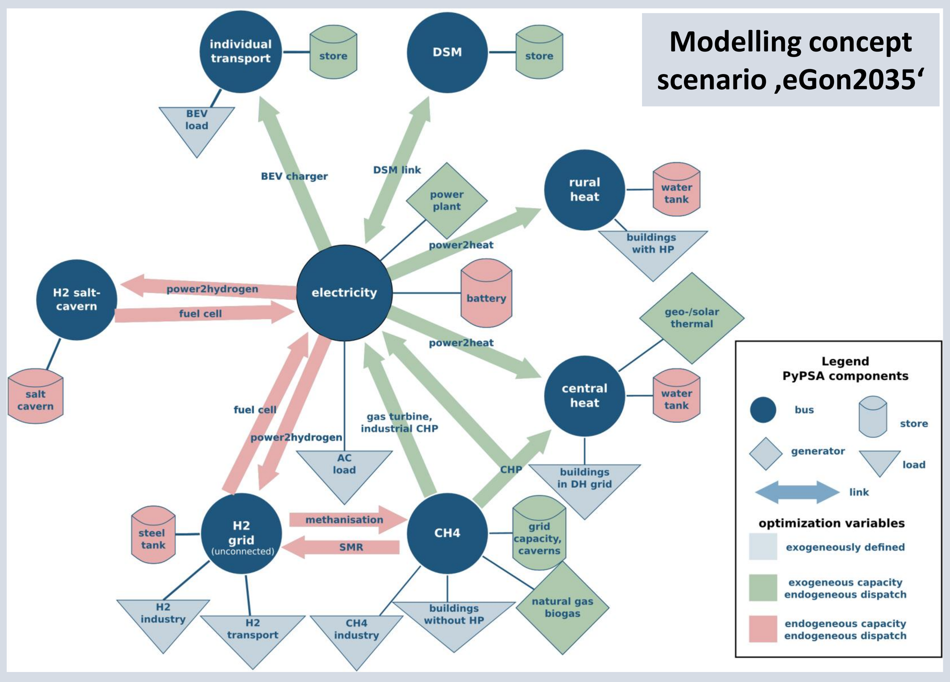
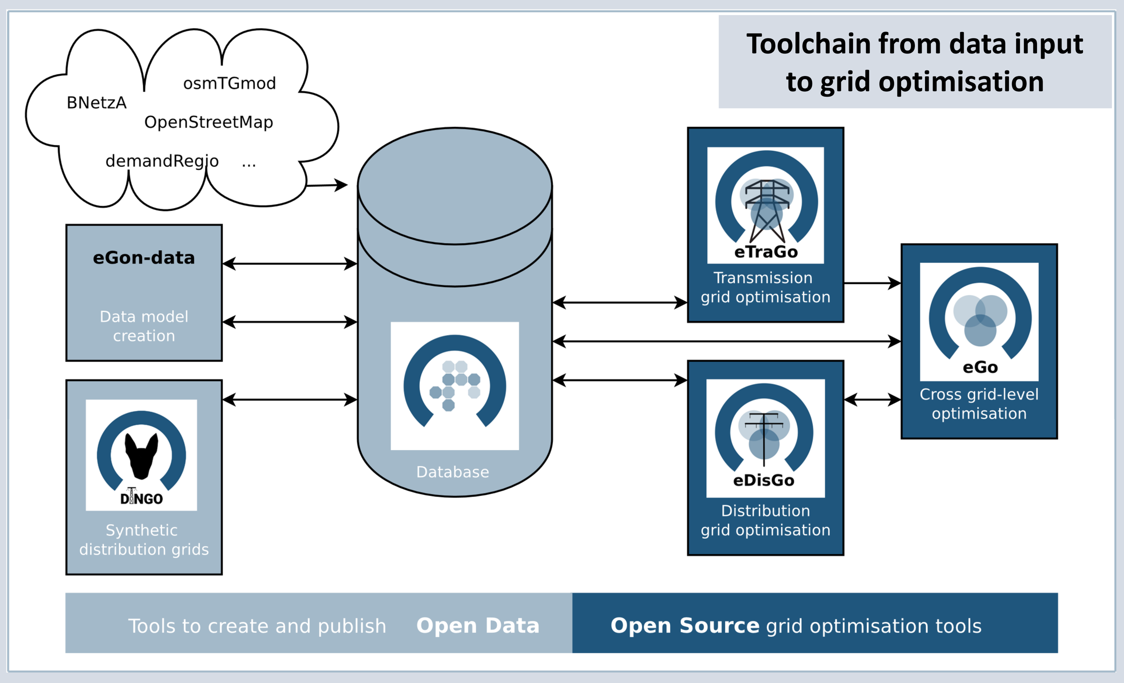
eGo^n

Open and cross-sectoral planning of transmission and distribution grids

Driven by the expansion of renewable generation capacity and the progressing electrification of other energy sectors, the electrical grid increasingly faces new challenges: **fluctuating supply of renewable energy** and simultaneously a **changing demand pattern** caused by **sector coupling**. However, the integration of non-electric sectors such as **gas**, **heat** and **e-mobility** enables **more flexibility options**. This project aims to investigate the effects of sector coupling on the electrical grid and the benefits of new flexibility options.





Basic project information

- **Project duration:** Dec 2019 – Jul 2023
- **Open-source** and **open-data-project**
- **Project partner:**
  - Flensburg University of Applied Sciences
  - Europa-Universität Flensburg
  - Reiner Lemoine Institute
  - German Aerospace Center (DLR) - Institute of Networked Energy Systems
  - Otto von Guericke University Magdeburg
  - Fraunhofer Institute for Energy Economics and Energy System Technology
- **Funded by Federal Ministry for Economics and Climate Action**
- **Website:** ego-n.org

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

eTraGo

electricity **Tra**nsmission **G**rid **o**ptimization

Basic information

Open source python tool based on PyPSA [1] covering the sectors electricity, heat, gas and mobility to optimize flexibility options and grid expansion in transmission grids including the 110 kV level

- Initially developed in the research project open_eGo [2]
- Publicly available on Github [3]

Grid model

The grid model is created by the python-tool eGon-data [4] and stored at the open energy data base [5]. eTraGo can access the oedb or local database and import the data model from there.
It includes the German high and extra-high voltage **power grid (110kV to 380kV)**, the **methane transmission grid** and their **connections to neighboring countries. Demand, supply and flexibility options** from the power, heat, gas and mobility sector are attached to the corresponding grid nodes.

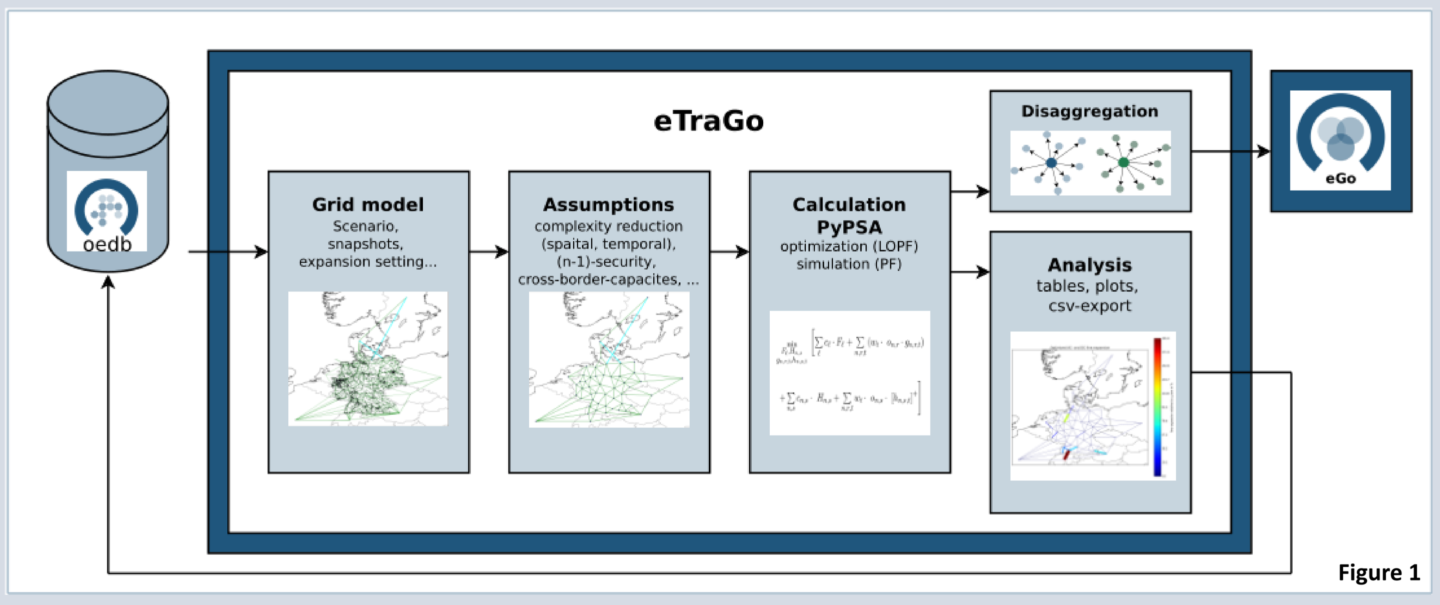


Figure 1

Complexity reduction

The grid model is characterized by a **large spatial and temporal complexity** (about 8,000 electrical / 600 gas nodes and 8,760 timesteps). Therefore, **different methods** are being applied to reduce the spatial and temporal complexity of the data model.

Temporal methods

Skip snapshots: Down sampling to every n-th timestep

Typical periods: Clustering to typical periods such as days or weeks

Segmentation: Clustering to segments of adjacent hours

→ See exemplary results for different methods in **figure 2**

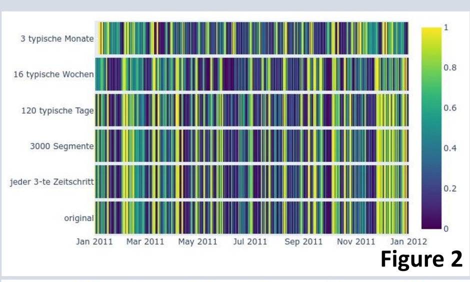


Figure 2

Spatial methods

k-means clustering: Clustering considering geographical position of nodes.

k-medoids Dijkstra clustering: Clustering considering the power and methane grid topology. Example in **figure 3** clustered to 300 AC and 80 gas buses.

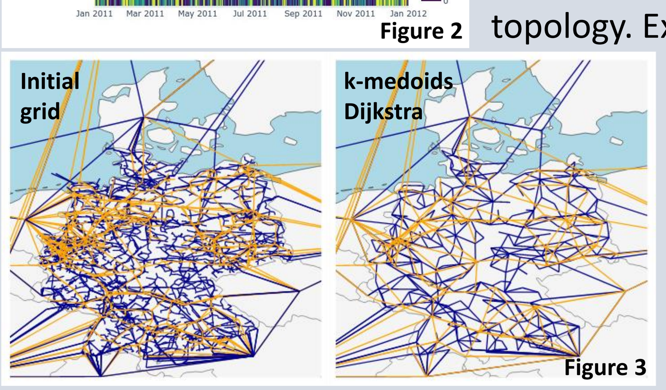


Figure 3

Hierarchical agglomerative clustering [WIP]: Aggregates nodes based on load and generation capacity factor time series data while taking the network topology into account.

Calculation method

Central calculation method is the **Linear Optimal Power Flow (LOPF)** from PyPSA [1]. Using this method, both **dispatch costs** for generation and **investments** into grid infrastructure, storage units and flexibility options are minimized. **Different constraints**, like e.g. Kirchhoff's Current Law or linearized AC-branch flows make sure that the technical behavior of power systems is considered. **Reactive power flows** can be calculated by performing a non-linear power flow after the LOPF.

First results for scenario *eGon2035*

Figure 4: **Grid and storage expansion**

Figure 5: Potential and dispatch of **short term flexibility options**

Figure 4

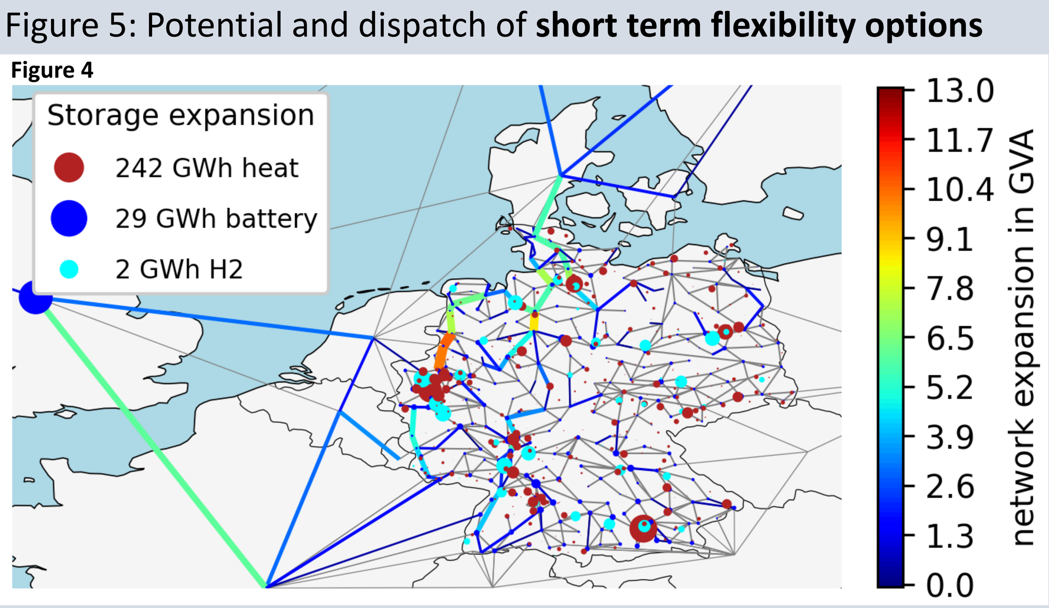
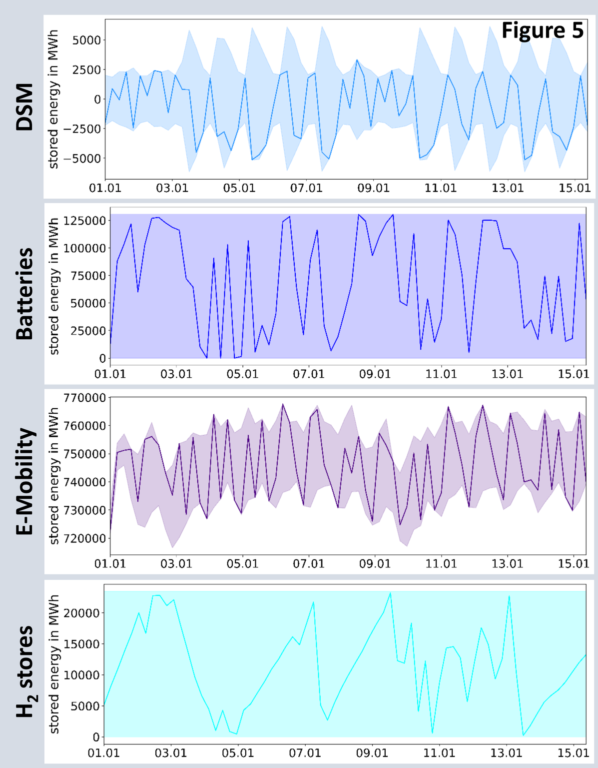


Figure 5



eGo

electricity **G**rid **o**ptimization

Basic information

Integrated optimization of flexibility options and grid extension measures for power grids based on eTraGo and eDisGo.

- Determination of grid expansion costs in MV and LV level using representative grids
- In total > 3.300 MV grid topologies for entire Germany
- Determination of representative grids through k-medoids clustering
- Grids are clustered on the basis of features with high impact on grid expansion needs, e.g. VRES expansion and increase of new consumers

OEDB

Disaggregation

Results from eTraGo based on input data reduced in complexity have to be disaggregated again to be used in eDisGo.

- Optimization results are disaggregated on a per cluster basis.
- For each node in the clustered network, relevant computed values are distributed to the subnetwork the node represents.
- Values are (mostly) distributed using weighted averages.
- Weigths are calculated differently, depending on the type of value that gets distributed, so e.g. "dispatch" is distributed differently than "state of charge".

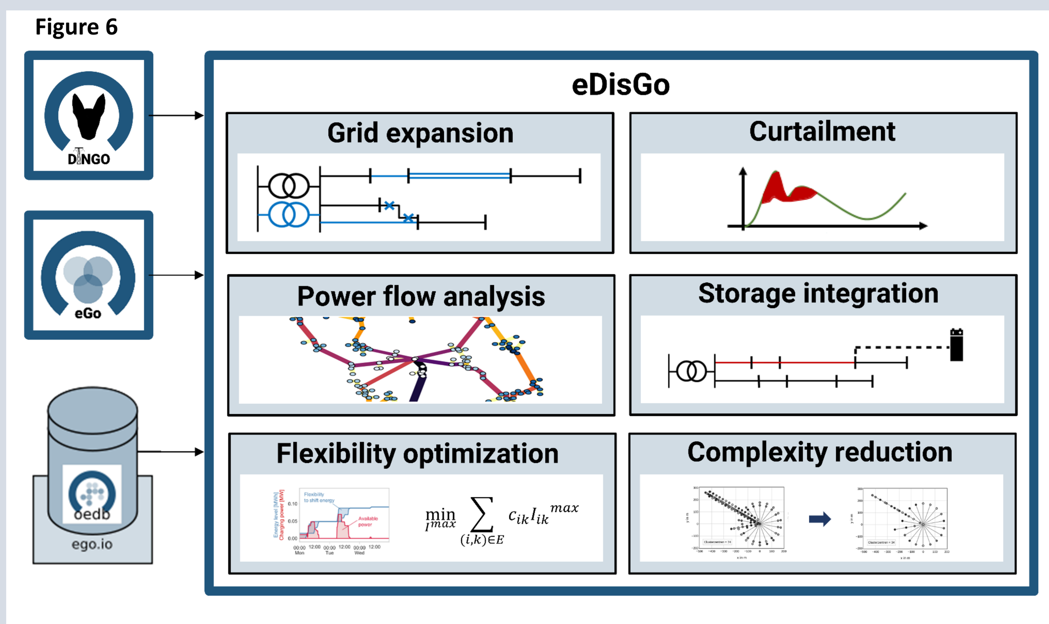
eDisGo

electricity **Dis**tribution **G**rid optimization

Basic information

- Open source toolbox to evaluate flexibilities measures as an alternative to conventional grid expansion in medium and low voltage grids
- Two-step approach including
  1) Optimization of flexibility dispatch considering constraints from the overlying grid (eTraGo results)
  2) Determination of resulting grid expansion needs
- Initially developed in the research project open_eGo [2]
- Publicly available on Github [6]

Figure 6



Two-step approach

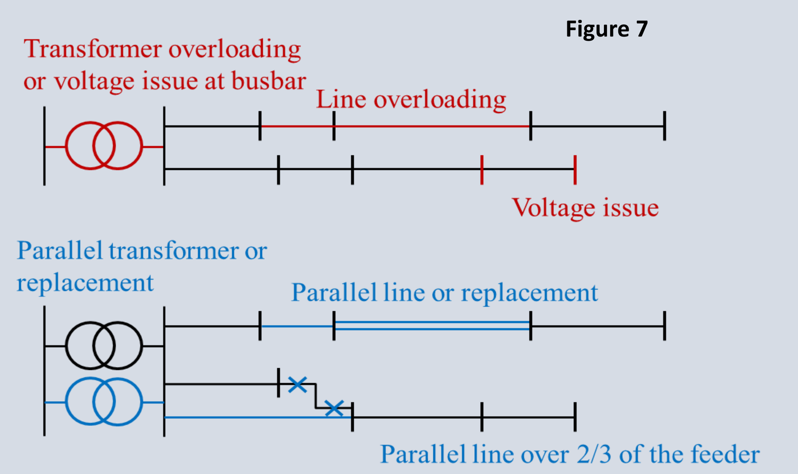
Step 1: Optimization

- Optimization of heat pump dispatch, EV charging, DSM usage, battery storage dispatch and VRES curtailment
- Consideration of:
  - Non-linear power flow constraints (Branch Flow Model)
  - Constraints from the overlying grid regarding exchange of active and reactive power
  - Constraints of each individual flexibility
- Complexity reduction
  - Second-Order-Cone relaxation to obtain convex problem
  - Spatial clustering: k-means-dijkstra on main feeder with focus on parts of the grid where grid expansion needs are expected
  - Temporal clustering: Consideration of weeks with highest grid issues

Step 2: Grid expansion needs

- Grid expansion measures according to dena distribution grid study [7]

Figure 7



References

[1] **PyPSA:** https://pypsa.org/
[2] **open_eGo:** https://openegoproject.wordpress.com/
[3] **eTraGo:** https://github.com/openego/eTraGo
[4] **eGon_data:** https://github.com/openego/egon-data
[5] **Open Energy Database:** https://openenergy-platform.org/dataedit/schemas
[6] **eDisGo:** https://github.com/openego/eDisGo
[7] **dena Verteilnetzstudie:** https://www.dena.de/themen-projekte/projekte/energiesysteme/dena-verteilnetzstudie/

Authors

eGon development Team