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TRANSFORMATION OF THE HEAT AND GAS INFRASTRUCTURE FOR A COST-OPTIMISED CLIMATE-NEUTRAL EUROPEAN ENERGY SYSTEM

Jens Schmugge, Hedda Gardian, Hans Christian Gils 9th International Conference on Smart Energy Systems, 12-13 September 2023, Copenhagen (SESAAU 2023)



Motivation: a dedicated hydrogen infrastructure becomes cost-optimal already for relatively low demand

- case study on CH₄ grid
 retrofitting in Germany
- hydrogen infrastructure for
 8 distinct H₂ demand
 scenarios
- pipeline versus truck transportation

Source: Husarek, Dominik; Schmugge, Jens; Niessen, Stefan (2021): Hydrogen supply chain scenarios for the decarbonisation of a German multi-modal energy system. In *International Journal of Hydrogen Energy* 46 (76), pp. 38008– 38025. DOI: 10.1016/j.ijhydene.2021.09.041.





REMix

REMix: open-source energy system optimisation framework





- code and documentation online since Sep 2023
- linear cost optimisation
- designed for modelling large-scale energy systems
- parallel solving with PIPS-IPM++
- written in GAMS, data preprocessing with Python
- capacity expansion and dispatch of all assets

 ${}^1 REMix\ repository:\ https://gitlab.com/dlr-ve/esy/remix/framework$

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REMix: more framework capabilities and model example





Documentation

- pathway optimisation
- multi-criteria optimisation
- modelling to generate alternatives (MGA)
- sector integrated models for Europe

¹van Ouwerkerk; Gils; Gardian et al.: Impacts of power sector model features on optimal capacity expansion: a comparative study. Renewable and Sustainable Energy Reviews, 157:112004, April 2022. ²Gils; Gardian; Kittel et al.: Model-related outcome differences in power system models with sector coupling—quantification and drivers. Renewable and Sustainable Energy Reviews, 159:112177, May 2022. ³Gils; Gardian; Kittel et al.: Modeling flexibility in energy systems comparison of power sector models based on simplified test cases. Renewable and Sustainable Energy Reviews, 158:111995, April 2022.



REMix model instance from the FlexMex project^{1,2,3}



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FINDINGS

Earlier REMix analysis for Germany: importance of flexible electrolysis, but need for variety of balancing technologies



Methanation capacity in GW(chem)

H₂ network capacity in GW(chem)

- sector integration in Germany (electricity, gas, heat and transport sector)
- electrolysis takes on very dominant role in 2050
- BUT: it does not displace need for other technologies

Source: Gils; Gardian; Schmugge (2021): Interaction of hydrogen infrastructures with other sector coupling options towards a zero-emission energy system in Germany. In *Renewable Energy* 180, pp. 140–156. DOI: 10.1016/j.renene.2021.08.016.



- CH₄ and H₂ caverns act as seasonal storage
- heat storage gives short-term flexibility to the system



Source: Gils; Gardian; Schmugge (2021): Interaction of hydrogen infrastructures with other sector coupling options towards a zero-emission energy system in Germany. In *Renewable Energy* 180, pp. 140–156. DOI: 10.1016/j.renene.2021.08.016.

Earlier REMix analysis for Europe: the impact of policy decisions on the power and gas infrastructure design

- electrolysis capacities throughout Europe, most in western parts
- CH₄ pipeline retrofitting option makes H₂ grid economically feasible
- no network expansion will lead to increased system costs of 15 %
- electrification of heat supply supplies most demand for that sector

Source: Wetzel; Gils; Bertsch (2023): Green energy carriers and energy sovereignty in a climate neutral European energy system. In *Renewable Energy*. DOI: 10.1016/j.renene.2023.04.015.





Next steps and ongoing modelling task: pathway for the gas transition

- pathways to a climate-neutral European energy system with focus on gas infrastructure
- Added value:
 - myopic pathway in 5-year steps (up to 2050)
 - regionalised European model scope
 - optional repurposement of CH₄ infrastructure
 - high technological detail, esp. in heat sector
 - comparison of electricity/CH₄/H₂ transportation



Aggregated electricity and gas grid capacities for 70 model nodes

Technological scope of the sector integrated model



Summary: hydrogen and the gas grid are potential key elements of the future energy system



- (1) hydrogen transportation infrastructure in Germany already economically feasible from demands of 50 TWh hydrogen on
- (2) electrolysis is important, but the predominant feature of sector-integration flexibility is a technology mix
- (3) heat storage and battery vehicles serve as short-term flexibility, gas caverns seasonally
- (4) no network expansion leads to higher costs in comparison

<u>open:</u>

- is transfer of energy more cost-effective via the electricity or the hydrogen grid?
- what is the influence of high technological resolution for a European scope?

Imprint



Topic: Transformation towards a cost-optimised climate-neutral European energy system

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