Technische Universität Berlin

ENSYS Digital Transformation in Energy Systems

# PyPSA Energy Research Software

www.pypsa.org

## PyPSA

*Python for Power System Analysis*

PyPSA is an open-source toolbox for **simulating and optimising modern power and energy systems** that include features such as conventional generators with unit commitment, variable wind and solar generation, storage units, coupling to other energy sectors, and mixed alternating and direct current networks.

### Functionality

PyPSA can calculate:

- static power flow (using both the full non-linear network equations and the linearised network equations)
- linear optimal power flow (least-cost optimisation of power plant and storage dispatch within network constraints, using the linear network equations, over several snapshots)
- security-constrained linear optimal power flow
- total electricity/energy system least-cost investment optimisation

### Components

- meshed multiply-connected AC and DC networks, with controllable converters between AC and DC networks
- standard types for lines and transformers following the implementation in pandapower
- conventional dispatchable generators and links with unit commitment
- generators with time-varying power availability, such as wind and solar generators
- storage units with efficiency losses
- simple hydroelectricity with inflow and spillage
- coupling with other energy carriers (e.g. resistive Power-to-Heat (P2H), Power-to-Gas (P2G), battery electric vehicles (BEVs), Fischer-Tropsch, direct air capture (DAC))
- basic components out of which more complicated assets can be built, such as Combined Heat and Power (CHP) units and heat pumps

## Contribution

All tools are actively developed and maintained by the Department of Digital Transformation in Energy Systems at the Technical University of Berlin and the **PyPSA community**. Any contributions are welcome and can be made via GitHub. Find contribution guidelines in the documentation for all tools.

PyPSA is used by several research institutes, companies and non-governmental organisations around the world. While much of this is proprietary work, several notable model implementations are available as open-source alternatives:

- Global sector-coupled model **PyPSA-Earth**, maintained by pypsa-meets-earth [6]
- **PyPSA-USA**: An Open-Source Energy System Optimization Model for the United States
- Chinese sector-coupled model **PyPSA-China** [7]
- Brazilian power system model **PyPSA-Brazil** [2]
- **PyPSA-PL**: optimisation model of the Polish energy system

## PyPSA-Eur

*Sector-Coupled Optimisation Model of the European Energy System*

PyPSA-Eur is a spatially and temporally highly resolved **linear optimisation model that covers the European continent**. The model is suitable both for operational studies and generation and transmission expansion planning studies. The continental scope and highly resolved spatial scale enables a proper description of the long-range smoothing effects for renewable power generation and their varying resource availability.

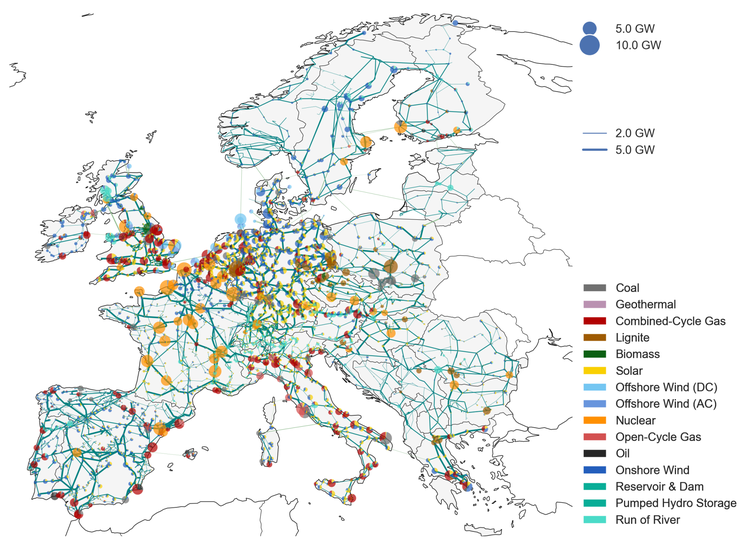



**Figure 1:** Electricity high-voltage grid from AC 220 kV to 750 kV (UA) and DC 150 kV upwards. Option to include planned transmission projects.

A **sector-coupled** extension adds demand and supply for the following sectors: transport, space and water heating, biomass, energy consumption in the agriculture, industry and industrial feedstocks, carbon management, carbon capture and usage/sequestration. This completes the energy system and includes all greenhouse gas emitters except waste management, agriculture, forestry and land use.

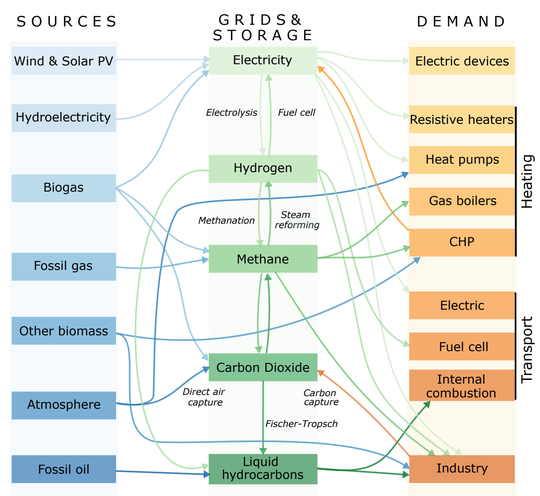



**Figure 2:** Overview of the sectors in sector-coupled extension

The generation of the model is controlled by the open workflow management system Snakemake [4]. In a nutshell, the Snakefile defines a rule for each defined script, describing which files the scripts the scripts consume and produce (their corresponding input and output files). The snakemake tool then runs the scripts in the correct order according to the rules' input and output dependencies. A **complete data processing pipeline** is therefore generated, from the raw data to the results.

## Open Source

All tools are open-source and available on GitHub. The code is licensed under the MIT license, which allows for free use and modification of the code.
The framework packages are available on PyPI and conda-forge and can be installed using pip or conda.

## Toolbox

*Other Projects in the PyPSA Ecosystem*

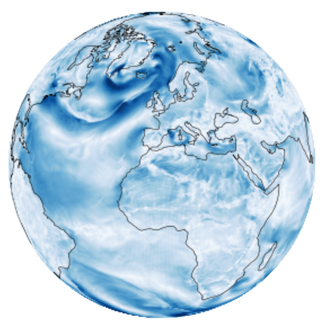
### linopy

*Linear ptimization with N-D labeled arrays in Python*

linopy facilitates **optimization with real world data**. It builds a bridge between data analysis packages like xarray & pandas and problem solvers like cbc, gurobi. linopy supports Linear, Integer, Mixed-Integer and Quadratic Programming while aiming to make linear programming in Python easy, highly-flexible and performant.

### atlite

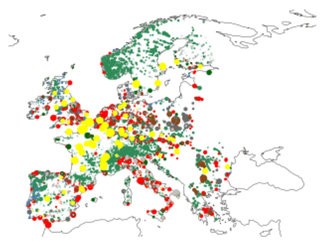
*Calculate renewable power potentials and time series*



atlite is a xarray-based Python library for **converting weather data into energy systems data**. It is designed to be lightweight, keeping computing resource requirements (CPU, RAM) usage low. It is therefore well suited to be used with big weather datasets.

### powerplantmatching

*Set of tools to combine multiple power plant databases*



powerplantmatching provides **ready-to-use power plant data for the European power system**. Starting from openly available power plant datasets, the package cleans, standardizes and merges the input data to create a new combined dataset, which includes all the important information. The package allows to easily update the combined data as soon as new input datasets are released.

## References


[1] T. Brown, J. Hörsch, and D. Schlachtberger. PyPSA: Python for Power System Analysis. *Journal of Open Research Software*, 6(4), 2018.

[2] Ying Deng, Karl-Kiên Cao, Wenxuan Hu, Ronald Stegen, Kai von Krbek, Rafael Soria, Pedro Rua Rodriguez Rochedo, and Patrick Jochem. Harmonized and open energy dataset for modeling a highly renewable brazilian power system. *Scientific Data*, 10(1):103, 2023.

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[4] F Mölder, KP Jablonski, B Letcher, MB Hall, CH Tomkins-Tinch, V Sochat, J Forster, S Lee, SO Twardziok, A Kanitz, A Wilm, M Holtgrewe, S Rahmann, S Nahnsen, and J Köster. Sustainable data analysis with snakemake [version 2; peer review: 2 approved]. *F1000Research*, 10(33), 2021.

[5] Fabian Neumann, Elisabeth Zeyen, Marta Victoria, and Tom Brown. The potential role of a hydrogen network in europe, 2023.

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[7] Xiaowei Zhou, Kai Strunz, Tom Brown, Hongbin Sun, and Fabian Neumann. Multi-energy system horizon planning: Early decarbonisation in china avoids stranded assets. *Energy Internet*, 1(1):81–98, 2024.