REMix: an open energy systems optimisation framework for large model instances

Jens Schmugge[1], Hans Christian Gils[1], Karl-Kiên Cao[1], Shima Sasanpour[1], Manuel Wetzel[1], Madhura Yeligeti[1], Hedda Gardian[1], Eugenio Salvador Arellano Ruiz[1], Ulrich Frey[1]

[1] German Aerospace Center (DLR), Institute of Networked Energy Systems, Curiestr. 4, 70563 Stuttgart, Germany
e-mail: remix@dlr.de

ENERGY SYSTEMS MODELLING FRAMEWORK

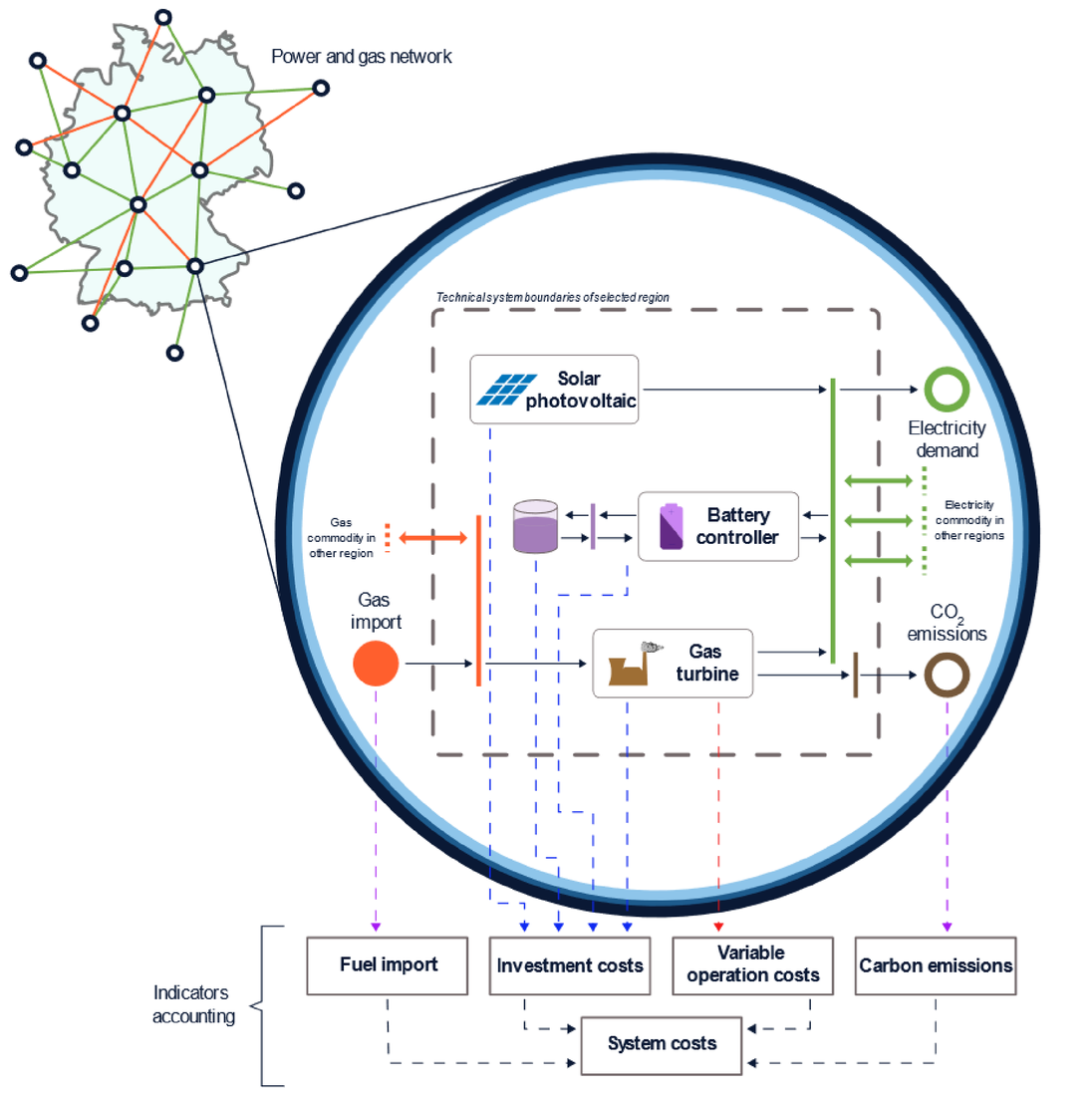

Fig. 1 - Schematic modelling concept of REMix.[a]

Features

- **linear programming (LP)** for cost optimisation
- written in GAMS, data preprocessing with Python
- designed for modelling **large-scale energy systems**
- **sector-integrated** modelling
- capacity expansion and dispatch of all assets
- parallel solving with **PIPS-IPM++**
- modelling to generate alternatives (MGA)
- multi-criteria optimisation
- pathway optimisation
- open source since September 2023

GitLab repository[a]

REMix
Renewable Energy Mix

LARGE-SCALE MODELS

Project Fahrplan Gaswende

- hourly resolution
- 70 nodes to model European energy system
- ~100 different technologies in total
- 45 in heat sector, with 17 heat groups to represent different temperature regimes

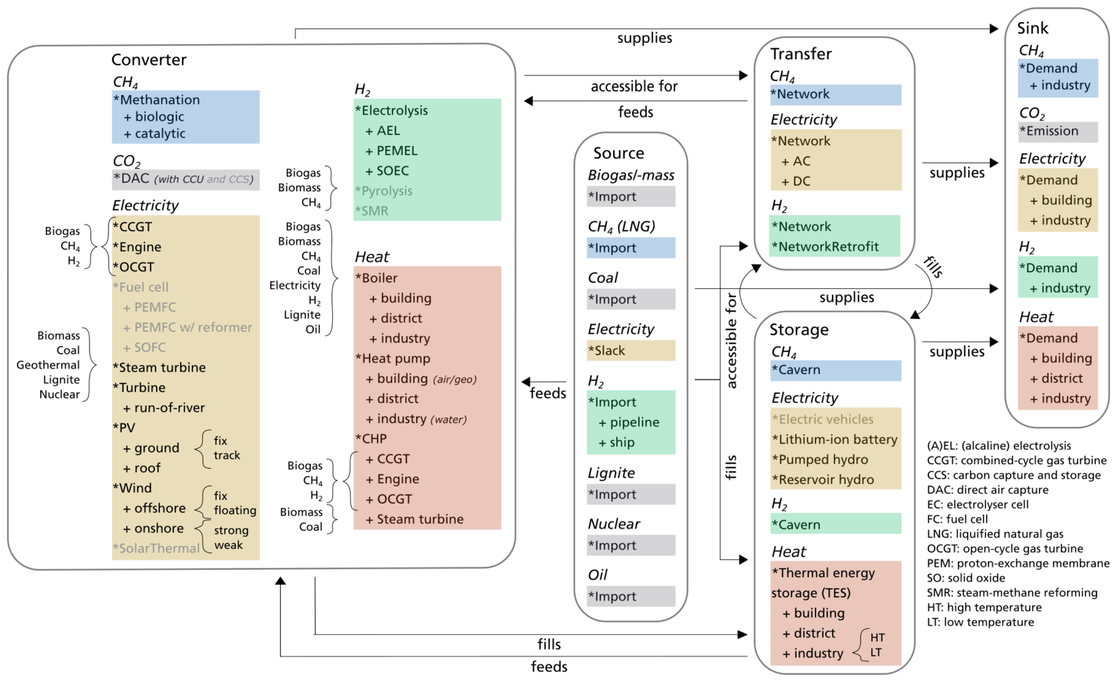

Fig. 5 - Technological scope: around 100 technologies; grey ones yet to be integrated.[d]

LARGE SCENARIO SPACE

Project UNSEEN

- consideration of parameter uncertainties in around 11,000 scenarios with Monte Carlo analysis
- coupling of REMix with agent-based model AMIRIS[e] via HPC workflow

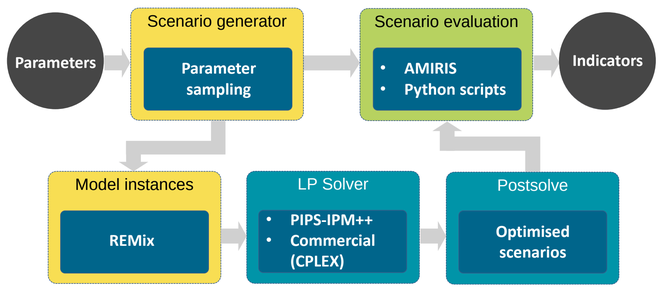

Fig. 6 - HPC workflow managed with JUBE.[f]

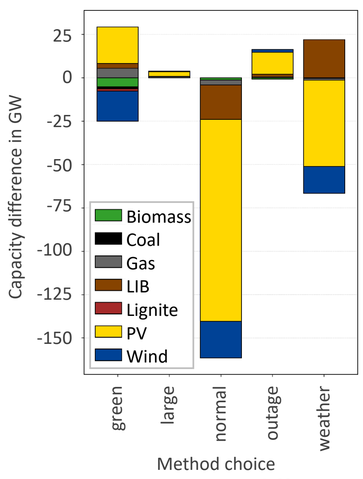

Fig. 7 - Mean capacity difference depending on method choice.[b]

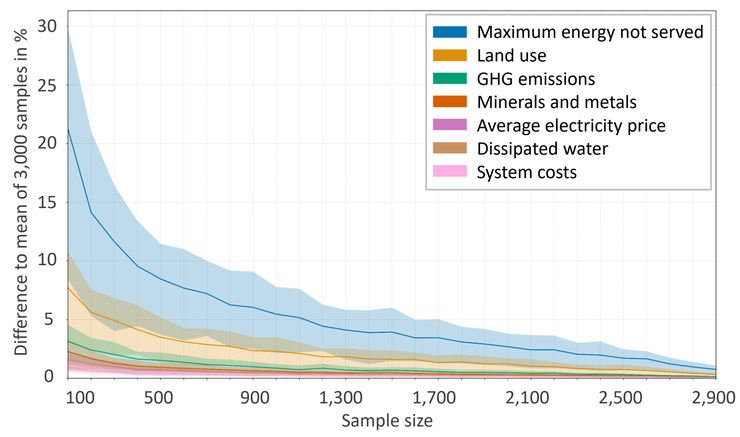

Fig. 8 - Relative deviation of key indicators depending on scenario sample size compared to mean value for 3,000 scenarios.[b]

SECURITY OF SUPPLY

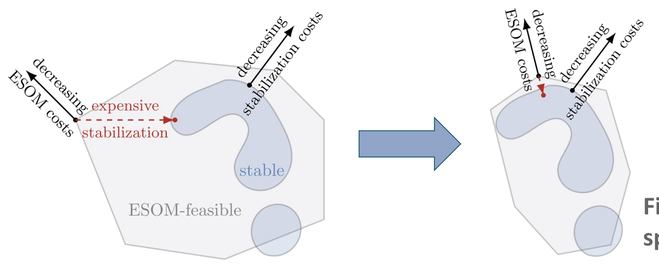

Fig. 2 - Reduction of the REMix solution space by addition of stability constraints.[b]

Project STAWESOM

- integration of stability constraints
- linking to AC grid model

Project ARTESIS

- optimisation of robust and adaptive pathways
- linking to consistent socio-economic scenarios

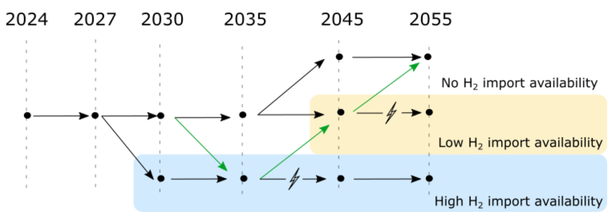

Fig. 3 - Schematic representation of the evaluation of adaptivity in the optimisation of transformation paths.[b]

Project ReMoDigital

- identification of resilient system designs
- comprehensive stress-test modelling

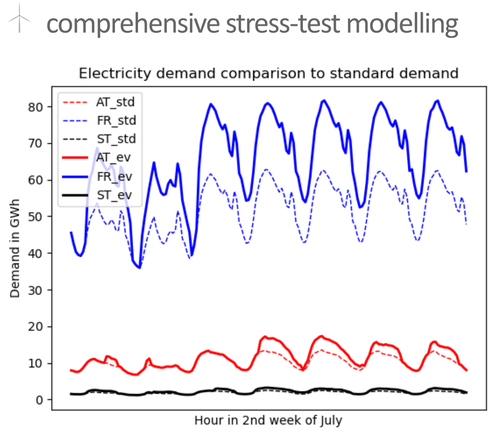

Fig. 4 - Exemplary impact of a heat wave on electricity demand in different regions.[c]

Project RESUME

- consideration of resource criticality
- multi-objective system planning

MODEL PERFORMANCE

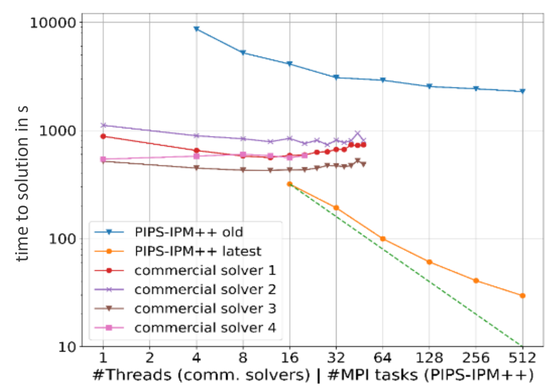

Fig. 9 - Scaling behaviour of different solvers on energy system optimisation model (ESOM) instances.[g]

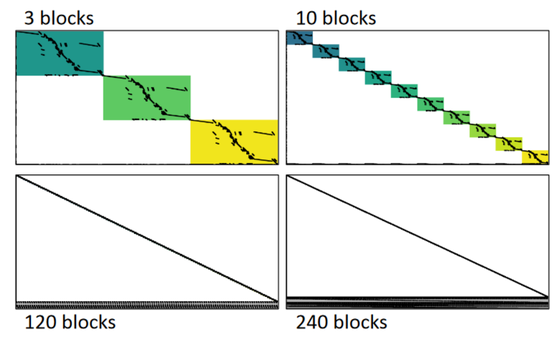

Fig. 10 - Manually annotated and permuted coefficient matrix of an ESOM instance.[h]

Parallel solving of large-scale ESOMs

- cross-sectoral investment and dispatch planning for generation, storage and transmission
- > 100 million variables / constraints

Project PEREGRINE

- objective: broad applicability of open-source LP solver PIPS-IPM++

Invitation: personal interviews

- Which solutions are desired? Interfaces (e.g., Pyomo)? Solver containers? Cloud-computing?
- reach out to karl-kien.cao@dlr.de

Research

- automatised block-structure detection and solver parameterisation

Institut für Vernetzte Energiesysteme

REFERENCES

[a] German Aerospace Center (DLR) (2023): *REMix framework*, https://gitlab.com/dlr-ve/esy/remix/framework.
[b] German Aerospace Center (DLR) (2024): to be published.
[c] Yeligeti, M. et al. (2024): to be published.
[d] Schmugge, J. et al. (2024): to be published.
[e] Schimeczek, C.; Nienhaus, K.; Frey, U.; Sperber, E.; Sarfarazi, S.-F.; Nitsch, F.; Kochems, J.; El Ghazi, A. A. (2023): *AMIRIS: Agent-based Market model for the Investigation of Renewable and Integrated energy Systems*. In: JOSS 8 (84), S. 5041. DOI: 10.21105/joss.05041.
[f] Jülich Supercomputing Centre (2022): JUBE Benchmarking Environment, https://www.fz-juelich.de/jsc/jube.
[g] Kempke, N.-Ch.; Koch, Th.; Vanaret, Ch. (2021): *PIPS-IPM++ - a massively parallel Interior-Point Method*, International Conference on Operations Research (OR 2021), 31.08.-03.09.2021, Bern, Switzerland.
[h] Cao, K.-K.; Frey, U.; Breuer, Th.; Wetzel, M.; Sasanpour, S.; Buschmann, J.; von Krbek, K.; Böhme, A. (2022): *A multi-perspective approach for exploring the scenario space of future power systems*, International Conference on Operations Research - OR 2022, 06.-09.09.2022, Karlsruhe, Germany.

Supported by:
Federal Ministry for Economic Affairs and Climate Action
on the basis of a decision by the German Bundestag