Supported by:

Federal Ministry
for Economic Affairs
and Energy

on the basis of a decision
by the German Bundestag

MuSeK

Model-Based Analysis to Evaluate the Contribution of the Gas Supply System for the Integration of Fluctuating Renewable Electricity Generation

16th IAEE European Conference

Ljubljana, 26 August 2019

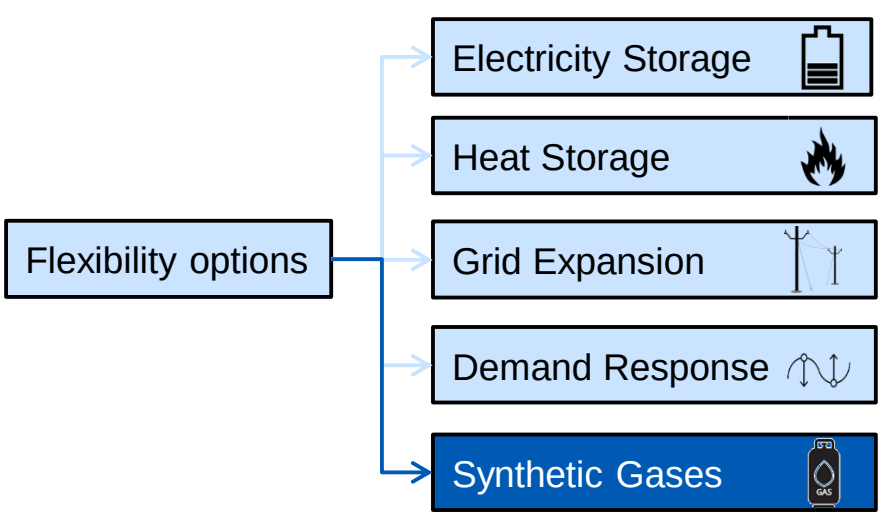
Hedda Gardian, Hans Christian Gils

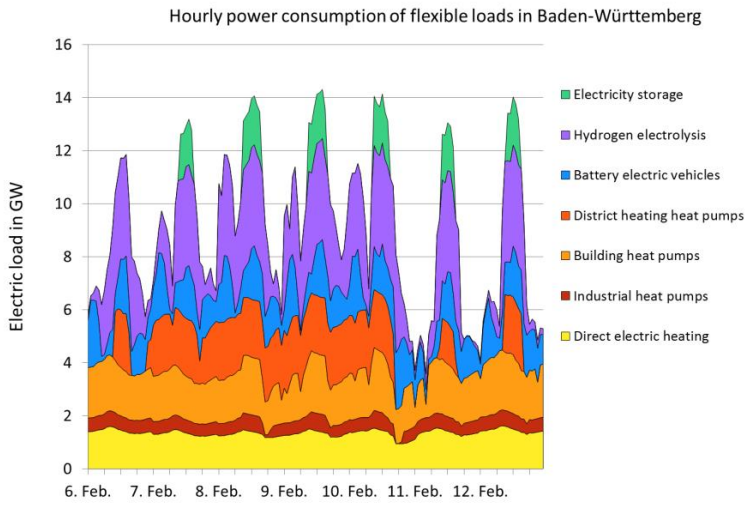
German Aerospace Center (DLR)
Energy Systems Analysis

DLR

Research topic

- Investigating the flexibility potential of the gas system in comparison with other flexibility options in a future energy system with a high share of RE
- Research project **MuSeKo**: Multi Sector Coupling
  - Examination of flexibility in the production and storage of synthetic gases
  - Interaction with other flexibility options
  - Identification of the least-cost dimensioning of converters and storages





Source: Schick, C. et al. (2018) Energiesystemanalyse Baden-Württemberg. Project report, http://www.strise.de/projekte/

REMix OptiMo: Energy System Model

Input: techno-economic parameters, potentials, scenario data

Model: REMix-OptiMo: Energy System Optimization Model

determining the least-cost composition and hourly operation of the power system

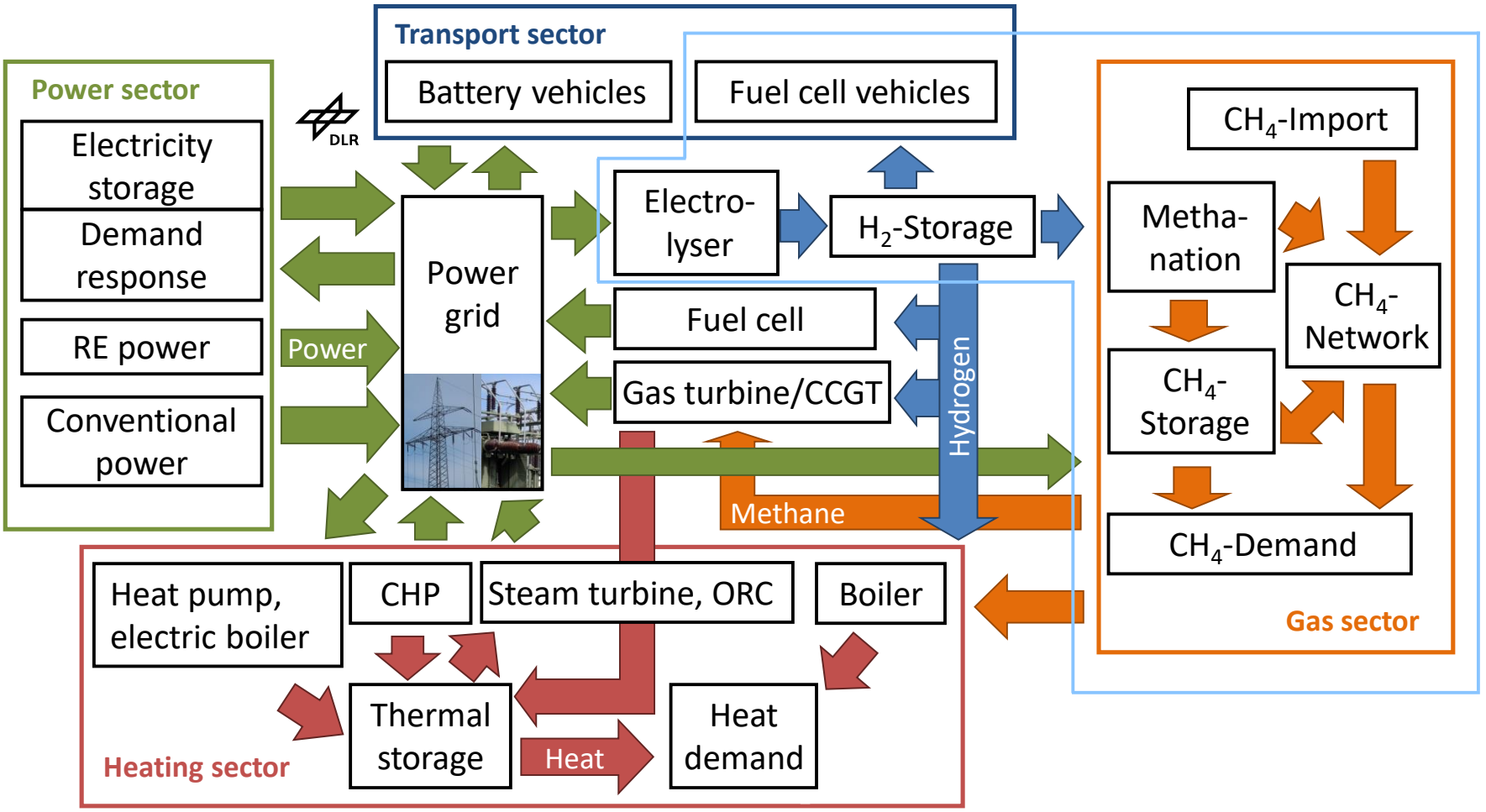
Minimize $C_{system} = \sum c_j x_j$

Output: hourly system operation, system costs, emissions, plant expansion

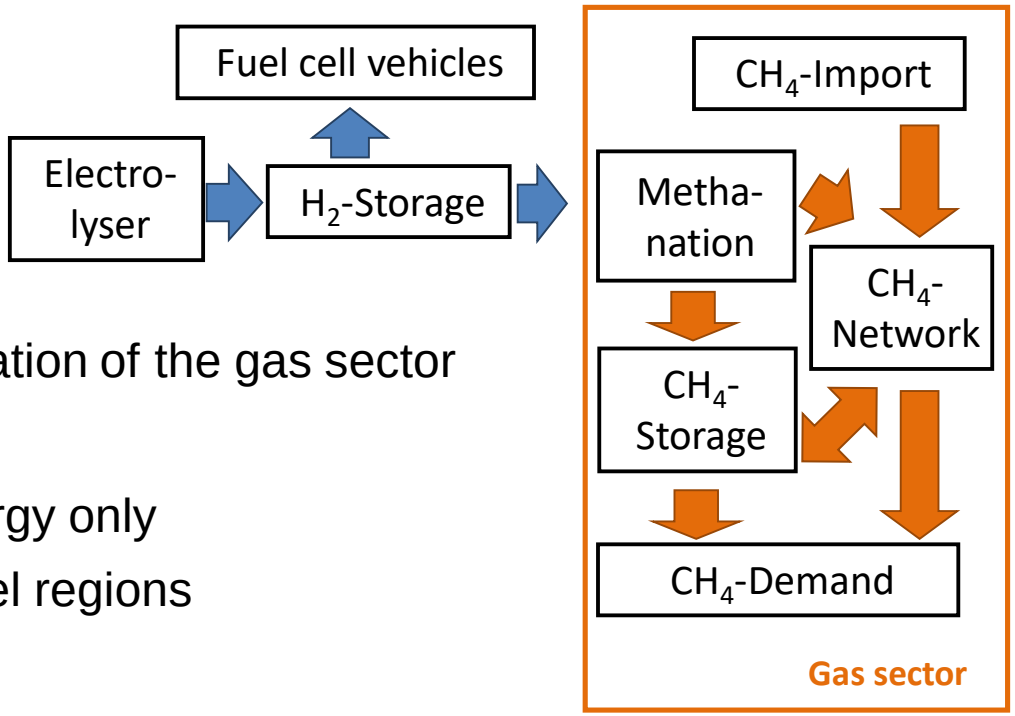
- Cost-minimizing model from an economic planner's perspective, here only LP
- Deterministic optimization realized in GAMS, solved with CPLEX
- Hourly resolution, typically perfect foresight for one year (8760 time steps)
- Simultaneous optimization of plant expansion and operation

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

Evaluation of flexible energy sector coupling with REMix

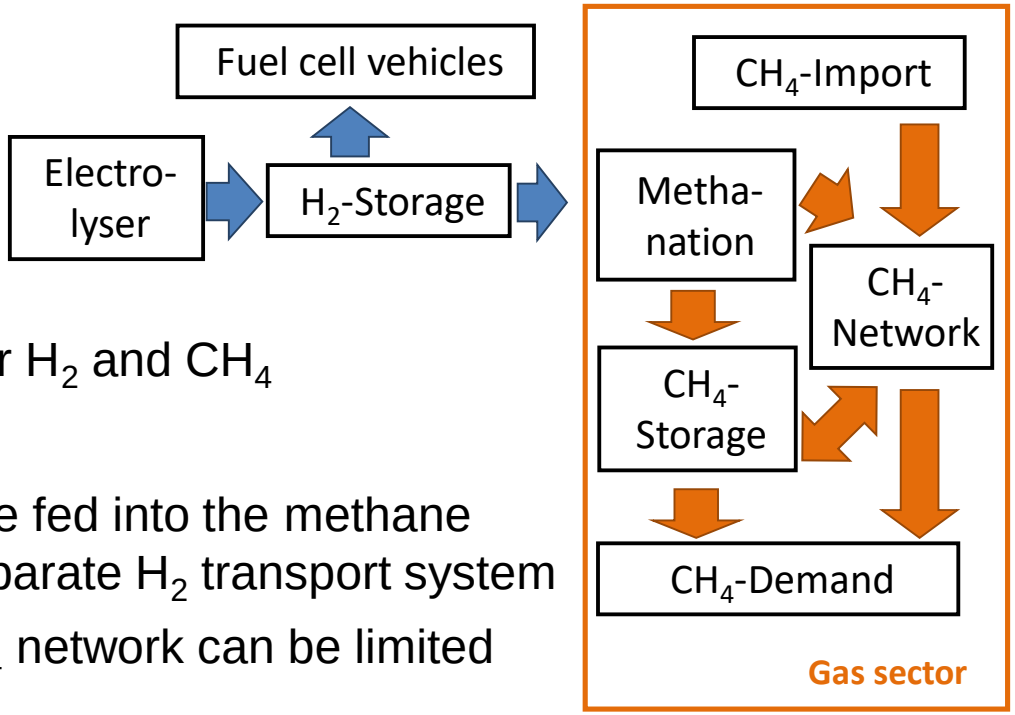


REMix enhancement for the gas sector



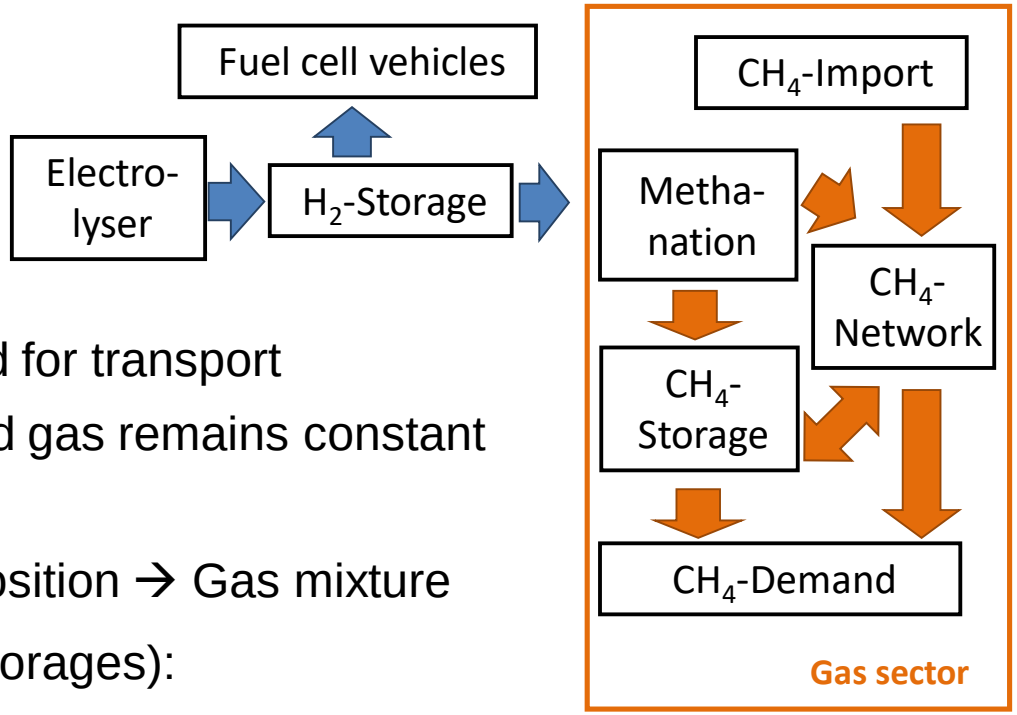
- Goal:
  - Reduced, linearized representation of the gas sector
- Limitations:
  - Consideration of chemical energy only
  - Aggregation according to model regions
- Modules:
  - Modular structure for flexible combination of technologies

REMix gas sector: demand and production



- Gas Demand:
  - Household/Industry demand for H_2 and CH_4
- Elektrolyzer:
  - Produced H_2 and biogas can be fed into the methane transport system as well as separate H_2 transport system
  - Share of H_2 that is fed into CH_4 network can be limited
- Methanation:
  - Generic module to transform input-fuel to output-fuel
  - Considering multiple efficiencies

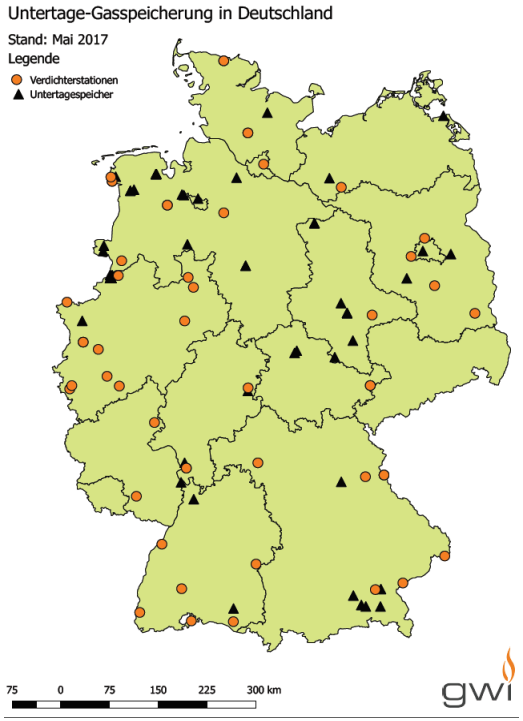
REMix gas sector: transport, storage and import

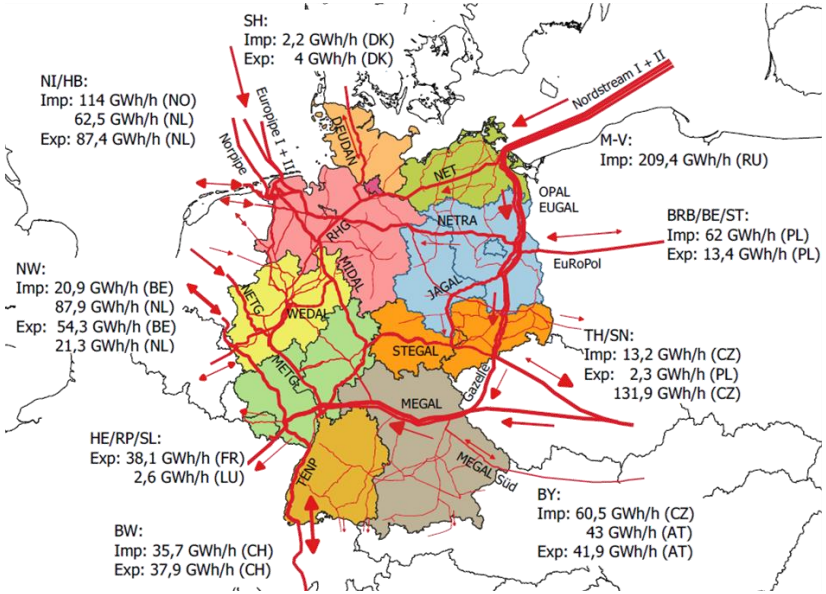


- Gas Network:
  - Compression energy is needed for transport
  - Chemical energy of transported gas remains constant
  - No transport delay
  - No consideration of gas composition → Gas mixture
- Gas Compression (pipelines and storages):
  - Gas- or electricity-powered
- Gas Import:
  - Modelling of import flows
  - Different gases can be imported

Data basis for the gas system modelling in MuSeKo

- Salt domes for CH_4 or H_2 hydrogen storage
- Data on existing assets: storage locations and capacities
- Evaluation of gas transport capacities
- Assumption of reversible flows
- Compressor capacities from literature and inquiries





REMix configuration in MuSeKo

- Regions:
  - Germany divided into states
  - Neighbouring countries
- Myopic application: 2020, 2030, 2040, 2050
  - Decommissioning at end of lifetime
  - No construction time
- Consideration of existing capacities:
  - Power/Gas network and storage
  - Wind/PV capacity w/o decommissioning
  - CHP/conventional capacity w/ decommissioning
- Capacity optimization of RE, gas power plants, CHP, electricity storage and of flexible sector coupling

→ Resulting problem size: **~100 Mio. variables**, **~50 Mio. equations**

Scenarios in MuSeKo

- Exogenously defined demand for electrical power, CH_4, H_2 and heat
- Exogenously defined fuel and CO_2-emission costs

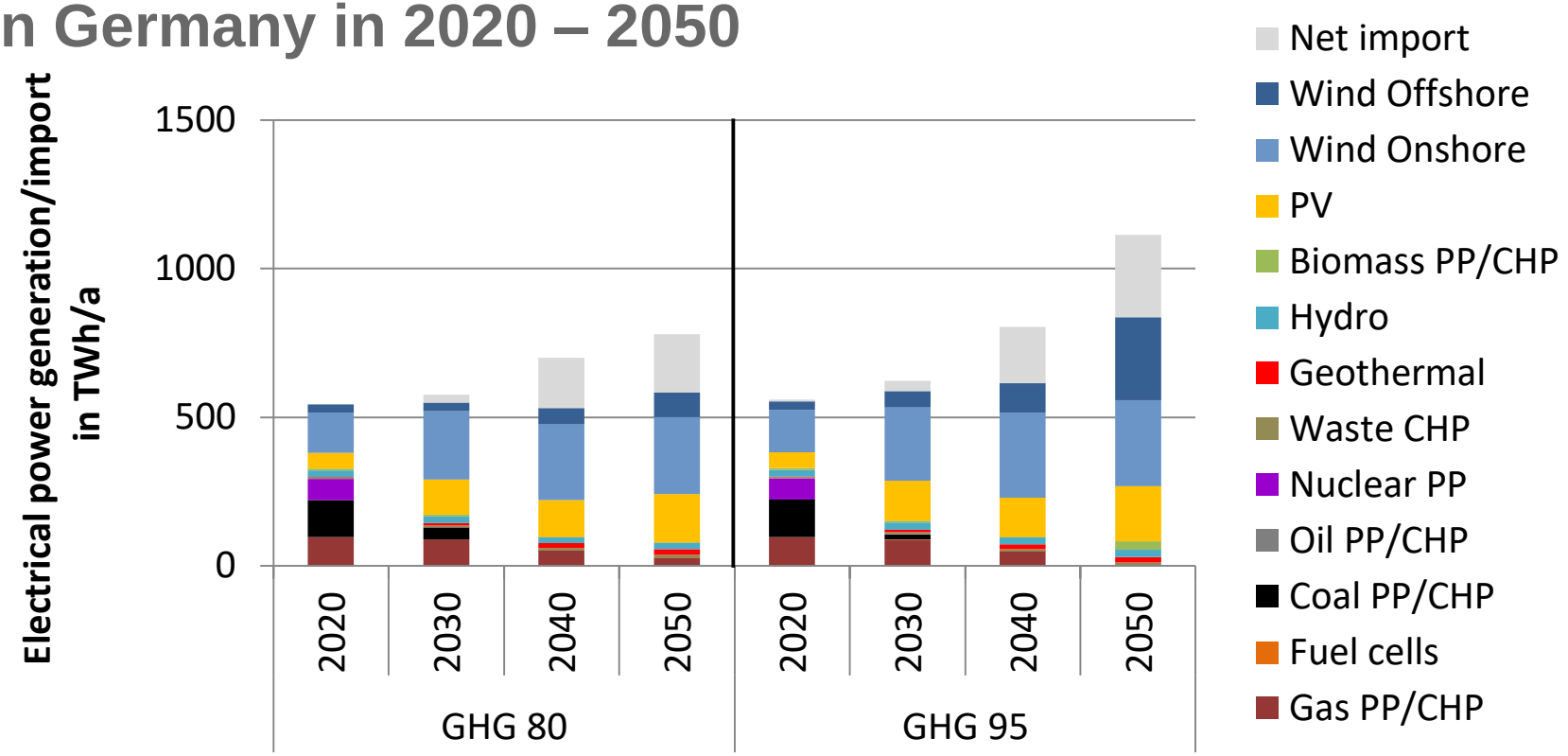
GHG 80

- Base-scenario
- 80% CO_2-reduction

GHG 95

- 95% CO_2-reduction
- Higher CO_2-emission costs
- Increased electrical power and H_2-demand in transport and heating sectors

Development of electrical power supply in Germany in 2020 – 2050

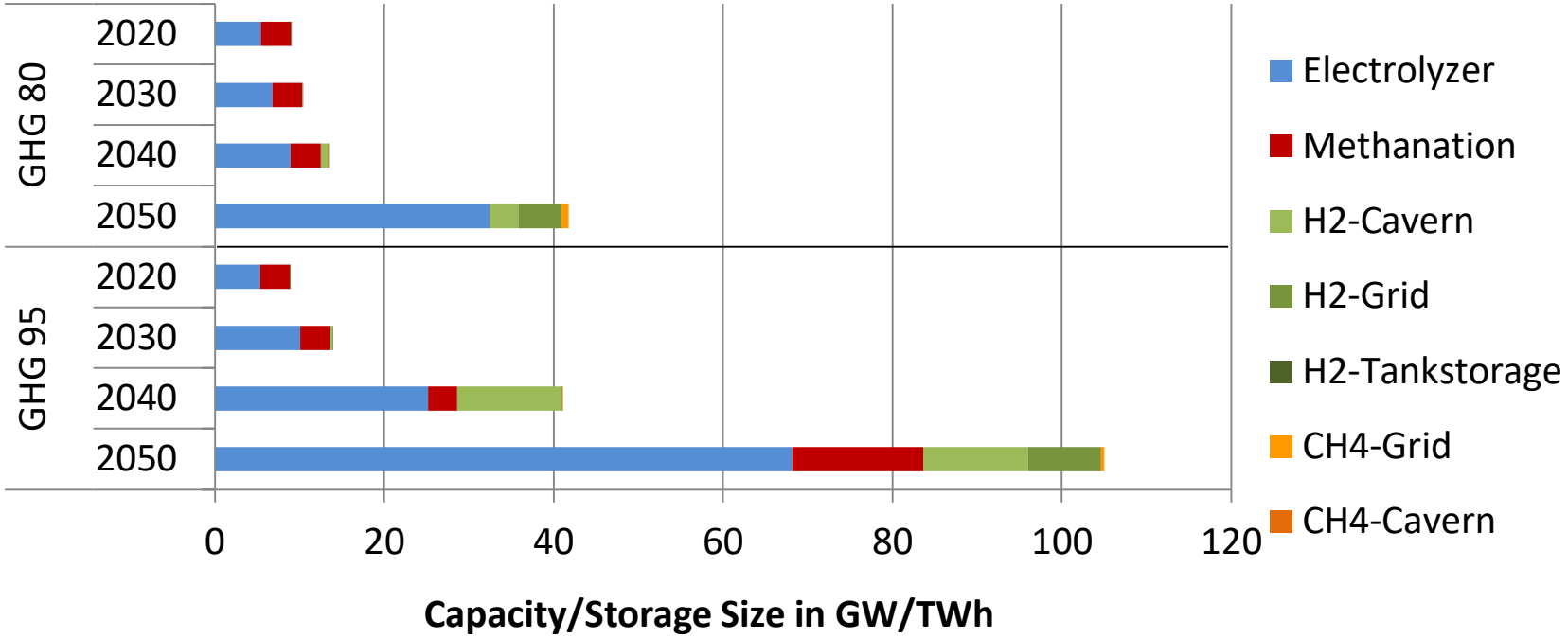


- Phasing out of nuclear energy by 2022 and coal energy by 2038
- Biomass only in GHG 95-scenario considered
- No back-up capacity of gas turbines in GHG 95
- GHG 95: 30 % more generation in 2050

DLR

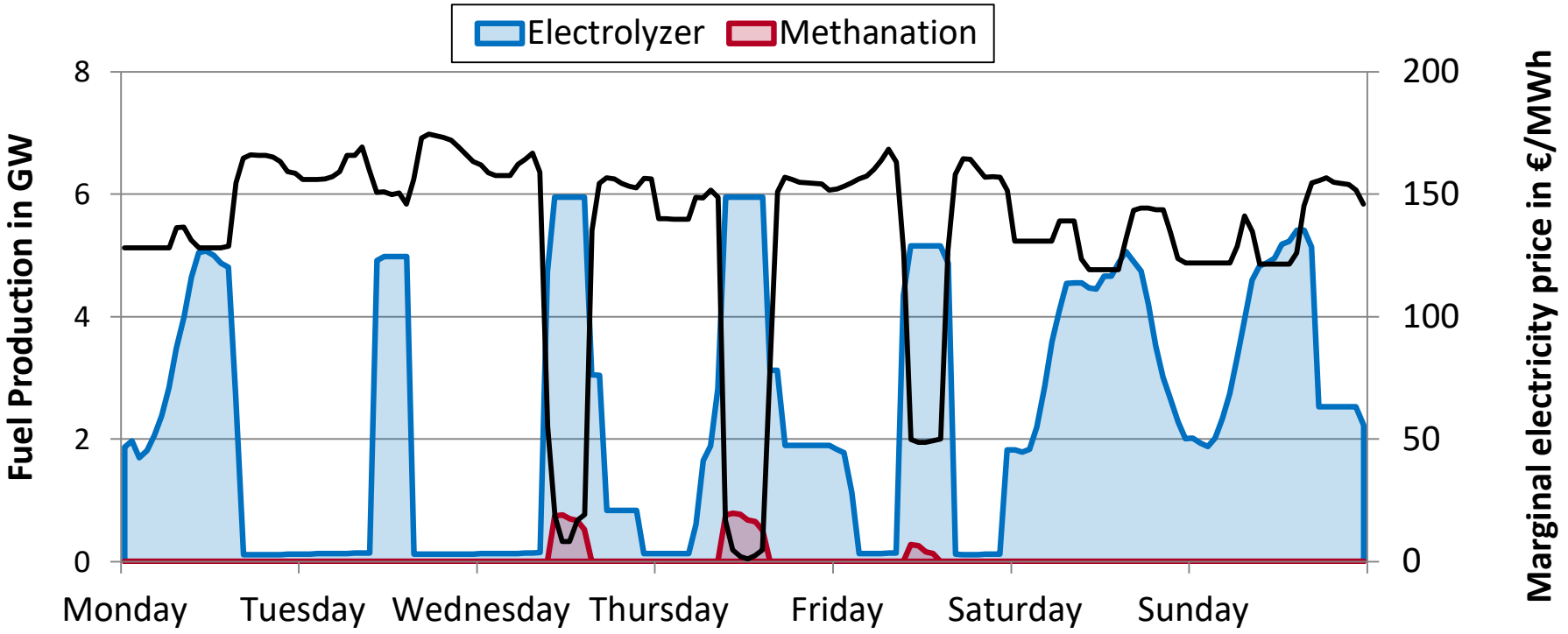
Preliminary results:
do not cite or quote

Development of the gas sector in Germany



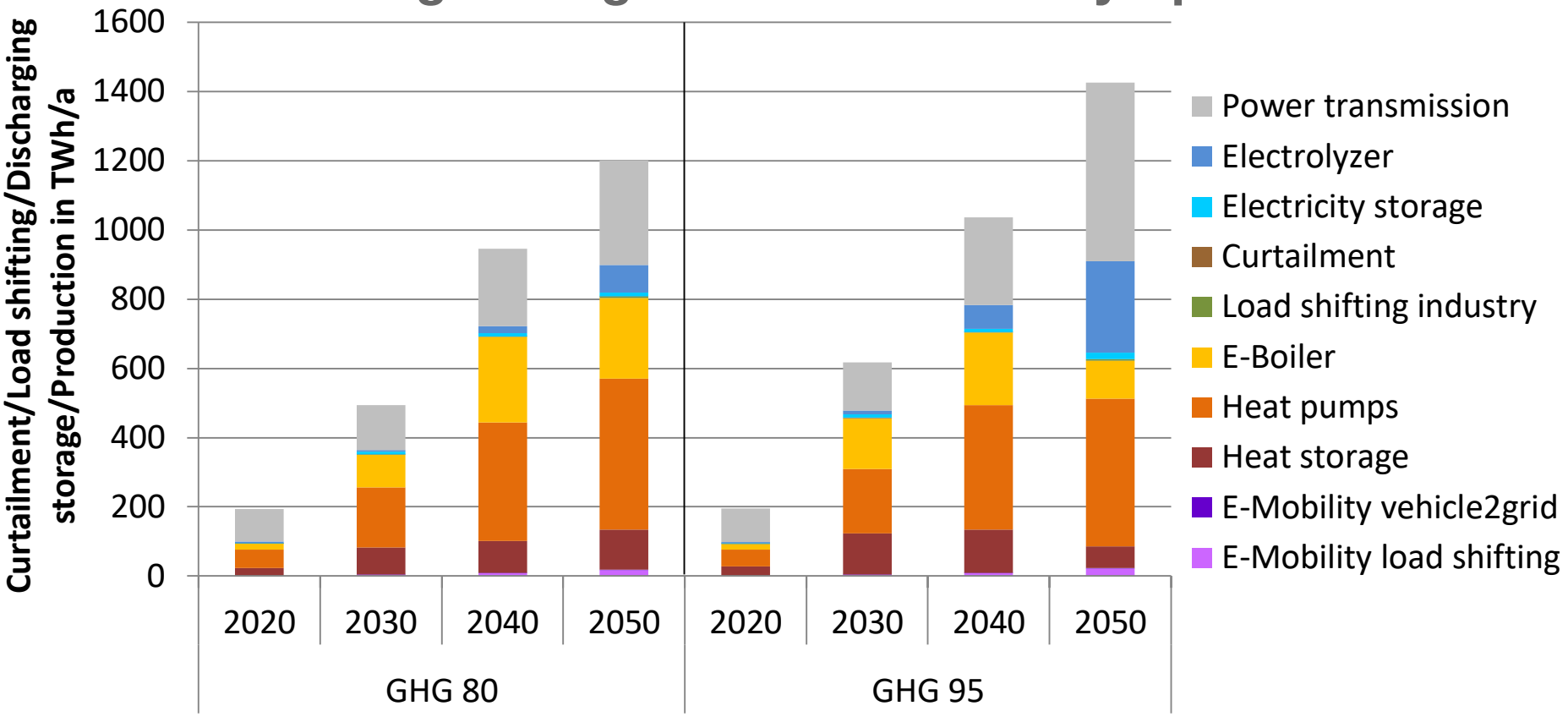
- Expansion of H_2-infrastructure
- Increase in methanation plant capacity only to fullfil CH_4-demand

Synthetic fuel production (GHG 95)



- H_2-production corresponds to electricity price and thus electricity production
- Methanation only comes into system at extremely low electricity costs

Load balancing through various flexibility options

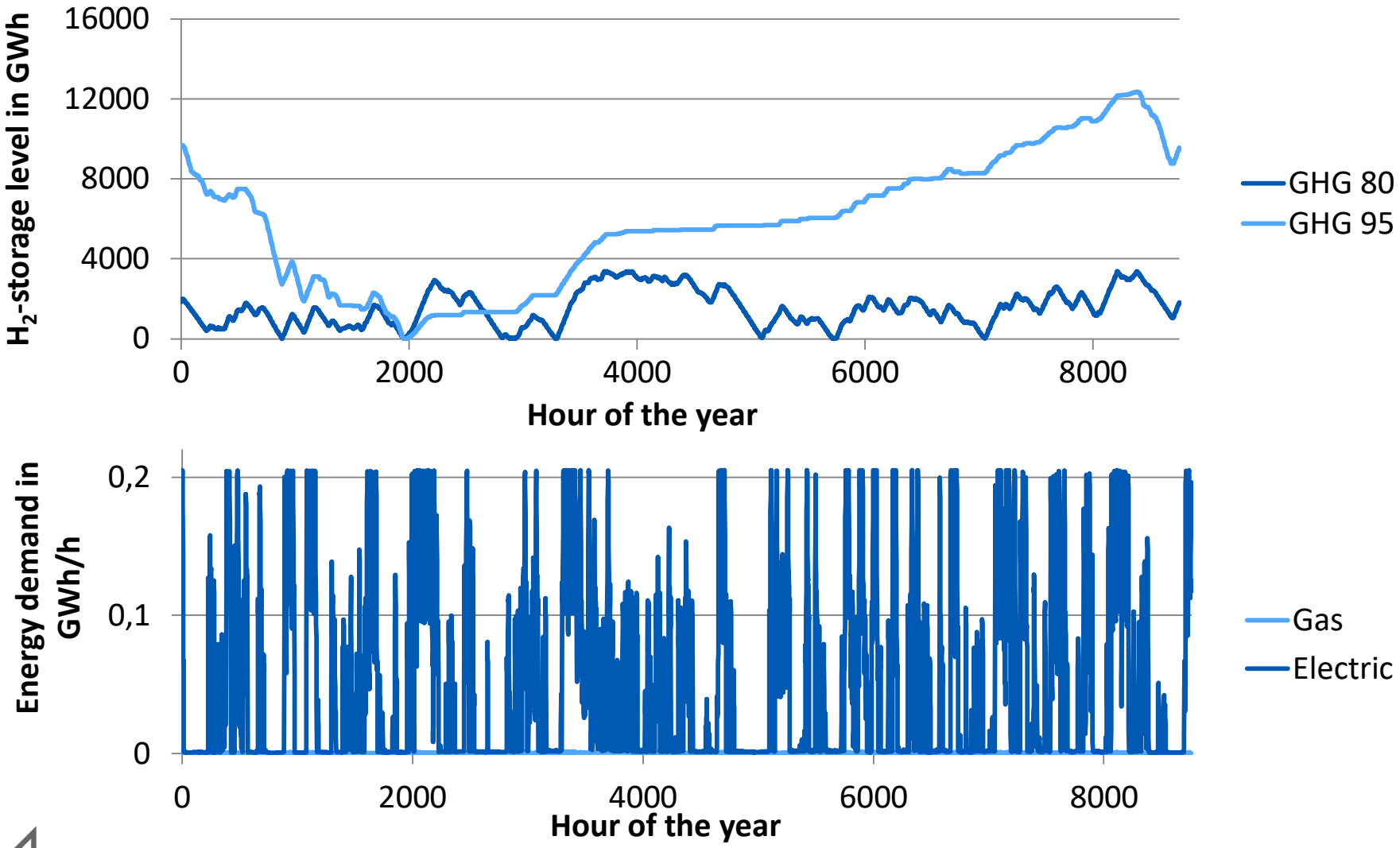


- About 30% of the battery vehicle charging demand is shifted
- Thermal energy storage buffers wind generation peaks
- Endogenous battery storage installation only outside Germany
- Power transmission is the most import balancing technology

DLR

Preliminary results:
do not cite or quote

Behaviour of gas sector components

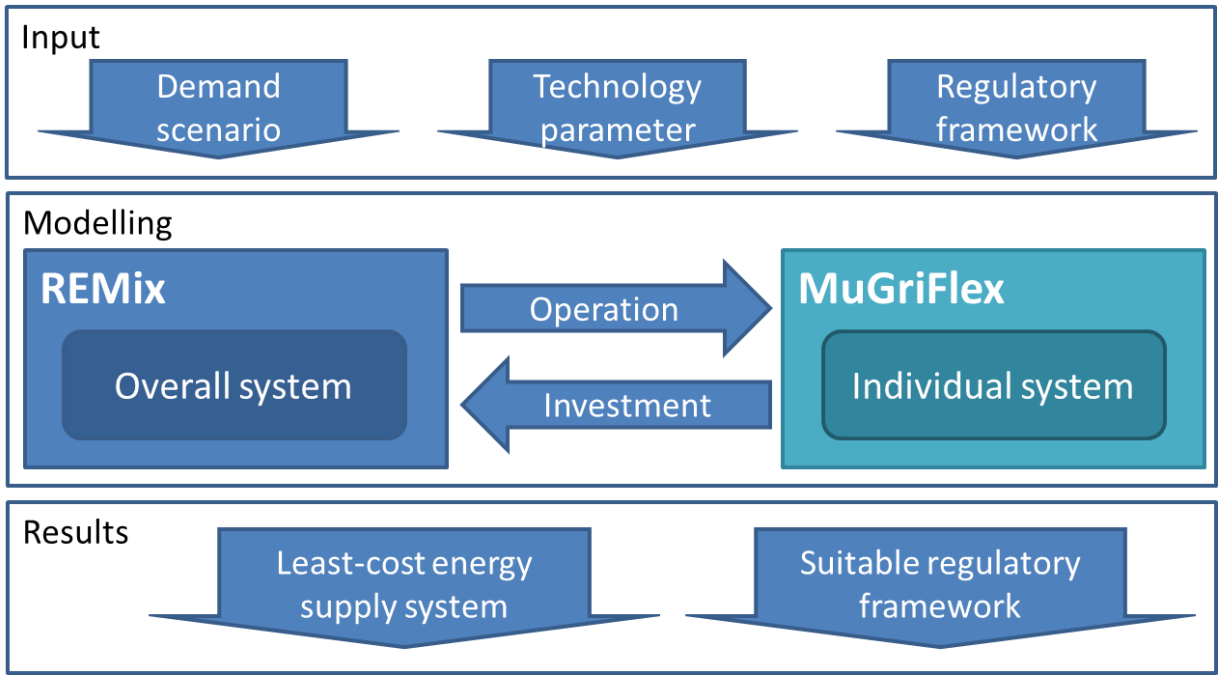


Preliminary results:
do not cite or quote

Summary

- Integrated consideration of all sector coupling options desirable
- Options of flexible sector coupling interact positively with each other
- Simplified representation of the gas sector improves analysis capabilities
- Flexible H_2-production can make a significant contribution to RE balancing
- Partial conversion of natural gas infrastructure to H_2 is an attractive option
- Methanation and seasonal storage become relevant in GHG 95 scenario

Outlook



- Comparison to business perspective
- Further analysis of interactions within the overall system
- Further scenarios and sensitivity analysis

MuSeK

Kontakt

Hedda Gardian

Department of Energy Systems Analysis, Institute of Engineering Thermodynamics, German Aerospace Center (DLR)

Pfaffenwaldring 38-40 | 70569 Stuttgart | Germany

Telefon +49 711 6862-8819 | hedda.gardian@dlr.de | www.DLR.de/tt

This presentation is based on results of the project “Modellbasierte Analyse der Integration erneuerbarer Stromerzeugung durch die Kopplung der Stromversorgung mit dem Wärme-, Gas- und Verkehrssektor“ (MuSeKo) funded by the German Federal Ministry of Economic Affairs and Energy (BMWi) under grant number FKZ: 03ET4038B.

Fraunhofer IFAM

DLR Deutsches Zentrum für Luft- und Raumfahrt

gwi Gas- und Wärme-Institut Essen e.V.

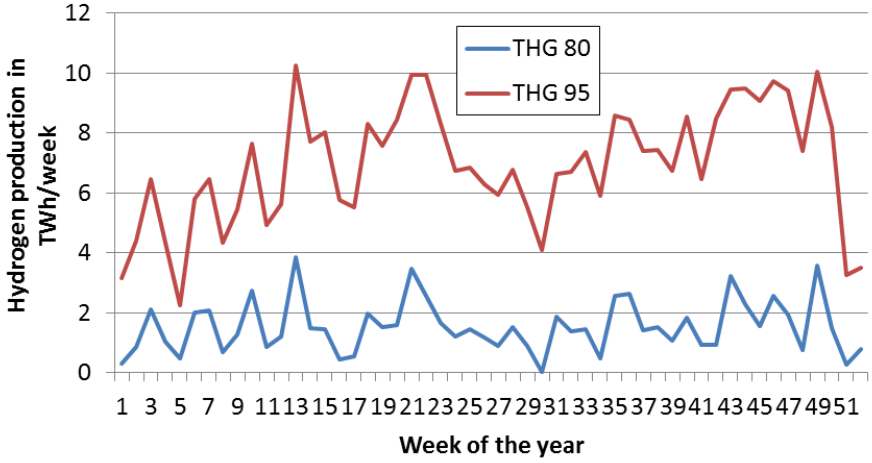
Supported by:

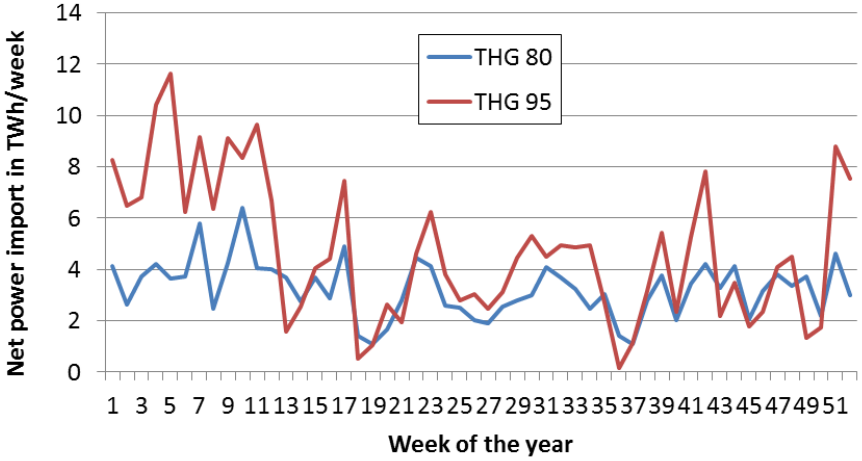
Federal Ministry for Economic Affairs and Energy

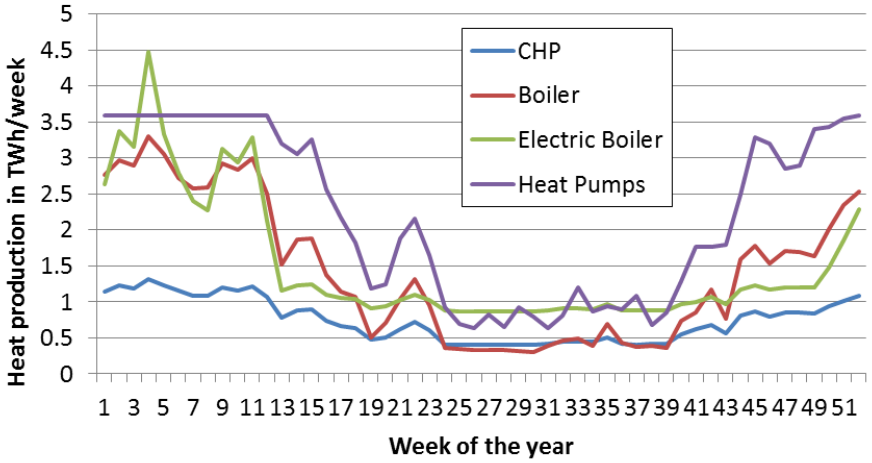
on the basis of a decision by the German Bundestag

DLR

Balancing of seasonal fluctuations







- Seasonal hydrogen storage becomes relevant in THG 95
- Heat pumps provide base load for district heating in winter

DLR

Preliminary results:
do not cite or quote