SYSTEMANALYSE
FORSCHUNGSNETZWERKE
ENERGIE

Backbone – An Adaptable Energy Systems Modelling Framework for Sector Coupling

Jonas Finke[1], Leonie Plaga, David Huckebrink, Sophie Pathe, Christine Nowak, Jan Mutke, Valentin Bertsch
Chair of Energy Systems and Energy Economics, Ruhr-Universität Bochum[2]

Gefördert durch:
PtJ Projektträger Jülich Forschungszentrum Jülich
Bundesministerium für Wirtschaft und Energie
aufgrund eines Beschlusses des Deutschen Bundestages

Backbone Framework

Motivation

- Increased use of renewable energy sources leads to growing flexibility demand and decentralisation
- Sector coupling (e.g. "Power-to-heat" or "Power-to-gas") can help meeting flexibility demand and decarbonising non-electricity sectors
- Energy system modelling (ESM) supports decision making in the increasingly complex sectors

Backbone [1]

- Open source energy system modelling framework
- Adaptable network structure (see Fig. 1) enables integration of various sectors, e.g. electricity, heat, hydrogen
- Investment and operational planning
- Any desired spatial and temporal resolution
- Technological detail, e.g. start-ups, efficiencies, integer variables
- Miscellaneous constraints, e.g. reserve requirements, emission limits, partial autarky
- Stochastic modelling through forecasts and samples

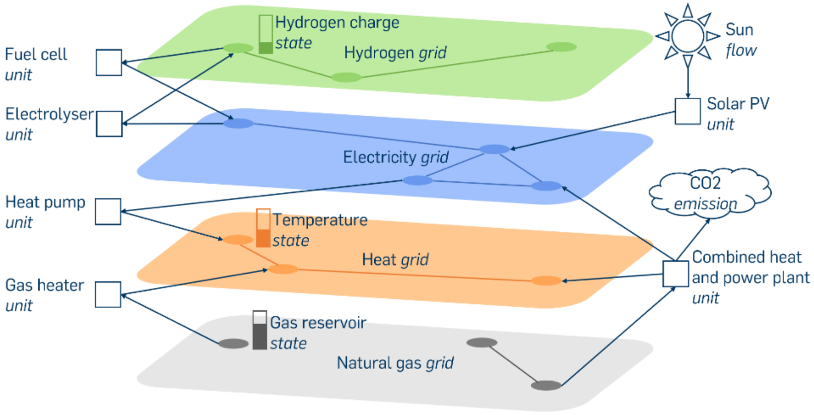

Fig. 1 (left): Backbone network example consisting of *nodes* (circles) in *grids*, connected by *lines*. *Units* convert energy with possibly multiple in- and outputs (arrows) from or to *nodes*, *flows* or *emissions*. Storages are modelled using nodal *states*.

PyPSA-to-Backbone Data Tool

Data acquisition and clustering of the European electricity grid

- Objective: consistently use open data across energy system models
- PyPSA-Eur [2] provides weather, grid, powerplant and demand data for the European electricity sector
- Clustering can be performed by PyPSA-Eur either for an arbitrary number of nodes or for user-specified clusters (see Fig. 2)
- Our tool converts the resulting network to a Backbone-compatible input file in an automated way

Fig. 2 (right): Application of custom clustering. The high resolution of the original data is indicated by the green circles. After clustering, Germany is resolved at a NUTS-2 level for detailed examination, whereas other countries are simplified strongly allowing for international energy exchange, as indicated by the coloured areas.

References

[1] Helistö, N. et al. Backbone—An Adaptable Energy Systems Modelling Framework. Energies 2019, 12, 3388.

[2] Hörsch, J. et al. PyPSA-Eur: An open optimisation model of the European transmission system. Energy Strategy Reviews 2018, 22, 207-215.

Future Work

- Alternative hydrogen pathways in energy systems
- Heat transition and emissions-based demand response
- Impact of climate change on energy systems
- Environmental impacts – life cycle assessment in ESM
- Multi-objective optimisation in ESM
- Considering behavioural aspects
- Integrating reduced-order process models in ESM

Current Studies

Energy storage technologies in Germany 2050

- Least-cost investment optimisation for the German power system in 2050 (resolution: 10 sub-regions, hourly) across different CO_2 reduction scenarios
- Investments in four selected energy storage and four generation technologies considered

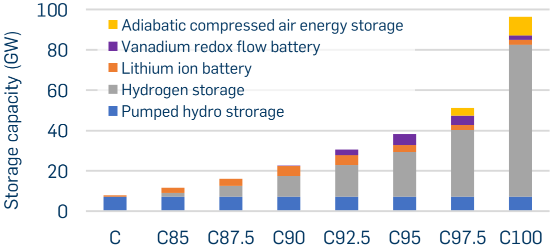

Fig. 3: Installed capacities of storage technologies across different CO_2 reduction scenarios, where Cx = x% reduction as compared to 1990. Pumped hydro storage investments are not allowed.

Influence of public acceptance of wind turbines on renewable expansion

- Expansion planning for Ireland and Germany (resolution: 8 sub-regions each) for 2030 with high renewable shares
- Maximum onshore wind potential constraint based on local public's acceptance (from survey data)
- In Germany, onshore wind is mainly substituted by PV, while in Ireland, it is mainly substituted by offshore wind
- Constrained onshore potential slightly increases costs for expansion, where costs rise more strongly in Ireland than in Germany (Ireland: 2.55%, Germany: 0.5%)

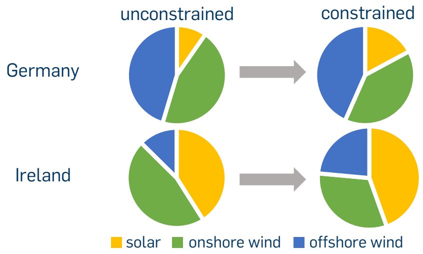

Fig. 4: Technology-specific shares of invested renewable energy in Germany and Ireland for 2030. Left: Onshore wind potential only constrained by technical and geographical constraints. Right: Onshore wind potential also constrained based on local public's acceptance.

---

[1] jonas.finke@ee.rub.de [2] Address: Universitätsstr. 150, 44801 Bochum, Germany. URL: https://www.ee.rub.de/

Chair of
Energy Systems &
Energy Economics

RUHR
UNIVERSITÄT
BOCHUM