

The Power of Many: Open Source for Critical Infrastructure

Michael Lindner* and Iegor Riepin*, $\triangle$

* Postdoc researcher at ENSYS group, TU Berlin

$\triangle$ PyPSA Labs

50Hertz The Summit — Ensuring Grid Stability for Tomorrow — 17 September 2026

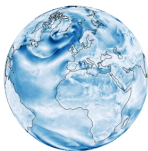
The PyPSA Ecosystem



PyPSA

Python for Power System Analysis –
the core framework for simulating and
optimising modern power systems.

The PyPSA Ecosystem



Atlite

A lightweight Python package for calculating renewable power potentials and time series.



PyPSA

Python for Power System Analysis – the core framework for simulating and optimising modern power systems.



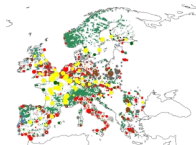
Linopy

Linear optimization interface for N-D labeled variables.



Map Your Grid

Community-driven initiative mapping the world's electrical grids to accelerate the energy transition worldwide.



Powerplantmatching

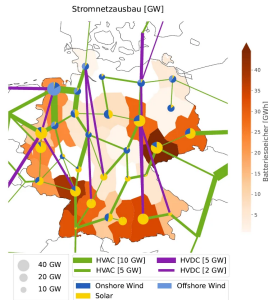
A toolset for cleaning, standardizing and combining multiple power plant databases.



Technology Data

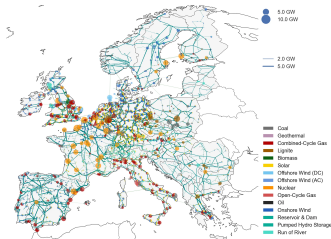
Compile assumptions on energy system technologies for various years.

Some PyPSA Models



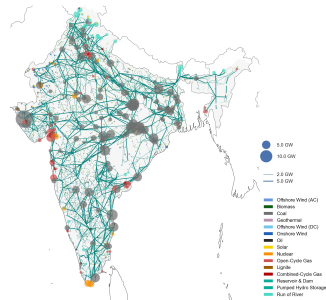
PyPSA-DE

High resolution, sector-coupled model of the German Energy System.



PyPSA-Eur

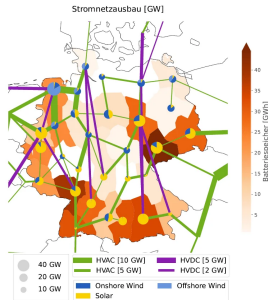
A sector-coupled open optimisation model of the European Energy System.



PyPSA-Earth

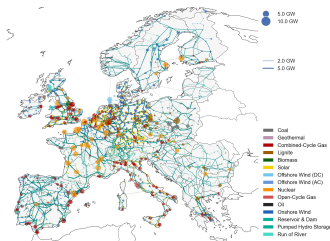
A flexible open optimisation model to study energy system futures around the world.

Our research focus @TUB-ENSYS



PyPSA-DE

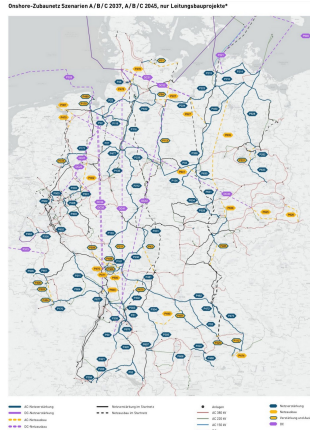
High resolution, sector-coupled model of the German Energy System.



PyPSA-Eur

A sector-coupled open optimisation model of the European Energy System.

- **Cost-effective pathways** to reduce CO₂ emissions
- **Evaluation** of grid expansion, as well as hydrogen and carbon management strategies
- **Co-optimisation** of generation, storage, conversion and **transmission infrastructure**
- **All open** source and open data



MaStR 
Marktstammdatenregister

Results Spotlight: PyPSA-DE in the Ariadne project



Ariadne Report
Die Energiewende
kosteneffizient gestalten:
Szenarien zur
Klimaneutralität 2045



Ariadne Report
Auswirkungen einer Anpassung
der Ausbauziele für
Erneuerbare Energien
für das Jahr 2030



Ariadne Report
Germany on the way to
climate neutrality.
Scenarios and
pathways in model
comparison.

Ariadne Report
Renewable energy
targets for Germany in
2030.



Price formation in a highly-renewable, sector-coupled energy system

Julian Geis¹, Fabian Neumann², Michael Lindner³, Philipp Hirtel¹, Tom Brown¹

¹Department of Digital Transformation in Energy Systems, Institute of Energy Technology, Technische Universität Berlin, Fachkollekt 10, Strausberger Platz 124
10587 Berlin, Germany
²Freiburger Institute for Energy Economics and Energy System Technology, Fraunhofer IEE, Esslingen 20, Esslingen
70734 Esslingen, Germany

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Keywords:
Climate-neutral energy system
Sector coupling
Electricity market
Price formation
Flexibility price

ABSTRACT

As variable renewable energy increases and more demand is electrified, we expect price formation in wholesale electricity markets to transition from being dominated by fixed fuel generators to being dominated by the opportunity costs of storage and demand management. In order to analyze this transition, we introduce a new method to investigate price formation based on a mapping from the dual variables of the energy system optimization problem to the bids and asks of electricity suppliers and consumers. This allows us to build the full supply and demand curves in each hour. We use this method to analyze price formation in a sector-coupled, climate-neutral energy system model for Germany, PyPSA-DE, with high temporal resolution and energy flexibility in 5-year steps from 2020 until full decarbonization in 2045. We find a clear transition from direct price levels, corresponding to fixed fuels, to a smoother price curve set by variable renewable energy sources, batteries and electrolysis. Despite higher price volatility, the fully decarbonized system deals with renewable prices in 75% of all hours. Our results suggest that flexibility and cross-sectoral demand bidding play a vital role in stabilizing electricity prices in a climate-neutral future. These findings are highly relevant for guiding investment decisions and tailoring policy, particularly in support of dynamic pricing, the expansion of energy storage across multiple timescales, and the coordinated development of renewable and flexibility technologies.

Energy Economics
Price formation in a highly-renewable,
sector-coupled energy system.



Managing the mismatch: The role of flexibility on the path to a carbon-neutral energy system

Julian Geis¹, Michael Lindner², Tom Brown¹

¹Department of Digital Transformation in Energy Systems, Institute of Energy Technology, Technische Universität Berlin, Fachkollekt 10, Strausberger Platz 124
10587 Berlin, Germany

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ABSTRACT

A rapid expansion of system flexibility is essential to integrate increasing shares of renewable energy into future energy systems. However, flexibility needs and technology-specific contributions to flexibility remain poorly quantified in energy system modelling. Existing methods are not widely applied, leaving key questions unanswered: which flexibility technologies are critical to climate neutrality, and what are the net implications of alternative deployment strategies? To address this gap, we apply a flexibility metric based on the alignment between technology operational and enabled load variability in a high-resolution, sector-coupled model of the German energy system, covering its transformation towards climate neutrality. For our default scenario, we find that daily electricity costs increase by a factor of 1.7 between 2020 and 2045, driven primarily by the expansion of solar PV. By 2045, electricity balances provide 20% of daily flexibility, while flexible electric vehicle charging contributes 30%. Systems with coordinated flexibility increase system costs by 0.5%, electricity prices by 1.4 €/MWh, and require 0.7% higher hydrogen and a coal expansion compared to our conventional system in 2045. In contrast, scenarios with high shares of flexible electric vehicle charging, vehicle-to-grid, two-way business and industrial demand-side management achieve system cost reductions of 1.2%, while also reducing electricity price ranges, decreasing average electricity prices by 0.4 €/MWh, and lowering backup capacity requirements by 20% (22 GWh). Overall, our results highlight the decisive role of specific flexibility technologies in achieving cost-efficient and energy secure climate-neutral energy systems, providing quantitative guidance for policy and investment decisions.

Advances in Applied Energy
Managing the mismatch: the role of
flexibility on the path to a
carbon-neutral energy system.

Results Spotlight: PyPSA-DE in the Ariadne project

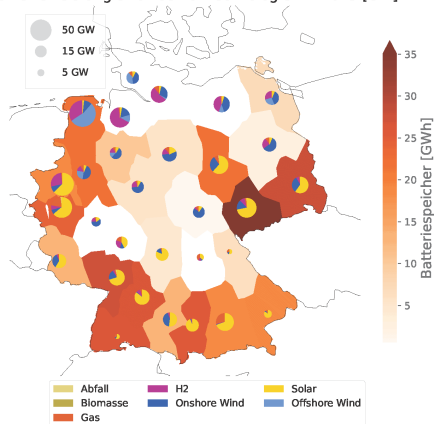


Ariadne Report
Die Energiewende
kosteneffizient gestalten:
Szenarien zur
Klimaneutralität 2045



Ariadne Report
Germany on the way to
climate neutrality.
Scenarios and
pathways in model
comparison.

Installierte Leistung Stromsektor TechnologiemiX 2045 [GW]



KOPERNIKUS
Ariadne **PROJEKTE**
Die Zukunft unserer Energie

Gefördert durch:



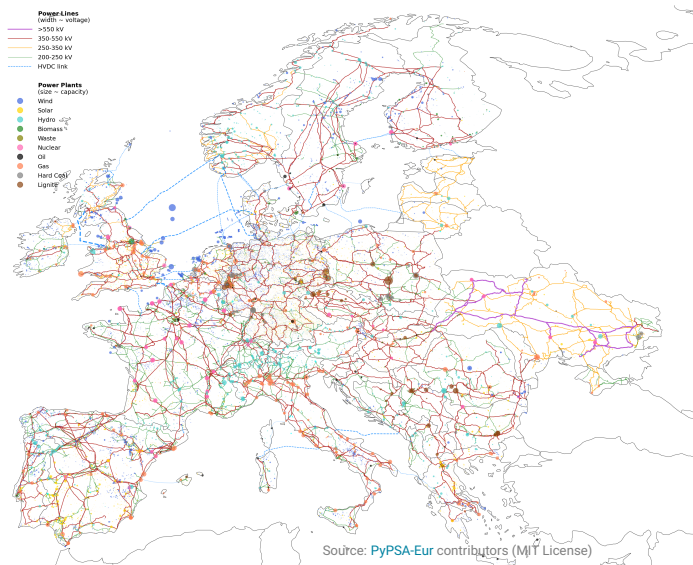
Bundesministerium
für Forschung, Technologie
und Raumfahrt

PyPSA-Eur extended to cover Ukraine and Moldova

In 2022, our group extended **PyPSA-Eur** to cover **Ukraine and Moldova** – to support work on Ukraine's energy crisis caused by the Russian full-scale invasion.

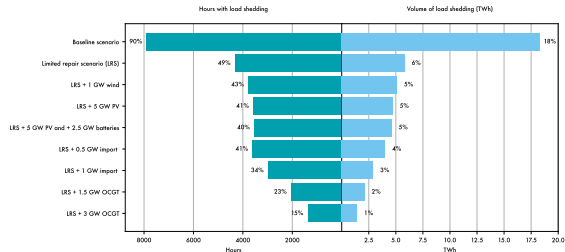
Several research groups have built upon this data extension:

- **Green Deal Ukraine**
- **Sotnyk et al., 2024**
- **Zachmann et al., 2025**
- **Tröndle et al., 2024**
- **Oxford EPG report**

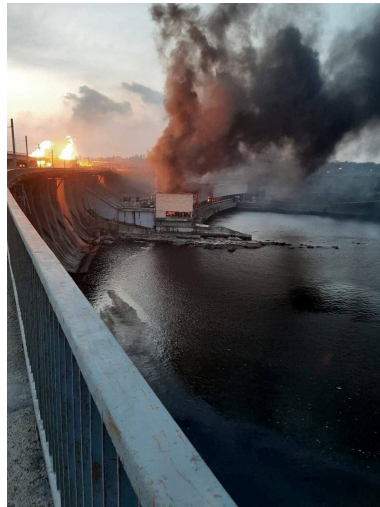
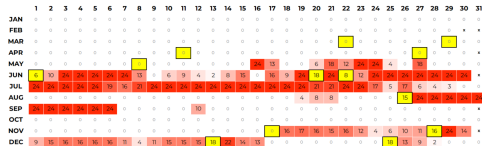


Source: **PyPSA-Eur** contributors (MIT License)

Mitigating Ukraine's Looming Electricity Crisis



1951 HOURS
with electricity outages in 2024



Source: Photo by Reuters (credit: Denys Shmyhal); left top:
<https://doi.org/10.1016/j.esr.2025.101724>; left bottom:
dixigroup.org

 PyPSA

Documentation

latest ▾

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 PyPSA/PyPSA
v1.3.0 ⭐ 2.1k 🗄 696

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Design

Network Object

The `pypsa.Network` is an overall container for all network . Components cannot exist without a network and are always attached to one. A network also holds functions to run different types of optimisation problems, compute power flows, read or write networks to files, retrieve statistics and plot the network.

```
>>> import pypsa
>>> n = pypsa.Network()
>>> n
Empty PyPSA Network 'Unnamed Network'
-----
Components: none
Snapshots: 1
```

 Tip

A short name, such as `n`, is recommended since it is used frequently to access the network's components and methods.

On this page

Network Object

Network Components

Buses

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Unit Conventions

Variable Conventions

Sign Conventions





Sustaining open-source energy system modelling with PyPSA

- Development & maintenance
- Support subscriptions
- Training workshops
- Modelling studies



pypsalabs.org

The Power of Many: Open Source for Critical Infrastructure

Dr. Michael Lindner (m.lindner@tu-berlin.de)

Dr. Iegor Riepin (iegor.riepin@tu-berlin.de)

PyPSA ecosystem: <https://pypsa.org/>

About RESILIENT project: <https://resilient-project.github.io/>

Power grid topology

OpenStreetMap data



Apply **standard line types** for capacity and parameters.

Calculate **dynamic line rating** potential from weather data.

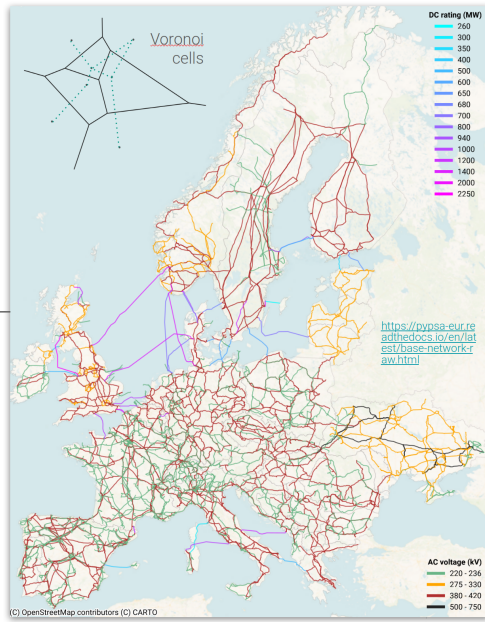
TYNDP projects



European network with

- ~5,800 buses
- ~7,300 AC lines (>220 kV)
- 36 HVDC links (+TYNDP)

<https://www.nature.com/articles/s41597-025-04550-7>

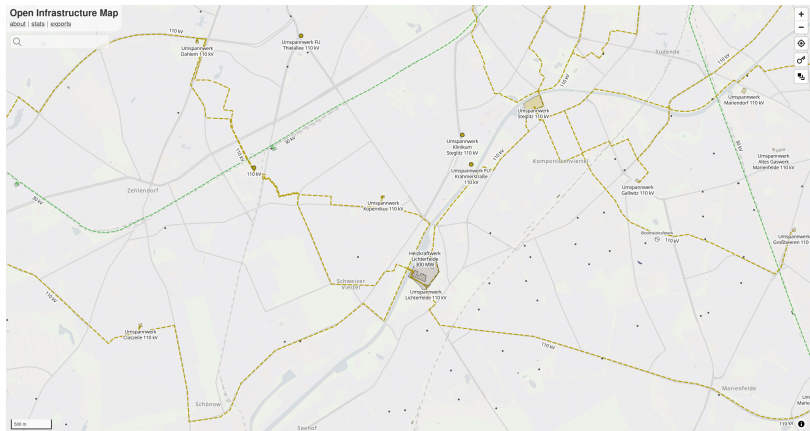


The Berlin blackout and the open data question

The January 2026 blackout in parts of Berlin raised attention to open infrastructure data.

Tools like **OpenInfraMap** allow anyone to explore the topology of the electricity grid, gas pipelines, etc. at street level.

openinframap.org



Security by obscurity is a dangerous fallacy

The assumption: restrict access to infrastructure data so adversaries can't use it. If they don't know where the lines run, they can't attack them.

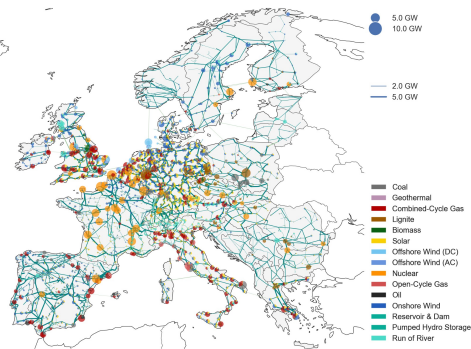
The reality: anyone who looks can find it

- commercial satellite imagery at **50 cm resolution**
- drone imagery and street-level photos
- commercial geospatial datasets
- public grid studies and regulatory filings
- web archives and cached maps

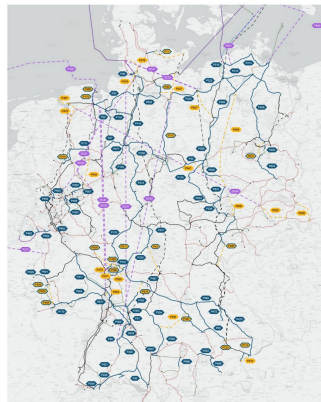


Source: Aerial photo: Enniger Substation 380 kV, [Wikimedia Commons](#) (CC BY-SA)

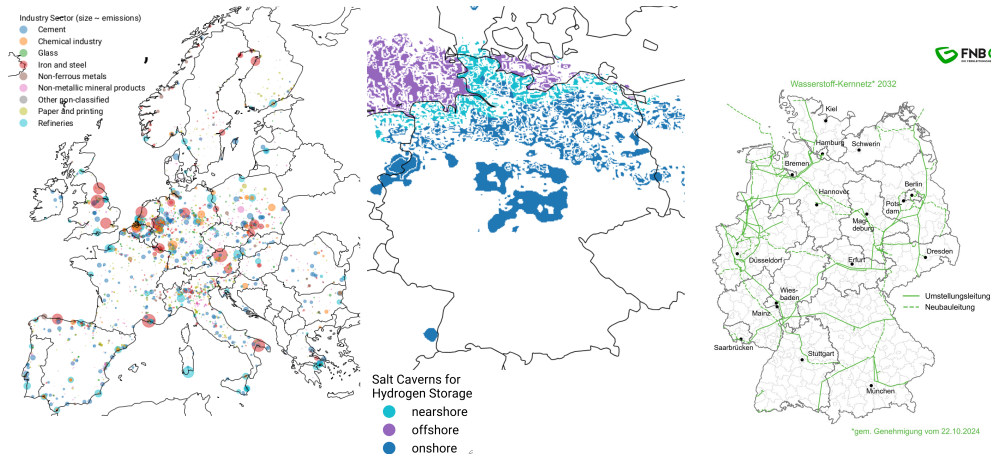
OPEN Data Spotlight: Electricity



Onshore-Zubaunetz Szenarien A/B/C 2037, A/B/C 2045, nur Leitungsbauprojekte*



OPEN Data Spotlight: Hydrogen



Source: Industrial sites: Hotmaps / PyPSA-Eur; caverns: Caglayan et al. (2020); hydrogen network: FNB Gas Wasserstoff-Kernnetz