Energy sector integration – opportunities and challenges arising from an electrification of heating and transport sectors

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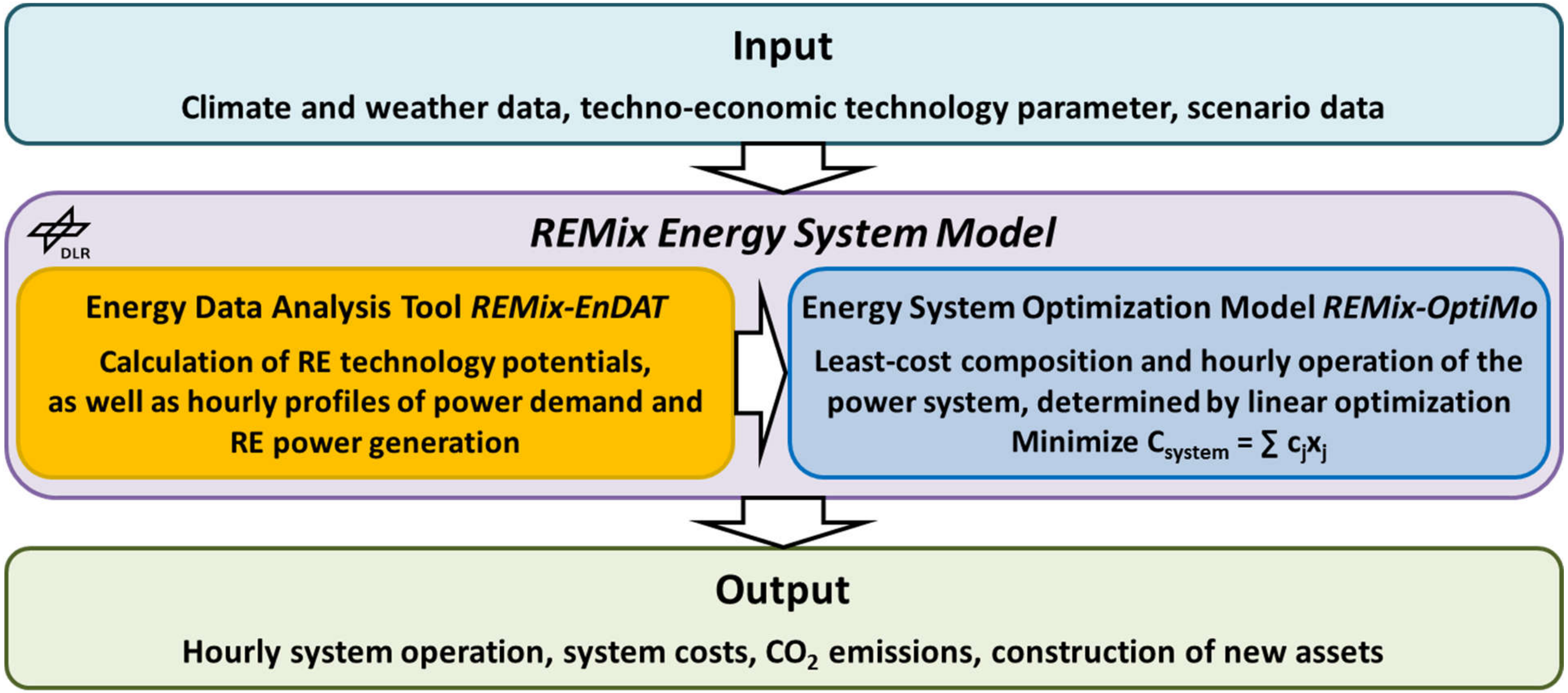
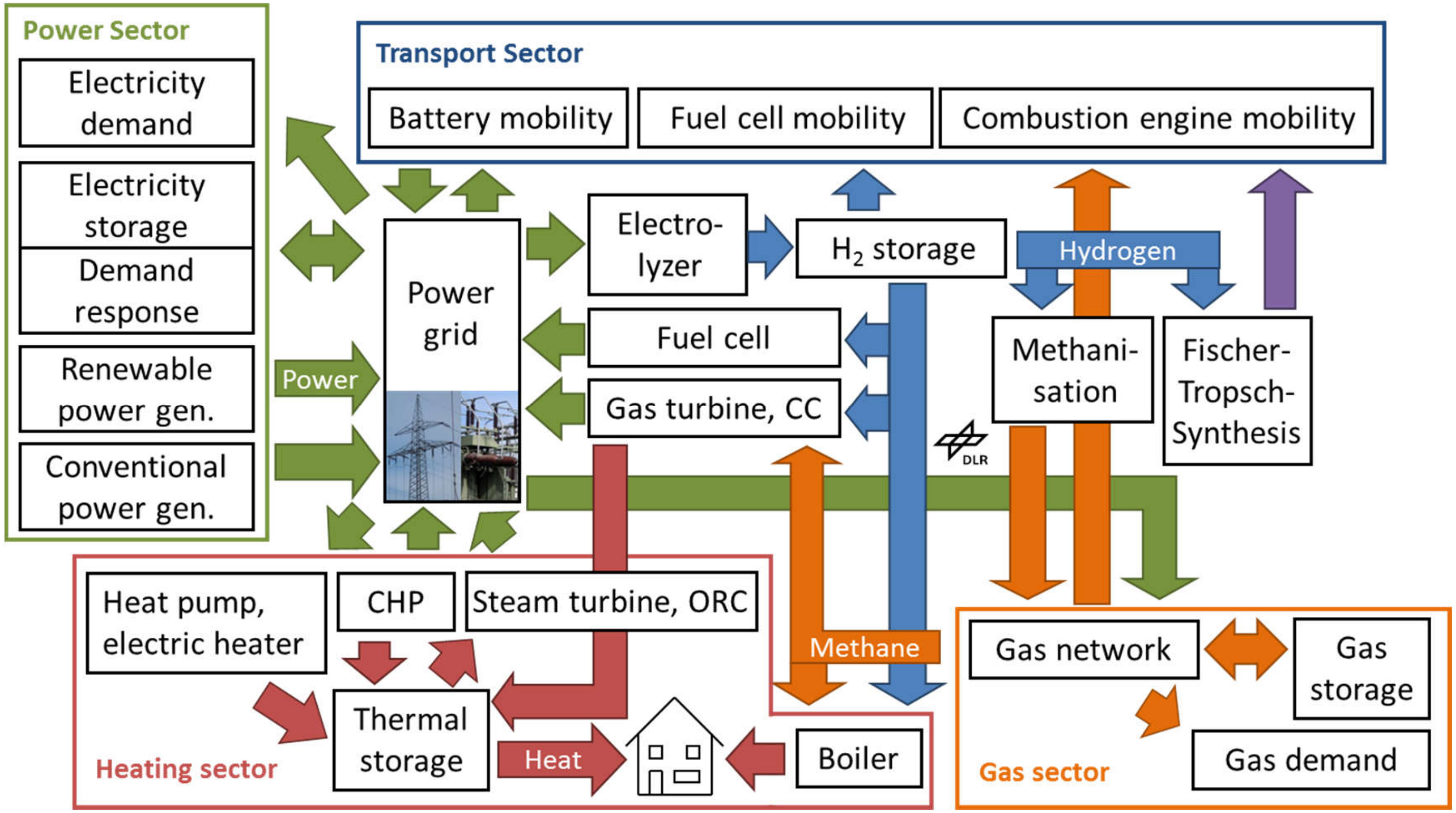
REMix Energy System Model



- Deterministic linear optimization model realized in GAMS
- Assessment of investment and hourly system dispatch during one year
- Scope: validation of regional, national and continental long-term energy scenarios

Source: Gils, H.C, Scholz, Y., Pregger, T., Luca de Tena, D., Heide, D. (2017) Integrated modelling of variable renewable energy-based power supply in Europe. Energy, 123: 173-188. http://dx.doi.org/10.1016/j.energy.2017.01.115

Representation of energy sector integration in REMix

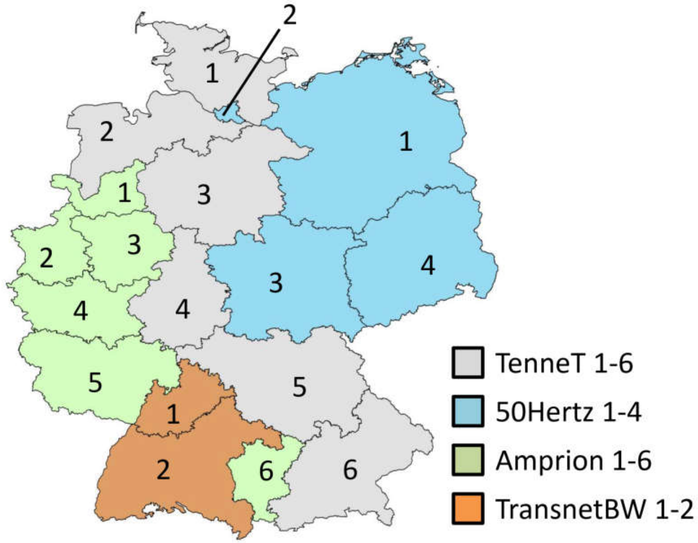


- Continuous and ongoing enhancement of the model scope
- Focus on power demand flexibility provided by energy sector integration

Case study: energy sector integration in Germany (1)

	Import	Decentralized	Offshore
Grid expansion*	Endogenous expansion in Germany and neighbours	No endogenous grid expansion	Endogenous expansion only in Germany
Self-supply	Each model region provides 65% of its demand	Each model region provides 90% of its demand	Each model region provides 65% of its demand
Given VRE capacities	PV: 74 GW Wind onsh. 69 GW Wind offsh. 29 GW	PV: 74 GW Wind onsh. 69 GW Wind offsh. 29 GW	PV: 74 GW Wind onsh. 69 GW Wind offsh. 45 GW

*excluding connection of offshore wind



- Target year 2050, RE share > 90% for domestic generation
- Scenarios vary in regional allocation of power generation and grid expansion
- Consideration of power exchange within Europe and 18 regions in Germany
- Competition of flexible sector integration with expansion of storage and backup

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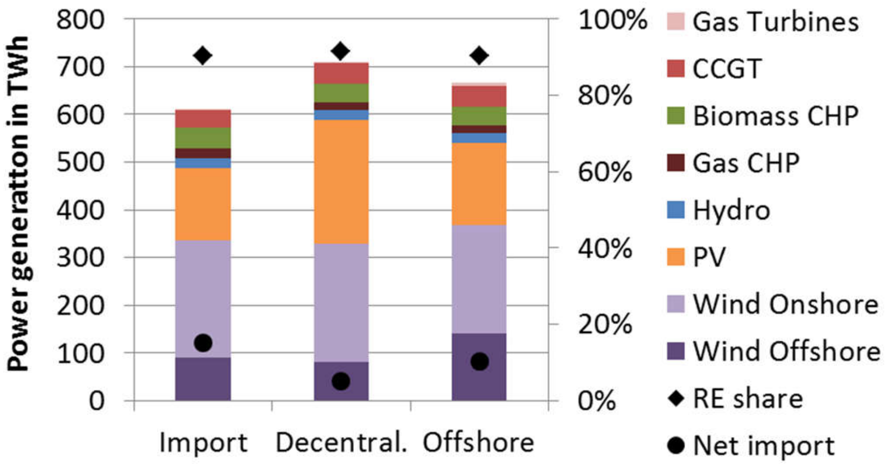
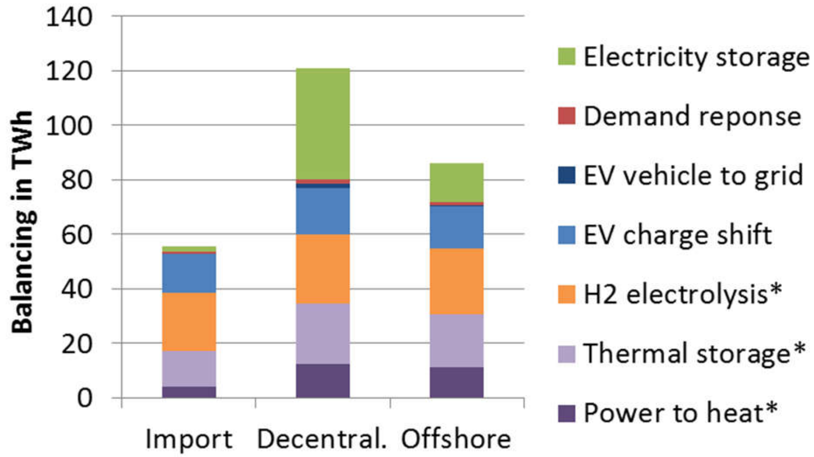
For details see the final report of the RegMex project, to be published in summer 2018 on http://elib.dlr.de

Case study: energy sector integration in Germany (2)



Power generation



Temporal balancing (* electricity equivalent)

- Around 35% of battery electric vehicle (BEV) charging demand is shifted
- Around 10% of the heat demand supplied by CHP and heat pump is stored
- Around 20% of decentralized H_2 demand is stored
- Inflexible heating and BEV charging increase CO_2 emissions by ~3-5 % each
- Grid expansion enables much smaller dimensioning of decentralized H_2 system
- (Optimised) H_2 infrastructure notably reduces battery storage demand

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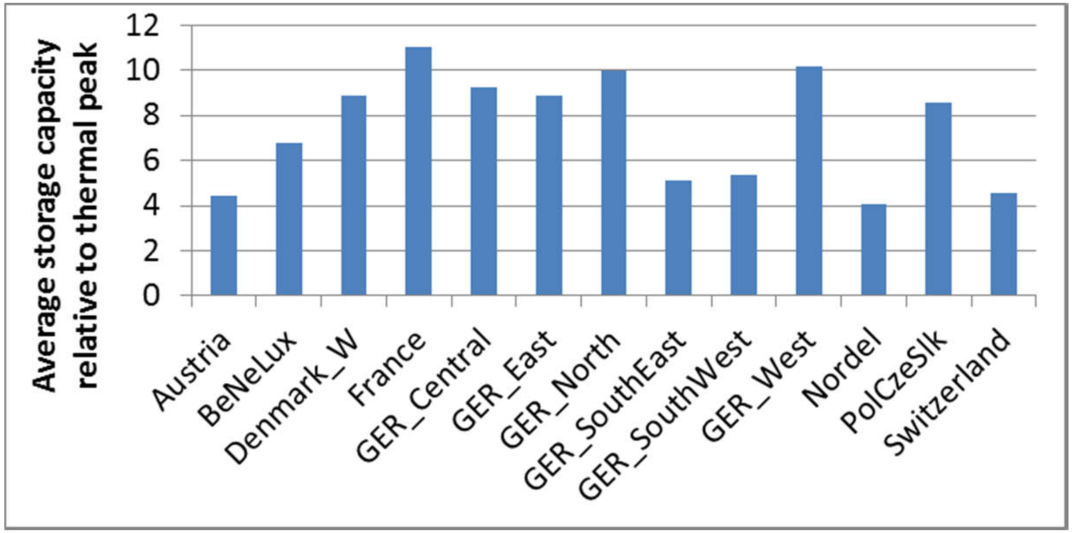
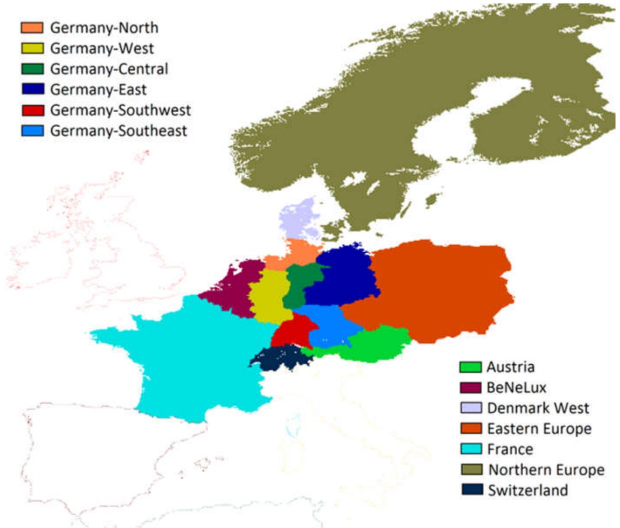
Case study: flexible electric heating and CHP in Europe



Resulting average storage size in district heating systems

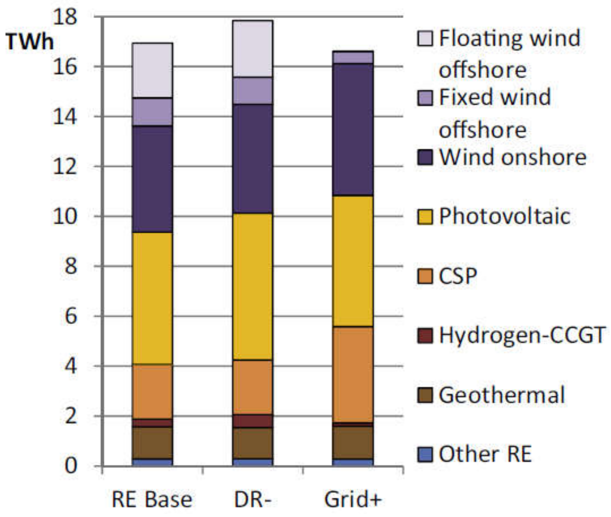


Considered regions/countries

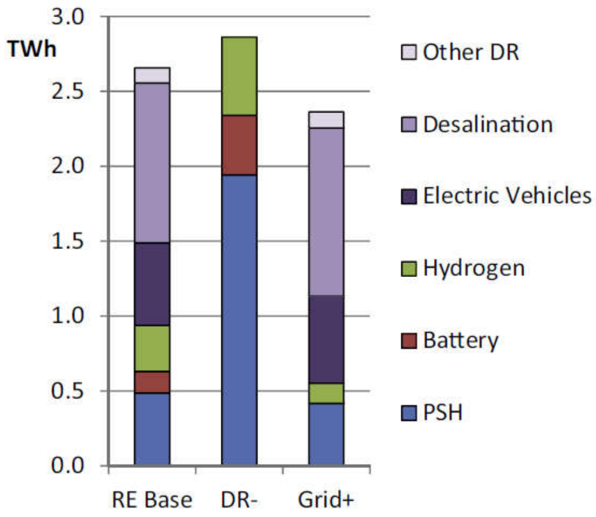
- Least-cost dimensioning of thermal storage in CHP and heat pumps systems
- Based on detailed assessment of heat demand and district heating potential
- Target year 2050, RE share 85%, VRE share 70%
- Model results show high potential for power-oriented operation, particularly in regions with high wind power supply share
- Usage of thermal storage hardly influenced by other balancing technologies

Source: Gils, H.C. (2017) A model-based analysis of the opportunities and constraints of enhanced energy sector integration. Spring Meeting of the Deutsche Physikalische Gesellschaft e.V., Conference Proceedings, http://elib.dlr.de/114406/1/Gils_tagungsband-ake-2017.pdf

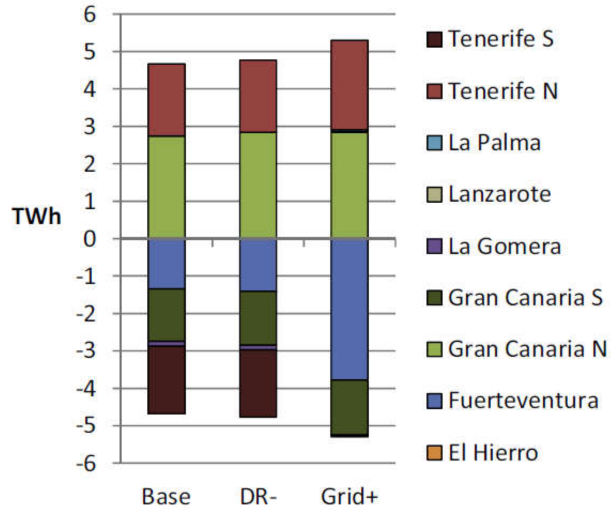
Case study: 100% RE supply on the Canary Islands



Power generation



Temporal Balancing

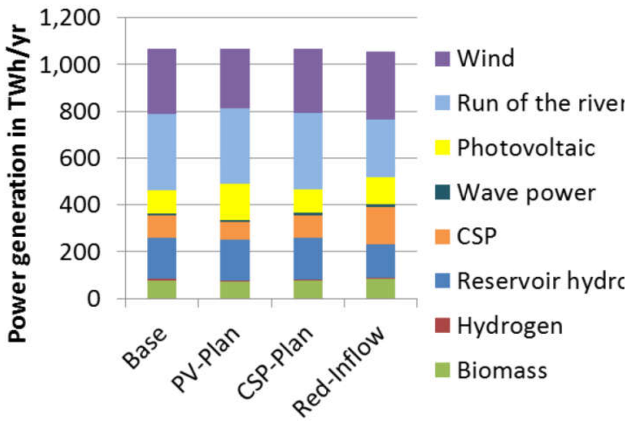


Spatial Balancing

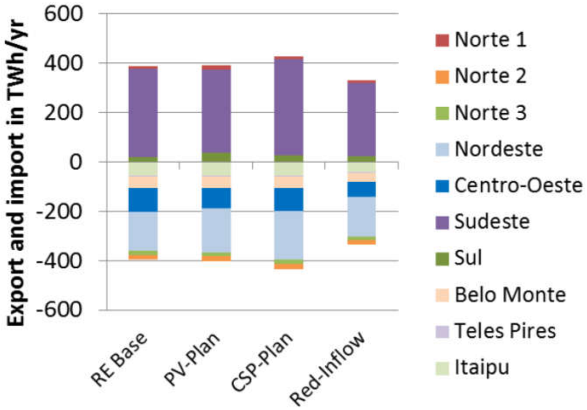
- Particular challenging island environment:
  - Limited possibility of spatial balancing through power transmission
  - Low availability of biomass and hydro power for dispatchable generation
- Important contribution of controlled battery electric vehicle charging, flexible hydrogen production and re-electrification to load balancing
- High curtailments indicate potential for additional balancing/storage

Source: Gils, H.C. and Simon, S. (2017) Carbon neutral archipelago – 100% renewable energy supply for the Canary Islands, Applied Energy, 188: 342-355. http://dx.doi.org/10.1016/j.apenergy.2016.12.023

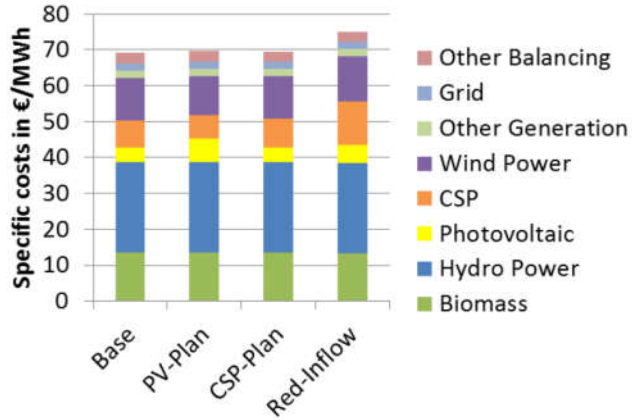
Case study: 100% RE supply in Brazil



Power generation



Spatial Balancing



Power generation costs

- High potential for dispatchable renewable generation: hydro, biomass, CSP
- Flexible sector integration is used if available, mostly controlled electric vehicle charging, but limited role for synthetic fuels/hydrogen
- Thermal storage mostly relevant in Concentrating Solar Power (CSP) stations
- Wind and PV cheaper than additional hydro power
- Reduced inflow to hydro stations favours additional CSP

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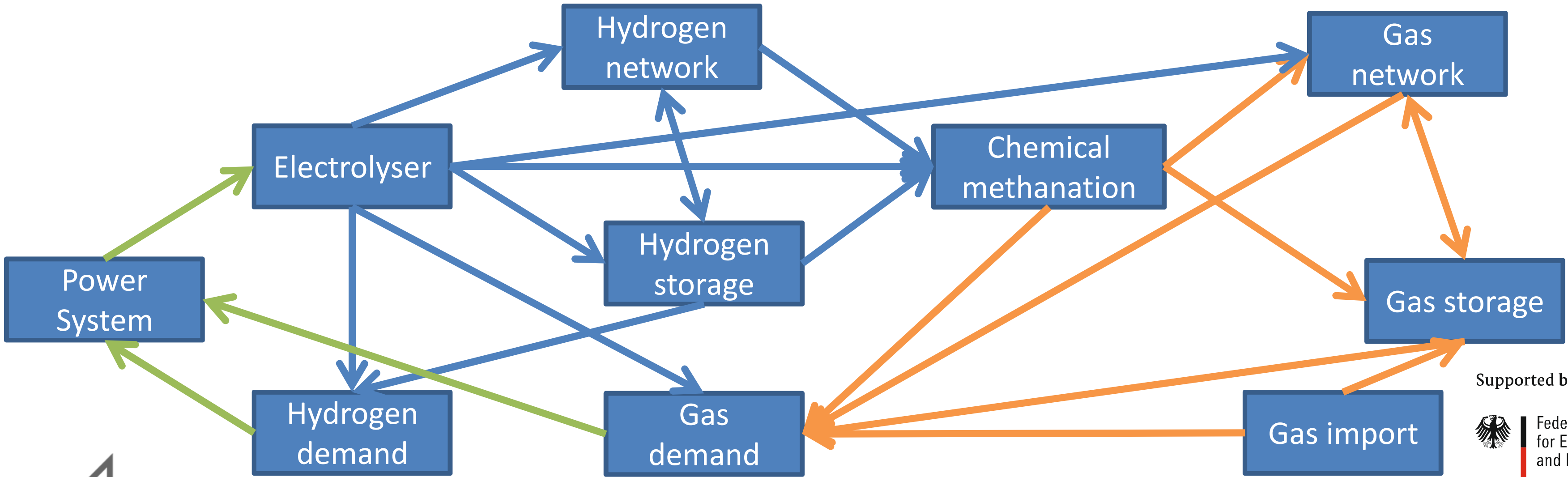
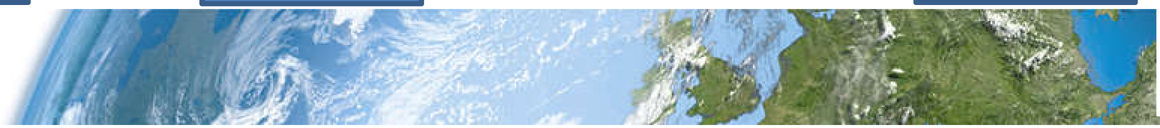
Source: Gils, H.C., Simon, S., Soria, R. (2017) 100% renewable energy supply for Brazil – the role of sector coupling and regional development, Energies 10,1859, https://doi.org/10.3390/en10111859

Implementation of the gas sector into REMix

- Scope:
  - simplified representation of synthetic gas production, storage, transport
  - consideration of the power demand for gas compression
- Requirements:
  - fully linearized implementation, limited to energy quantities
  - negligence of gas properties and technical details of compressors & pipes
- Realization:
  - Modular structure allows for flexible combination of elements





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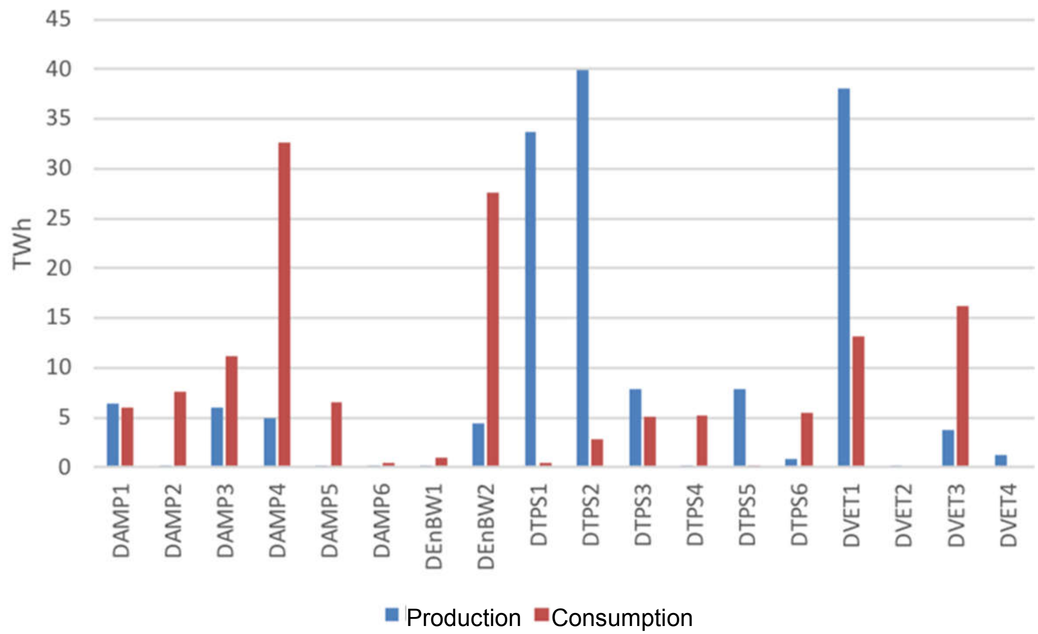
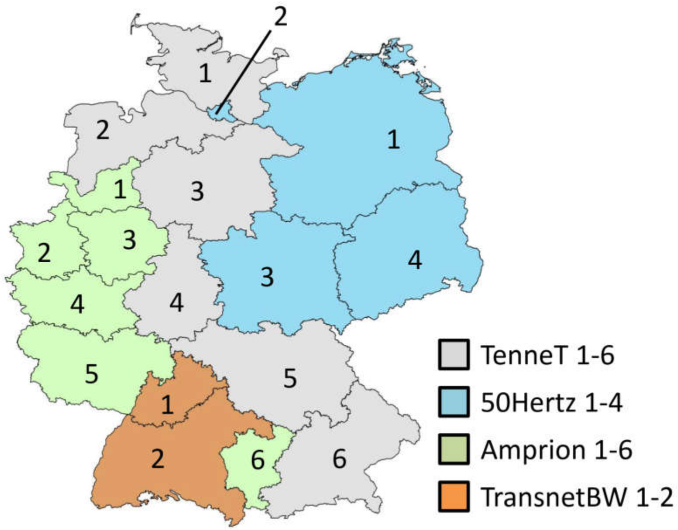
Exemplary results using the model enhancement

- Test case evaluating the production, transport and usage of renewable gas
- Regionally resolved island system for Germany with 100% RE supply
- Gas production mostly in coastal regions, reconversion further south
- Dimensioning and location of highly influenced by power grid capacity





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Summary and outlook

- REMix includes all major energy sector integration technologies in high detail
- Evaluation of flexible energy sector integration from overall systems‘ perspective

- Significant demand flexibility of BEV charging, electric heating and H_2 electrolysis, which can complement and replace power transmission and storage

- Current focus on more detailed implementation of gas sector/synthetic fuels
- Ongoing projects focused on energy sector integration
  - Interaction of different options, influence of supply and grid infrastructure
  - Integration of business perspective through model coupling

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