  - Consideration of behavioural aspects in energy systems modelling is important
  - Results of least-cost optimisation models of limited use
  - Combination of energy systems modelling and MCDA can help to consider consumer behaviour and acceptance
- Next steps
  - Utility maximisation of consumers => valuation of energy services
  - Behavioural aspects of consumer adoption of technologies (e.g. electric vehicles)

  ⇒ Trilateral “CREDENCE” project
- Some trends and challenges for the BOR community
  - Decentralisation of and participation in everything (“Shareconomy”, distributed opposition and use of social media for forming opinions)

  ⇒ Tools and methods needed for “mass (online) preference elicitation”
    - Interactive / educative => understandable explanations/support very important
    - Natural language processing of model input in addition to model output
  - How combine mass participation with facilitation by (MCDA) experts?

Source: Wulf, D. & Bertsch, V. (2017) A natural language generation approach to support understanding and traceability of multi-dimensional preferential sensitivity analysis in multi-criteria decision making. Expert Systems with Applications, 83, pp. 131-144.

References

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Thank you very much for your attention!

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