FOSDEM 2023 - Energy track

4° February 2023

Open data and open-source adoption in the energy sector

filling the gaps with the open community

Davide Fioriti

Assistant Professor, University of Pisa

Co-Director of PyPSA meets Earth initiative

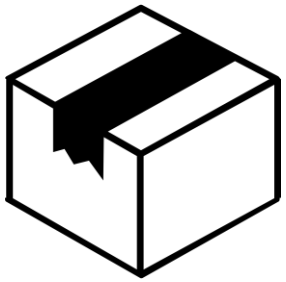
davide.fioriti@unipi.it

UNIVERSITÀ DI PISA

PyPSA meets Earth

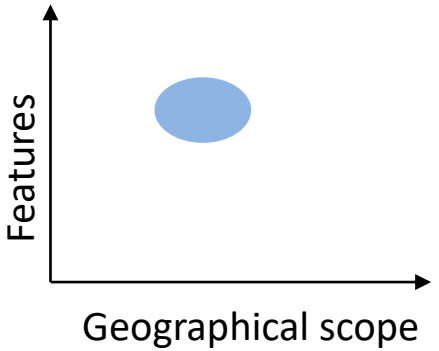
The Business-as-usual in energy planning

Entities



Closed data and tools
(Plexos, PowerFactory, …)

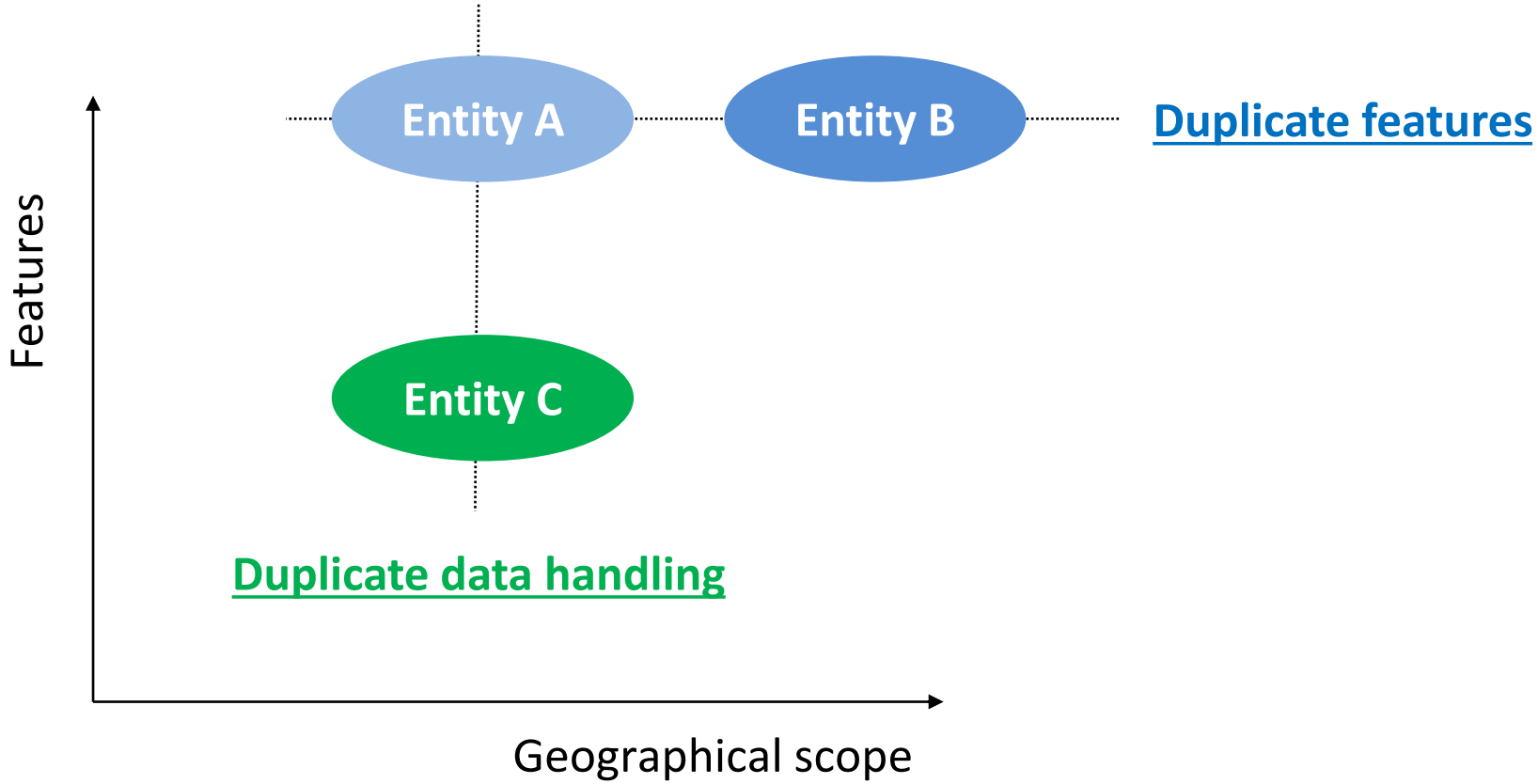
Narrow-focused results



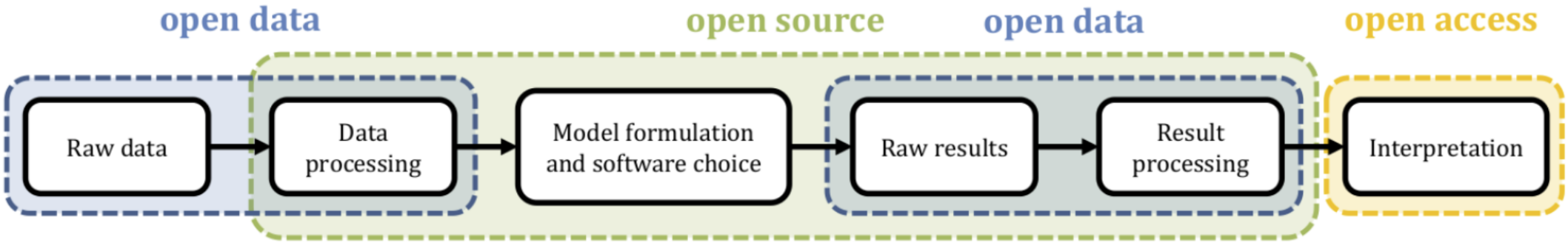
Non-transparent results

What's inside the box?

Business-As-Usual leads to duplication



The Open approach in energy planning



Coworking and efficiency:

«Let's not reinvent the wheel»

Tom Brown, https://github.com/max-parzen/max-parzen.github.io/blob/main/assets/presentations/brown-openmod_za.pdf
https://openmod-initiative.org/manifesto.html

Awareness is raising …

Public institutions

https://commission.europa.eu/about-european-commission/departments-and-executive-agencies/informatics/open-source-software-strategy_en

The European Commission's policies focus on generating value for the economy and society through the reuse of public sector information.

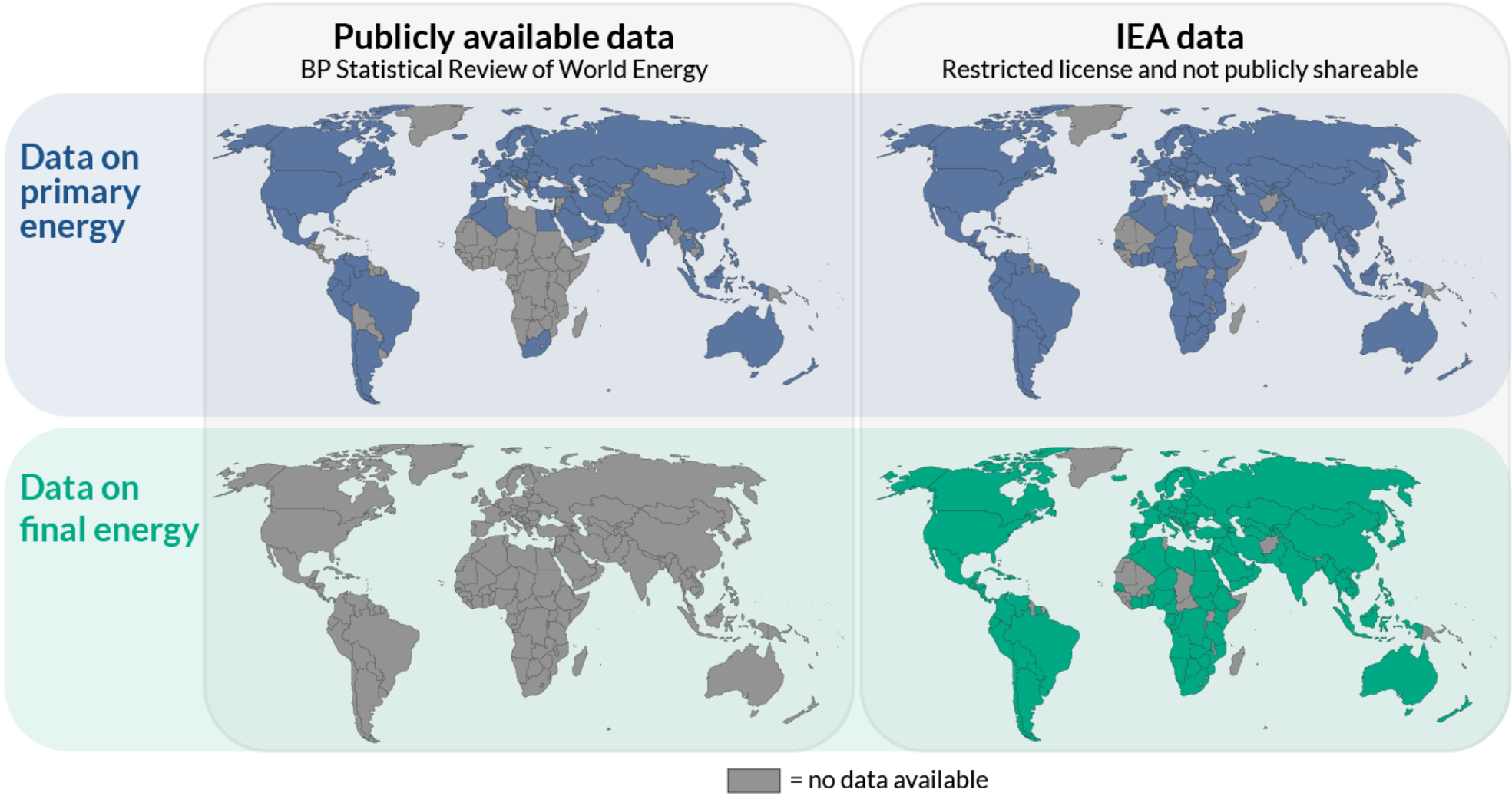
https://digital-strategy.ec.europa.eu/en/policies/open-data

Industry

https://www.edsoforsmartgrids.eu/latest-news/oh-yes-open-source-is-the-big-thing-for-dso-and-tso-press-release

https://github.com/alliander-opensource

… but far from complete

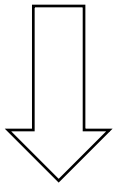


Available from: https://ourworldindata.org/iea-open-data

Open tools and data are great but

Users may be concerned by

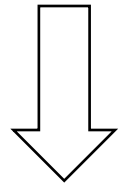
1. Software quality and security
2. Long-term sustainability
3. Licensing issues



Coordinated developments

Developers may be concerned by

1. Loosing property of the work
2. Preserve potential business to sustain the open-source project

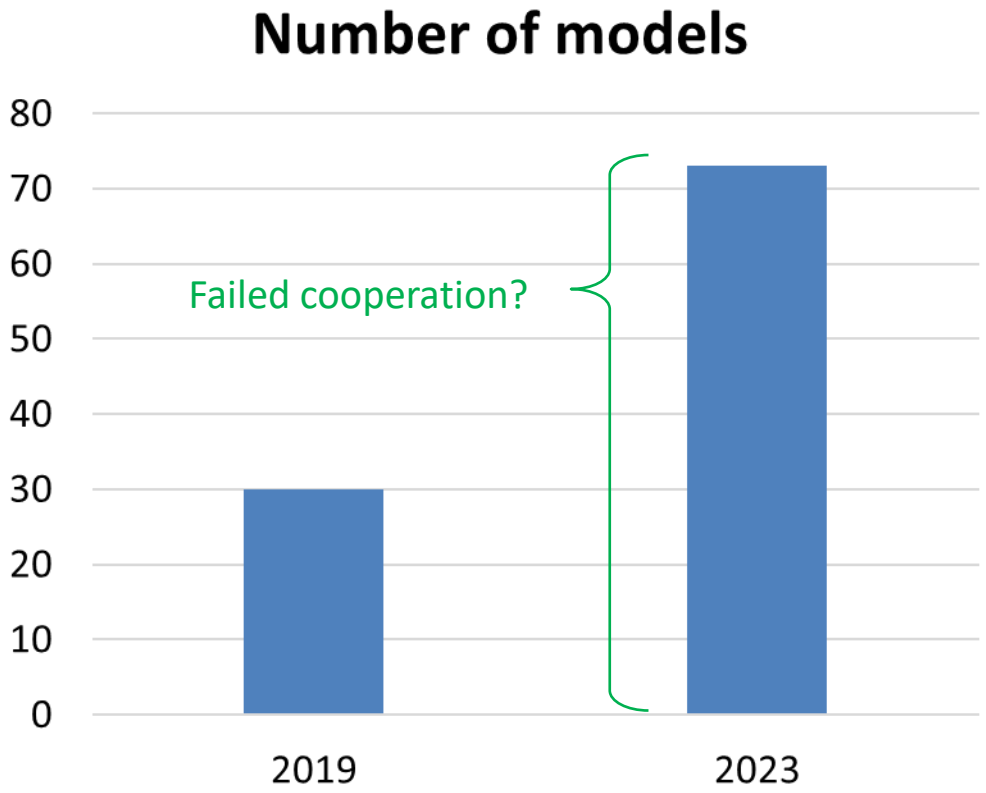


Choose appropriate licence

https://wiki.openmod-initiative.org/wiki/Choosing_a_license

https://snyk.io/learn/risks-of-open-source-software/
https://www.contrastsecurity.com/hubfs/Understanding-the-Risks_WhitePaper_042020_Final.pdf?hsLang=en
https://wiki.openmod-initiative.org/wiki/Choosing_a_license

Open energy models are increasing … too much?



Need for:

- Guidance across models
- Better coordination

M. Groissb¨ock, “Are open source energy system optimization tools mature enough for serious use?” Renewable and Sustainable Energy Reviews, vol. 102, pp. 234–248, 3 2019
https://wiki.openmod-initiative.org/wiki/Open_Models

Open Model list by OpenMod community

Overview of models by purpose, scope and modelling type

Model	Sectors	Model class	Math modeltype	Timeresolution	Georesolution	Is suited for many scenarios
AMIRIS	electricity	Agent-based electricity market model	Simulation Agent-based	Hour	National	true
ASAM	Electricity Electricity Market Electric power	Agent-based Simulation Market Model Electricity System Model German and European Electricity Market	Simulation Agent-based	15 Minute	Individual power stations	true
AnyMOD	User-dependent	Framework	Optimization	Hour	User-dependent	true
Backbone	All	Framework	Optimization	Hour	Depends on user	true
Balmorel	electricity district heating	GAMS	Optimization	Hour	something between NUTS 3 and country	false
Breakthrough Energy Model	Electricity	Framework	Optimization Simulation	Hour	Nodal	false
CAPOW	Electric power	CAISO and Mid-Columbia markets/U.S. West Coast	Simulation	Hour	Zonal	true
CESAR-P	electricity heating cooling domestic hot water	Swiss building stock	Simulation	Hour	depending on input data	false
Calliope	User-dependent	Framework	Optimization	Hour	User-dependent	true
CapacityExpansion	electricity heat gas	Capacity Expansion Problem	Optimization		input data dependent	true
DESSTinEE	All / Electricity	Simulation	Simulation	Hour	National	true
DIETER	electricity plus sector	Optimization	Optimization	Hour	In most applications so far, Germany as one	true

https://wiki.openmod-initiative.org/wiki/Open_Models

- **Guidance** across existing models
- Provide **application-based recommendations**:

  What to use for planning studies?
  What to use for EMS?

Tools for energy planning used in Africa

Software	Version	Citation	Language	Free and Open	Power Flow	Transport Model	LOPF	SCOPF	Unit Commitment	Sector-Coupling	Pathway Optimization
Calliope	v0.6.8	[12]	Python	✓		✓			✓	✓	
Dispa-SET	v2.4	[13]	GAMS	✓		✓			✓		
GridPath	v0.14.1	[14]	Python	✓		✓	✓		✓		✓
LEAP	2020.1.63	[15]	NA[b]							✓	
NEMO	v1.7	[16]	Julia	✓	✓	✓	✓		✓		
OSeMOSYS	2022	[17]	GNU[a]	✓		✓				✓	✓
PLEXOS	9	[18]	NA[b]			✓	✓	✓	✓	✓	✓
PyPSA	v0.20.0	[4]	Python	✓	✓	✓	✓	✓	✓	✓	✓
SPLAT-MESSAGE	2022	[19]	GAMS			✓					
TIMES	2022	[20]	GAMS			✓	✓		✓	✓	✓

Open-source competes!

Closed-source standard

Parzen, Maximilian and Abdel-Khalek, Hazem and Fedorova, Ekaterina and Mahmood, Matin and Frysztacki, Martha Maria and Hampp, Johannes and Franken, Lukas and Schumm, Leon and Neumann, Fabian and Poli, Davide and Kiprakis, Aristides and Fioriti, Davide. PyPSA-Earth. A New Global Open Energy System Optimization Model Demonstrated in Africa. Preprint available at https://arxiv.org/abs/2209.04663; https://zenodo.org/record/6857191

Coordination is required

1. **Work together** rather than duplicate efforts
2. **Share knowledge** to grow stronger together
3. **Share data** sources and processing procedures

Süsser D, Pickering B, Hülk L and Pfenninger S. Open energy system modelling to support the European Green Deal [version 1; peer review: not peer reviewed]. *F1000Research* 2022, **11**:531 (https://doi.org/10.12688/f1000research.121619.1)

OPEN Global Independent Research Initiative

PyPSA *meets* Earth

Speed up the global energy transition

by open data and open-source tools

TOGETHER

OPEN Global Independent Research Initiative

PyPSA meets Earth

USER AND DEVELOPER COMMUNITY

Open · Collaborative · Dialogue · Training · Empower

> 200pp on Discord

DATA

Creating open data · Predicting data · Data workflow · High resolution

> 10 open datasets

ENERGY SYSTEM MODELS

High resolution · Features · Performant · Problem formulator · Modular

PyPSA-based

SOLVER

Help sustaining · Support developers · Reveal bottlenecks · Initiate new paths

No commercial ones!

Everyone is welcome to join!

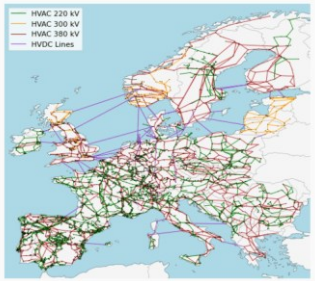
GROW AN EXISTING USER BASE

PyPSA

PyPSA

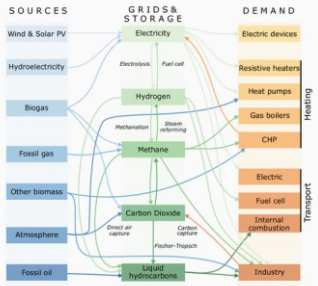
A python software toolbox for simulating and optimising modern power systems.

PyPSA-Eur



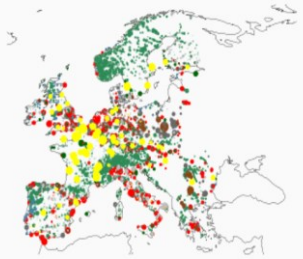
An open optimisation model of the European transmission system.

PyPSA-Eur-Sec



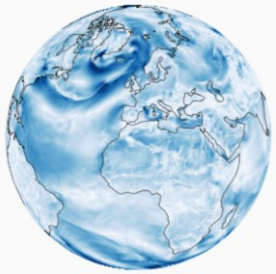
A sector-coupled open optimisation model of the European energy system.

Powerplantmatching



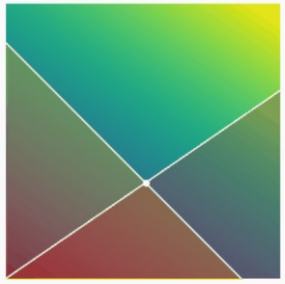
A toolset for cleaning, standardizing and combining multiple power plant databases.

Atlite



A Lightweight Python Package for Calculating Renewable Power Potentials and Time Series

Linopy



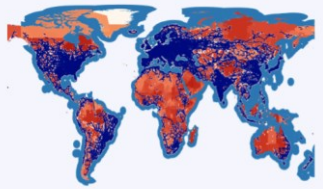
Linear optimization interface for N-D labeled variables.

PyPSA meets Earth

PyPSA-Africa

An open optimization model of the African transmission system

PyPSA-Earth

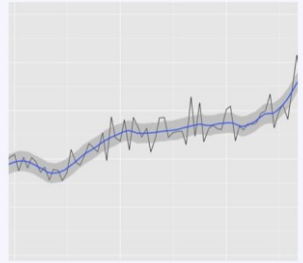


A highly flexible **sector-coupled** energy system model of the global energy system

Detect-Energy

A machine learning framework to detect energy assets from satellites

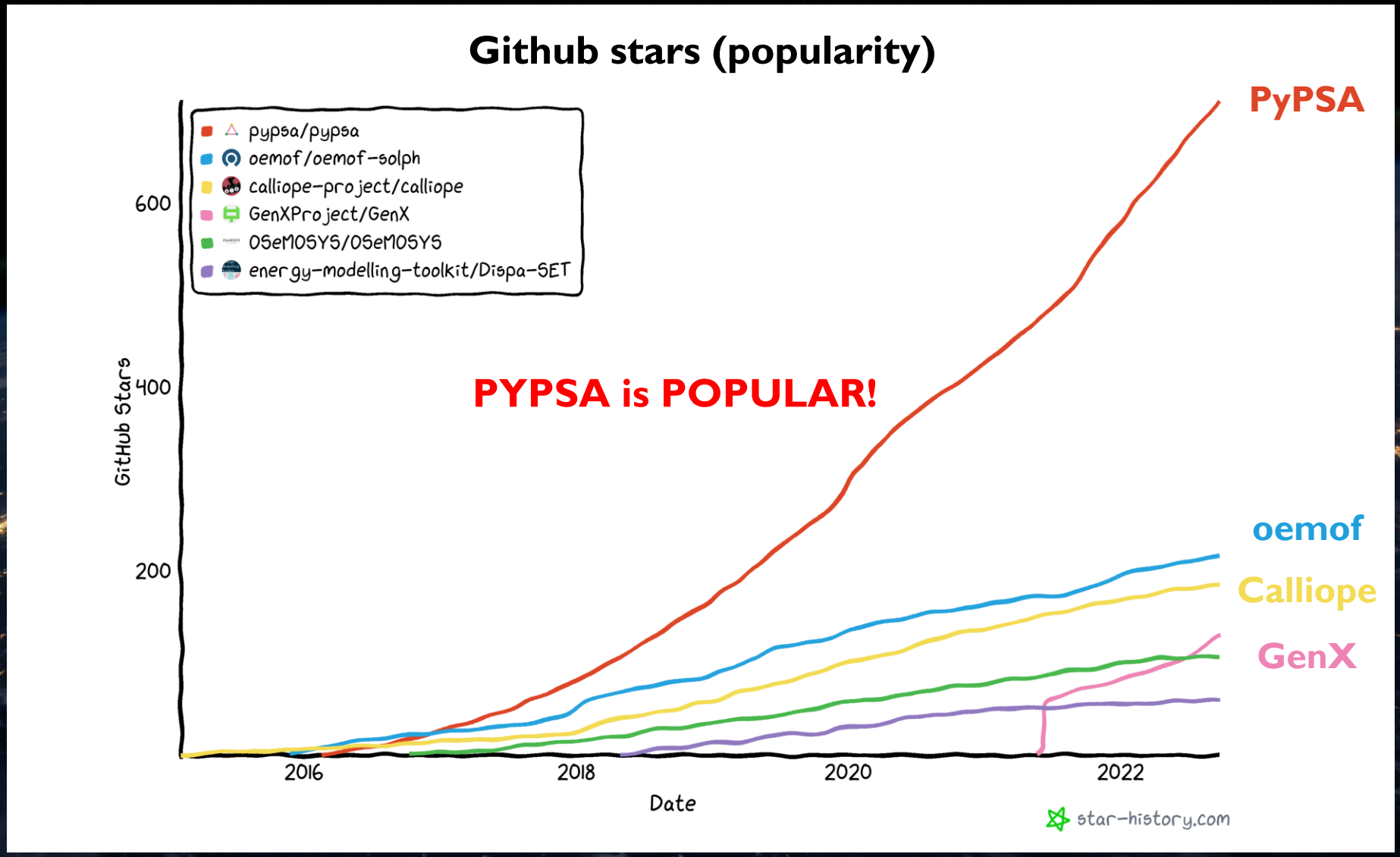
Demand-Creator



A general framework to create demand timeseries in subnational resolution

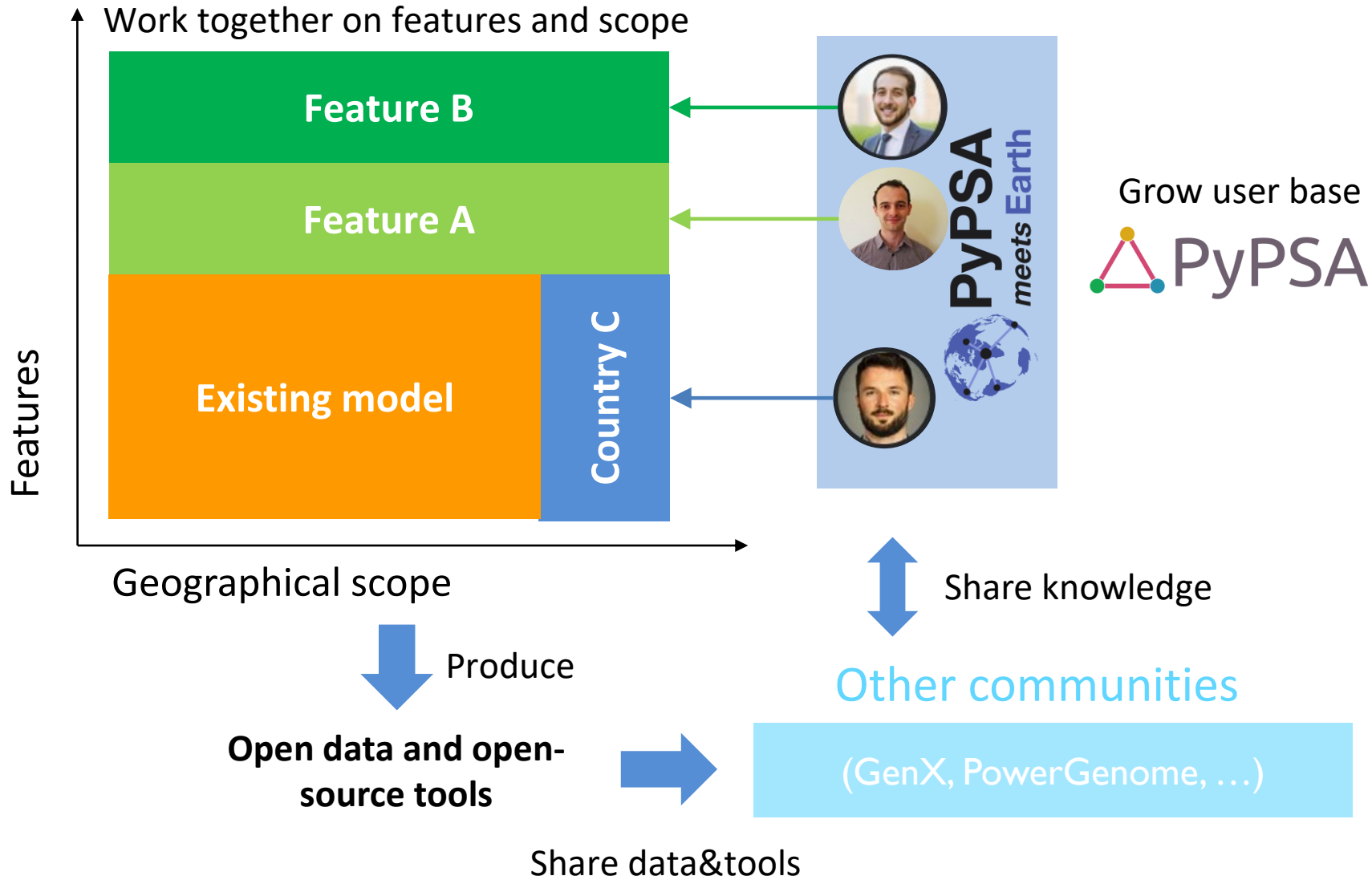
More to come with your support!

WHY PYPSA? POPULARITY



A GLOBAL COMMUNITY

Our Recipe in a nutshell



How to plan for a bright future?

TOOLS FOR:

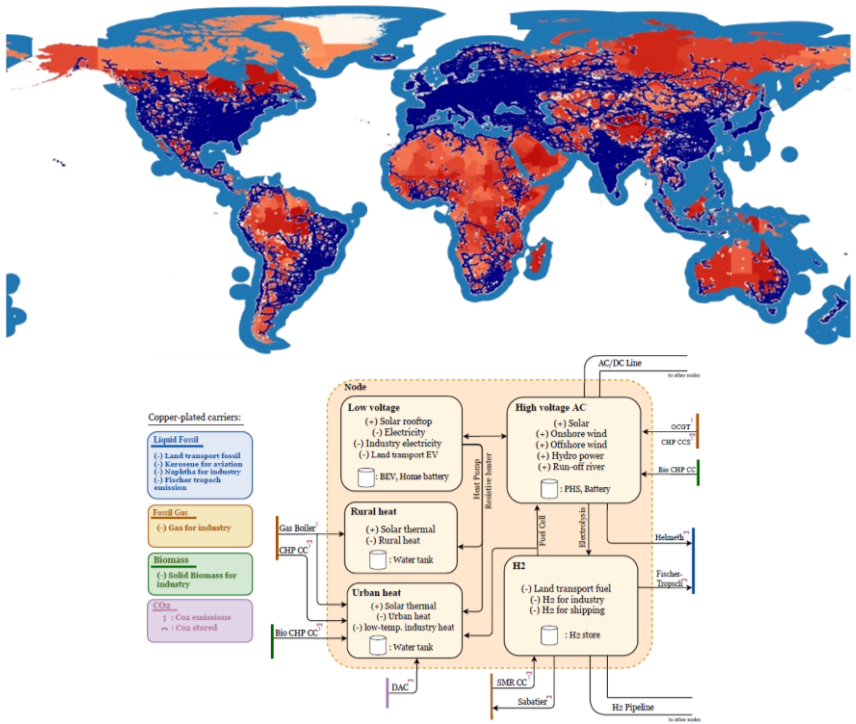
- Policy analysis
- Investment analysis
- Continent-wide synergies
- Decarbonization pathways

The models

PyPSA-Earth

Earth sector-coupled model

(validated model for Africa + other regions)



https://github.com/pypsa-meets-earth/pypsa-earth

PyPSA-Distribution

Distribution model

(under development)

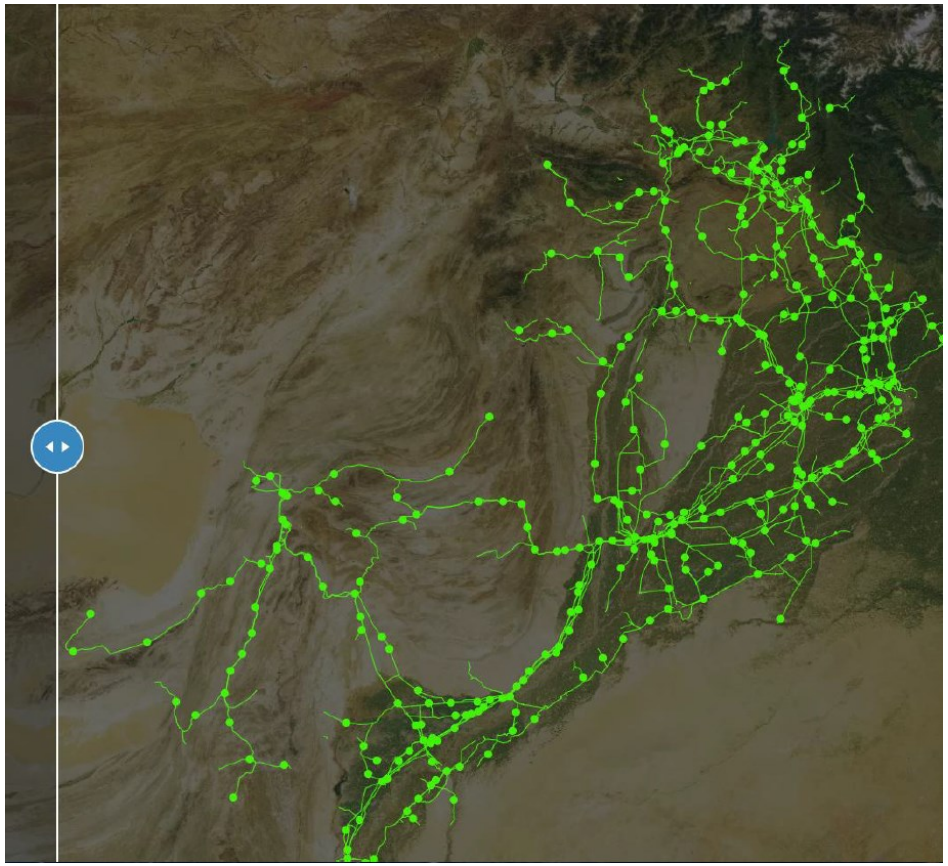
https://github.com/pypsa-meets-earth/pypsa-distribution

Maximilian Parzen, Hazem Abdel-Khalek, Ekaterina Fedorova, Matin Mahmood, Martha Maria Frysztacki, Johannes Hampp, Lukas Franken, Leon Schumm, Fabian Neumann, Davide Poli, Aristides Kiprakis, Davide Fioriti, 2022. PyPSA-Earth. A New Global Open Energy System Optimization Model Demonstrated in Africa. https://doi.org/10.48550/arXiv.2209.04663

How to deal with missing data?

Available network data

Most-likely truth

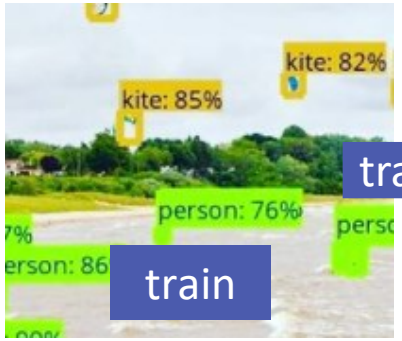


CC, https://devseed.com/ml-grid-docs/results/mapping-output-and-speed/

The data-creation tools

Detect-Energy

Estimate energy infrastracture



transfer

> 15 trained models

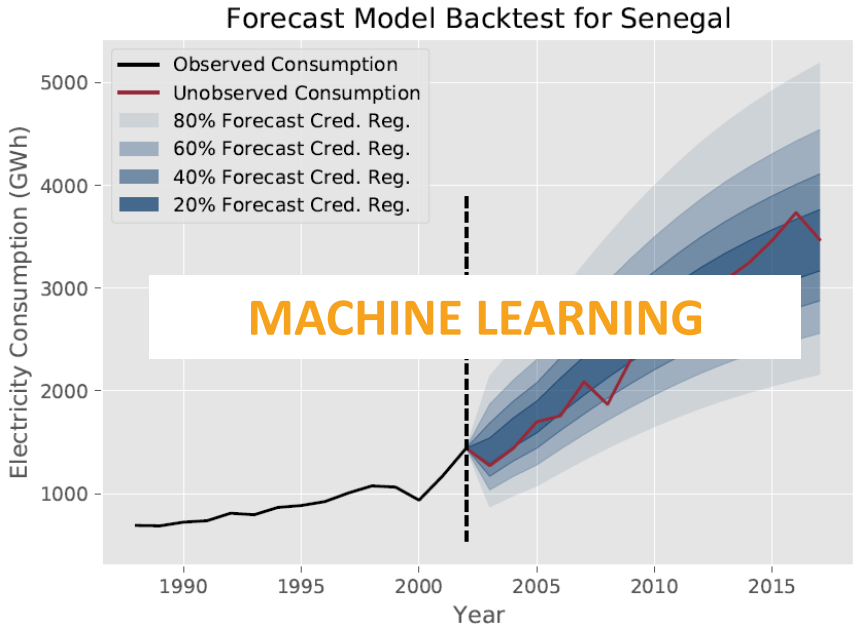
> 5 AI processing techniques (GAN, detectron2, …)

https://github.com/pypsa-meets-earth/detect-energy

AI-ENABLED

Demand Creator

Estimate demand



Sources: S. J. Lee, D. Suri, P. Somani, C. L. Dean, J. Pacheco, R. Stoner, I. Perez-Arriaga, J. W. Fisher III, and J. Taneja, "How probabilistic electricity demand forecasts can expedite universal access to clean and reliable electricity," *Energy for Economic Growth*, 2021.; S. J. Lee, C. L. Dean, D. Suri, P. Somani, J. Pacheco, R. Stoner, I. Perez-Arriaga, J. W. Fisher III, and J. Taneja, "Probabilistic forecasts of country-level electricity demand in Africa," 2022 (not yet public). – Soon to be open-sourced, please contact authors

maxar.com/open-data

https://figshare.com/articles/dataset/Electric_Transmission_and_Distribution_Infrastructure_Imagery_Dataset https://pxhere.com/en/photo/560374

PyPSA-Earth: A deep-dive into energy planning

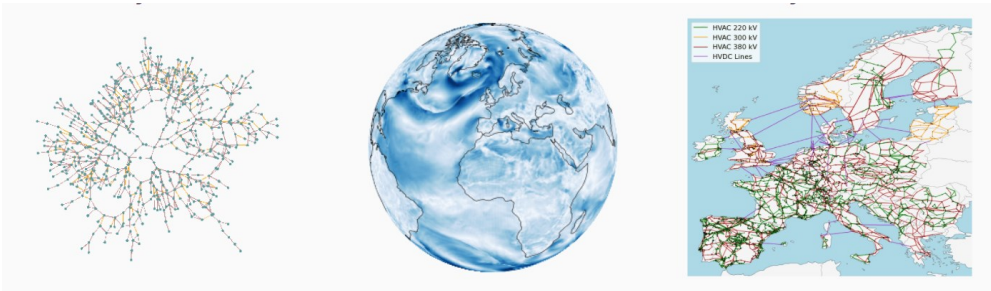
Functionalities

Technical and policy makers need

- **Robust**
  - PyPSA-Earth leverages on validated models
- **Reliable**
  - Community support (>200pp)
- **Low cost**
  - Open-source
- **Simple**
  - python™ & GUI (soon, thanks @Max)
- **Planning and dispatch tools**
  - PyPSA-Earth leverages on PyPSA

PyPSA meets Earth

We thank



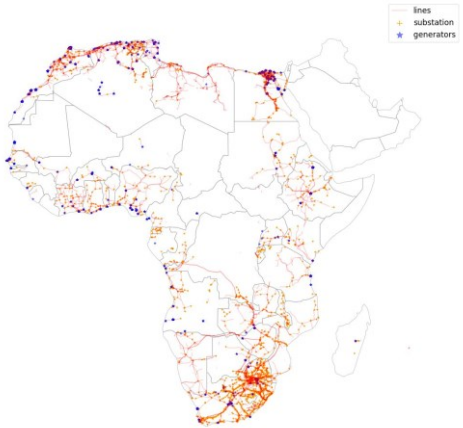
PyPSA Atlite PyPSA-Eur

https://github.com/PyPSA

Data analysis

Dataset open:

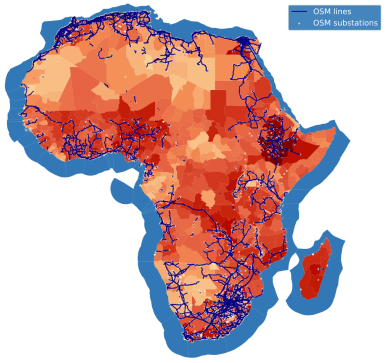
- OpenStreetMap (OSM)
- Database of Global Administrative Areas (GADM)
- ERA5 from Copernicus Climate Change Service
- ….



Download
Filter
Merge

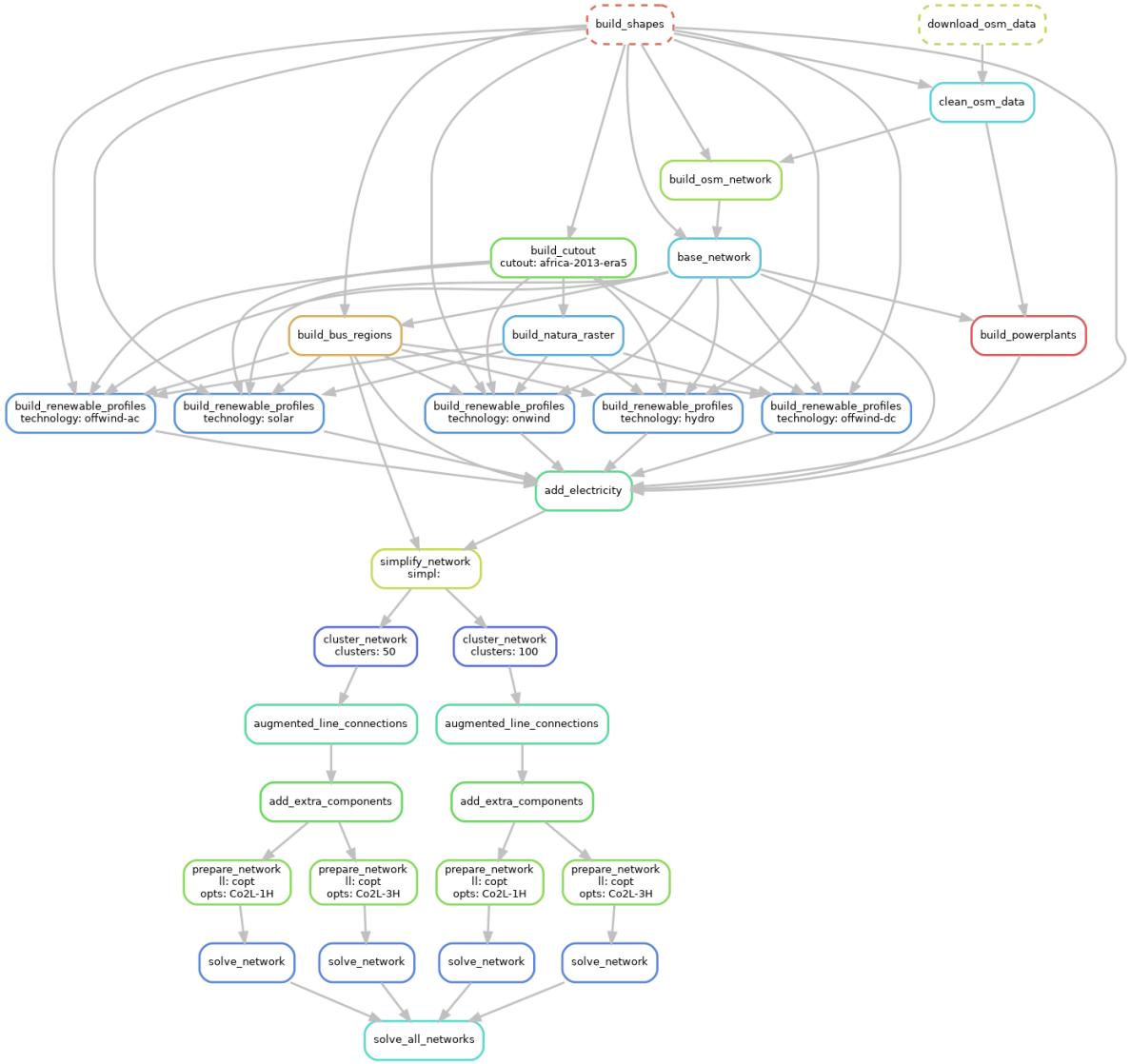
- **Network description in high resolution**
- **Estimate installed capacity**
- **Estimate demand and renewable production time series**

GDP,
Population,
RES,
…



Network data

The general methodology: make it in small pieces!



Config file

SNAKEMAKE

Download raw data

Clean data

Create model

Optimize model

Results

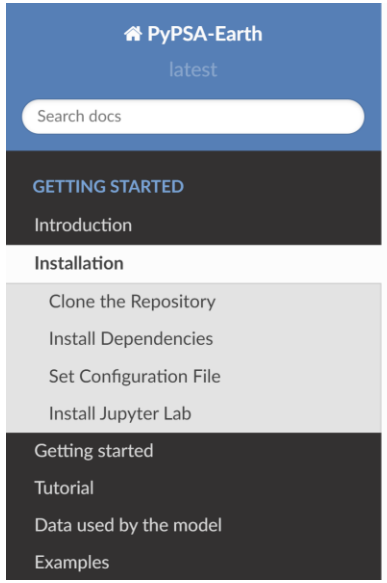
How easy is it to run?

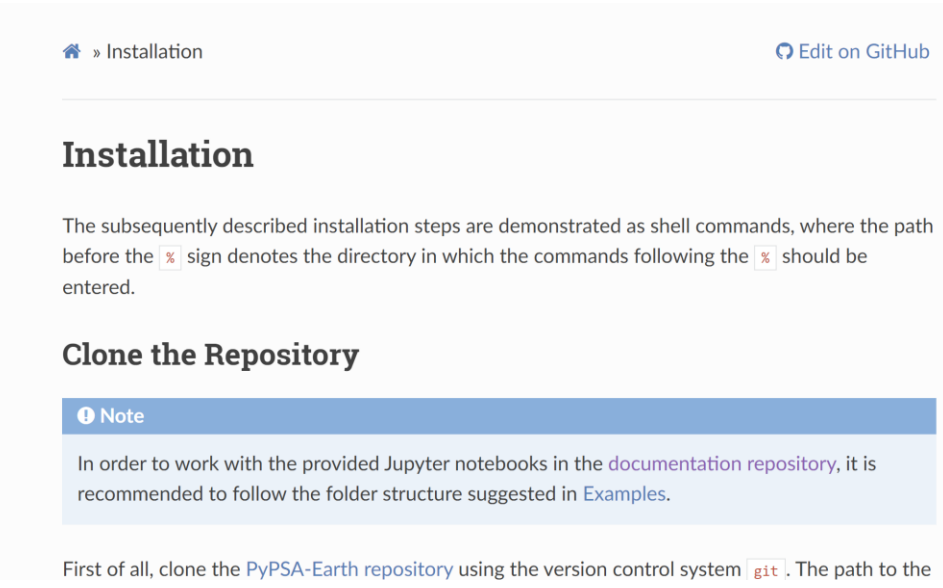
Choose the countries and run one line! …

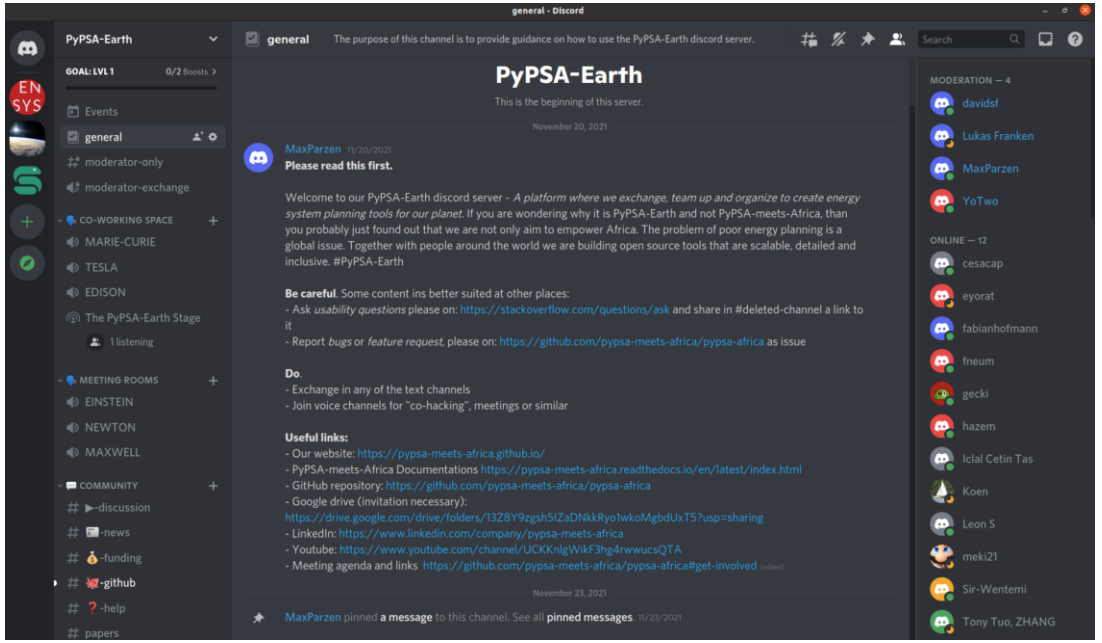
```
countries: ["NG", "BJ"]
```

```
.../pypsa-earth (pypsa-earth) % snakemake -j 1 solve_all_networks
```

When things go wrong (always), see documentation and discord!



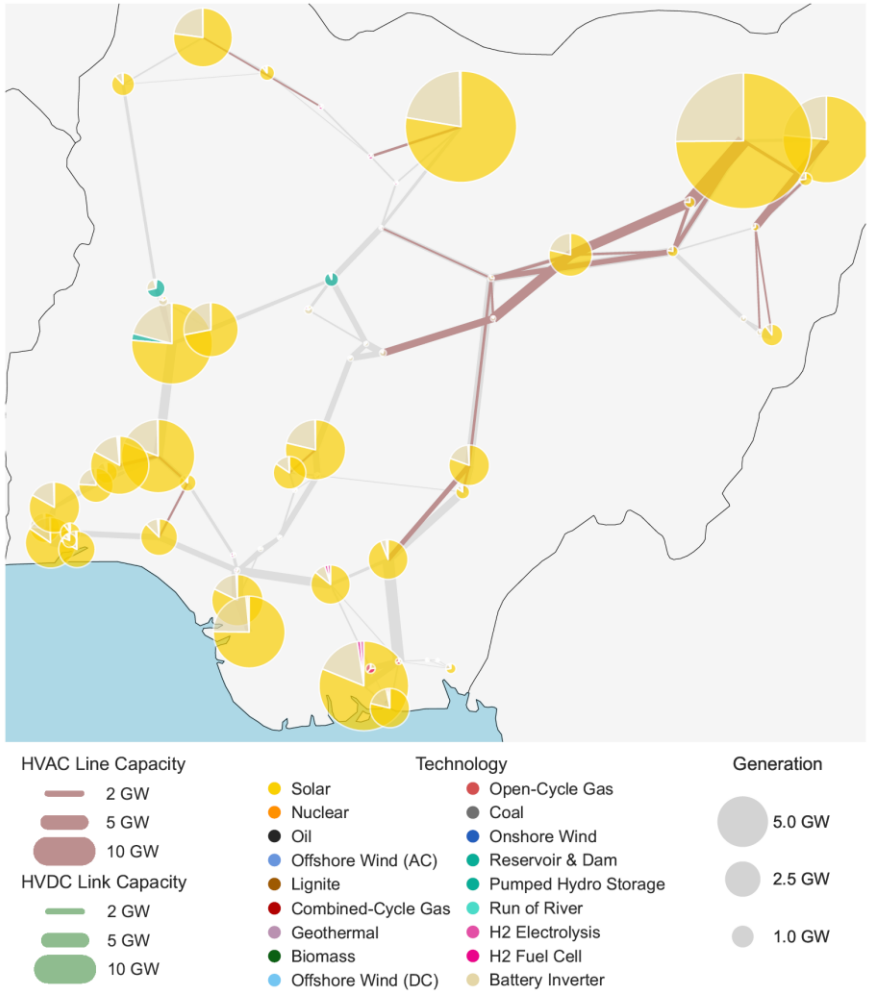




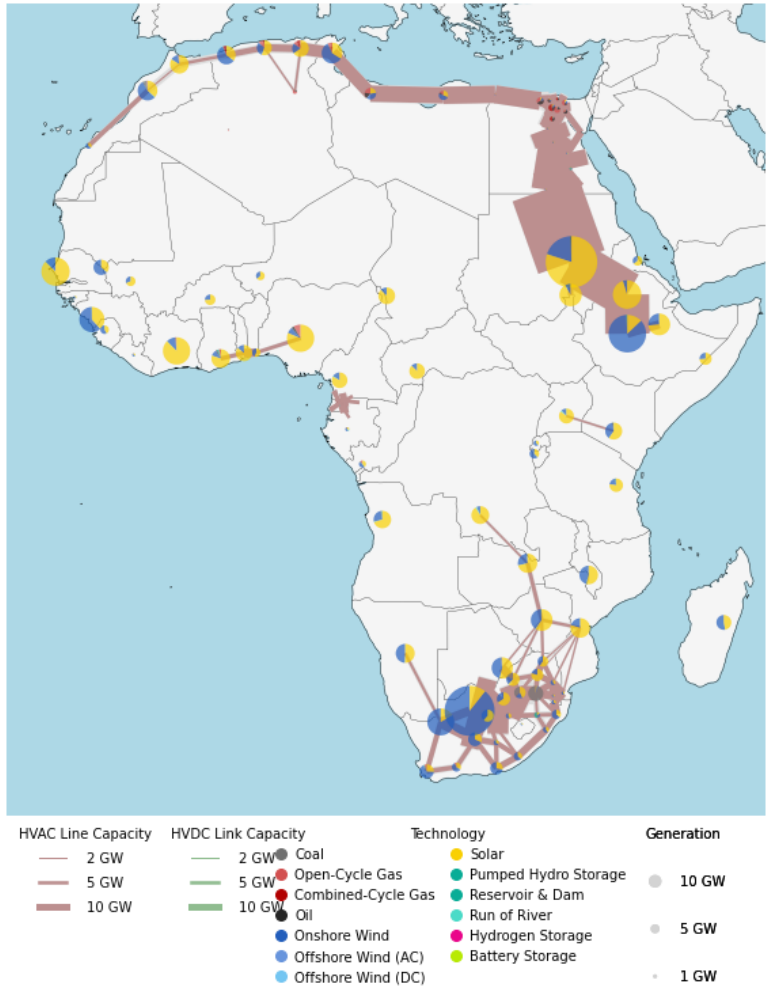
https://pypsa-earth.readthedocs.io/en/latest/short_tutorial.html

PyPSA-Earth for Net-Zero energy planning

Nigeria



Africa



Parzen, Maximilian and Abdel-Khalek, Hazem and Fedorova, Ekaterina and Mahmood, Matin and Frysztacki, Martha Maria and Hampp, Johannes and Franken, Lukas and Schumm, Leon and Neumann, Fabian and Poli, Davide and Kiprakis, Aristides and Fioriti, Davide. PyPSA-Earth. A New Global Open Energy System Optimization Model Demonstrated in Africa. Preprint available at https://arxiv.org/abs/2209.04663; https://zenodo.org/record/6857191

Our messages

SHARE KNOWLEDGE

WORK TOGETHER

SHARE DATA

Questions?

Davide Fioriti

Assistant Professor, University of Pisa
Co-Director PyPSA meets Earth
davide.fioriti@unipi.it

https://pypsa-meets-earth.github.io/
https://github.com/pypsa-meets-earth/pypsa-earth

PyPSA-Earth for Net-Zero energy planning

Nigeria

Africa

arXiv > physics > arXiv:2209.04663

Search... All fields Search

Help | Advanced Search

Physics > Physics and Society

[Submitted on 10 Sep 2022]

PyPSA-Earth. A New Global Open Energy System Optimization Model Demonstrated in Africa

Maximilian Parzen, Hazem Abdel-Khalek, Ekaterina Fedorova, Matin Mahmood, Martha Maria Frysztacki, Johannes Hampp, Lukas Franken, Leon Schumm, Fabian Neumann, Davide Poli, Aristides Kiprakis, Davide Fioriti

Macro-energy system modelling is used by decision-makers to steer the global energy transition toward an affordable, sustainable and reliable future. Closed-source models are the current standard for most policy and industry decisions. However, open models have proven to be competitive alternatives that promote science, robust technical analysis, collaboration and transparent policy decision-making. Yet, two issues slow the adoption: open models are often designed with limited geographic scope, hindering synergies from collaboration, or are based on low spatially resolved data, limiting their use. Here we introduce PyPSA-Earth, the first open-source global energy system model with data in high spatial and temporal resolution. It enables large-scale collaboration by providing a tool that can model the world energy system or any subset of it. This work is derived from the European PyPSA-Eur model using new data and functions. It is suitable for operational as well as combined generation, storage and transmission expansion studies. The model provides two main features: (1) customizable data extraction and preparation scripts with global coverage and (2) a PyPSA energy modelling framework integration. The data includes electricity demand, generation and medium to high-voltage networks from open sources, yet additional data can be further integrated. A broad range of clustering and grid meshing strategies help adapt the model to computational and practical needs. A data validation for the entire African continent is performed and the optimization features are tested with a 2060 net-zero planning study for Nigeria. The demonstration shows that the presented developments can build a highly detailed energy system model for energy planning studies to support policy and technical decision-making. We welcome joining forces to address the challenges of the energy transition together.

Comments: 36 pages, 14 figures, 3 tables
Subjects: **Physics and Society (physics.soc-ph)**
Cite as: arXiv:2209.04663 **[physics.soc-ph]**
(or arXiv:2209.04663v1 **[physics.soc-ph]** for this version)
https://doi.org/10.48550/arXiv.2209.04663

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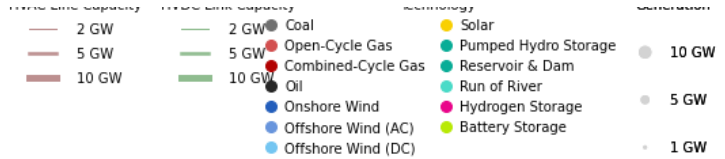
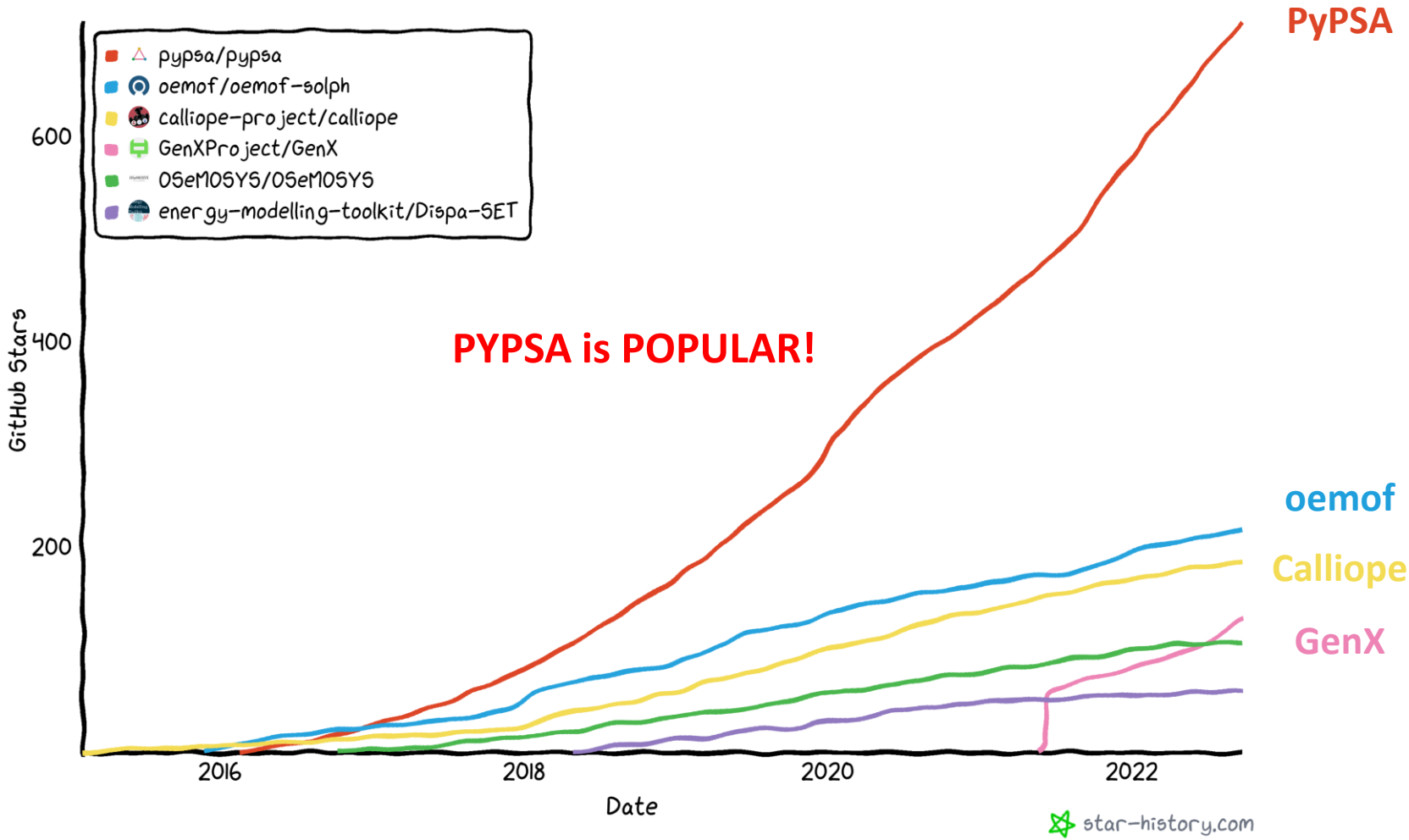
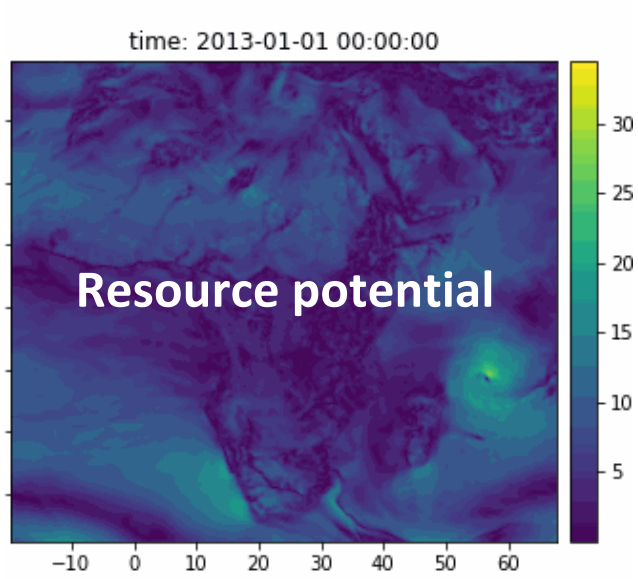


Parzen, Maximilian and Abdel-Khalek, Hazem and Fedorova, Ekaterina and Mahmood, Matin and Frysztacki, Martha Maria and Hampp, Johannes and Franken, Lukas and Schumm, Leon and Neumann, Fabian and Poli, Davide and Kiprakis, Aristides and Fioriti, Davide. PyPSA-Earth. A New Global Open Energy System Optimization Model Demonstrated in Africa. Preprint available at https://arxiv.org/abs/2209.04663; https://zenodo.org/record/6857191

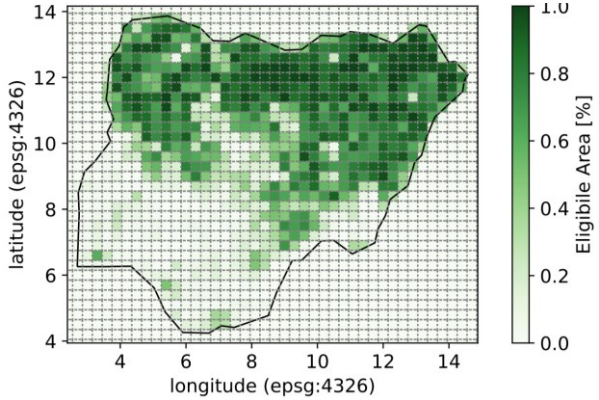
Github stars (popularity)



Renewable production



Land constraints

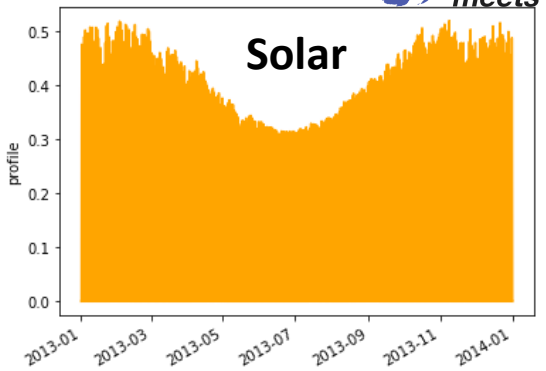


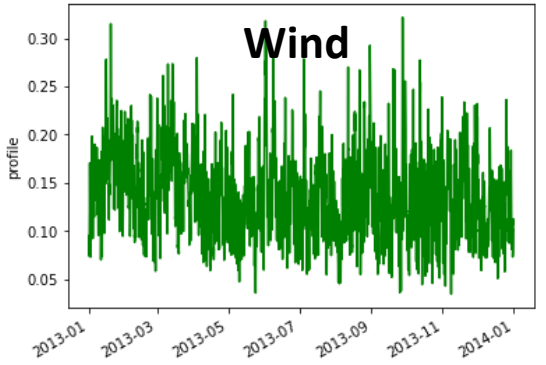
Pictures by Johannes Hampp/Max Parzen

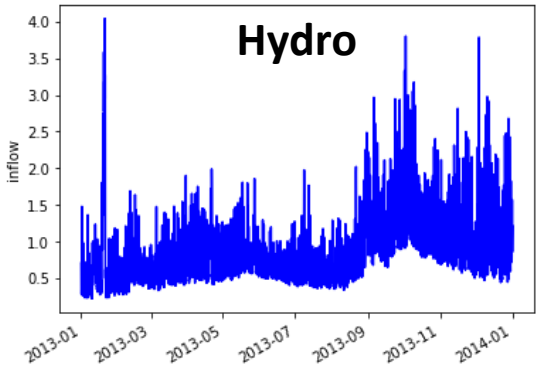
Atlite

https://github.com/PyPSA/atlite

PyPSA meets Earth





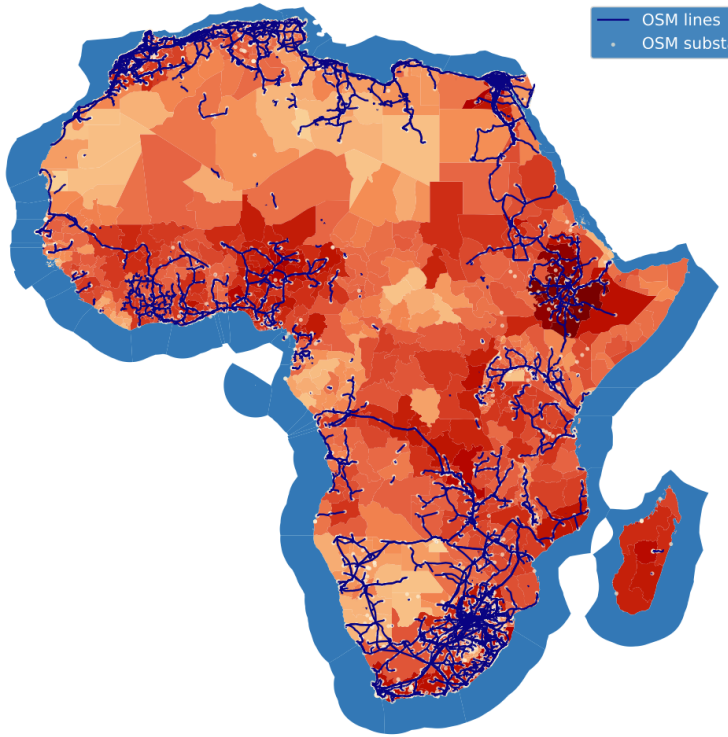


CSP (coming),…

Clustering to dominate complexities

Original

["Africa"]

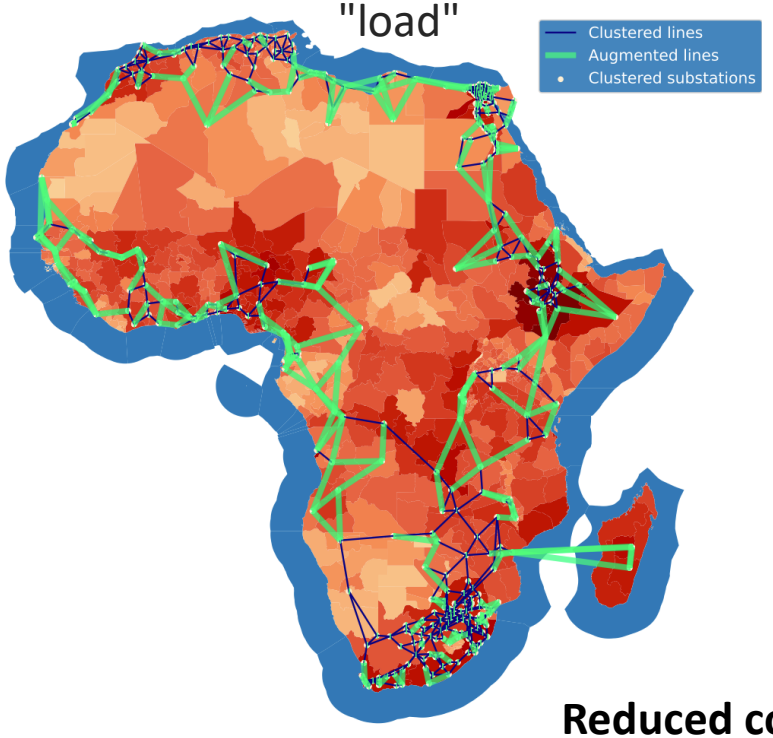


["Nigeria"]

After clustering

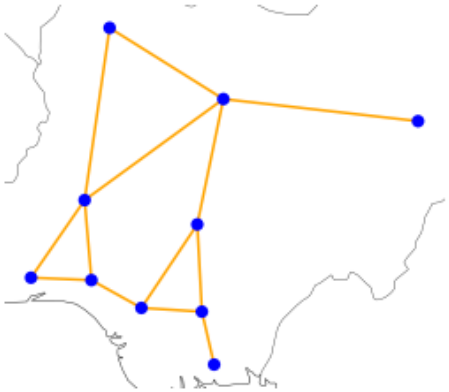
["Africa"]

420-node grid, distr. param. : "load"



["Nigeria"]

10-node grid



Reduced complexity
Keep representability of the problem

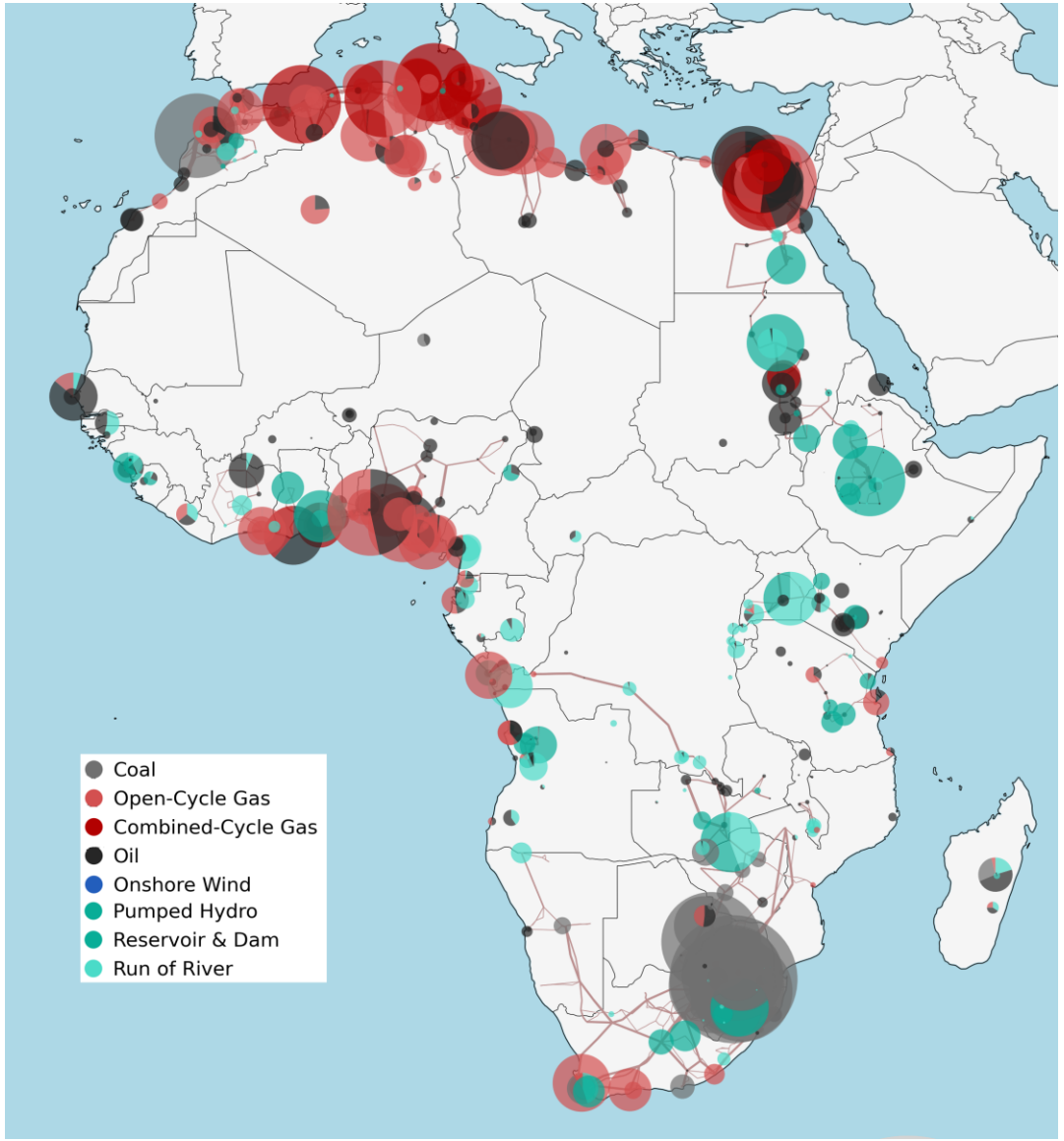
Installed capacity

Combine multiple datasets:

- Carbon Monitoring for Action (**CARMA**)
- Global Energy Observatory (**GEO**)
- Global Power Plant Database (**GPD**)
- OpenStreetMap (**OSM**)
- …yours?

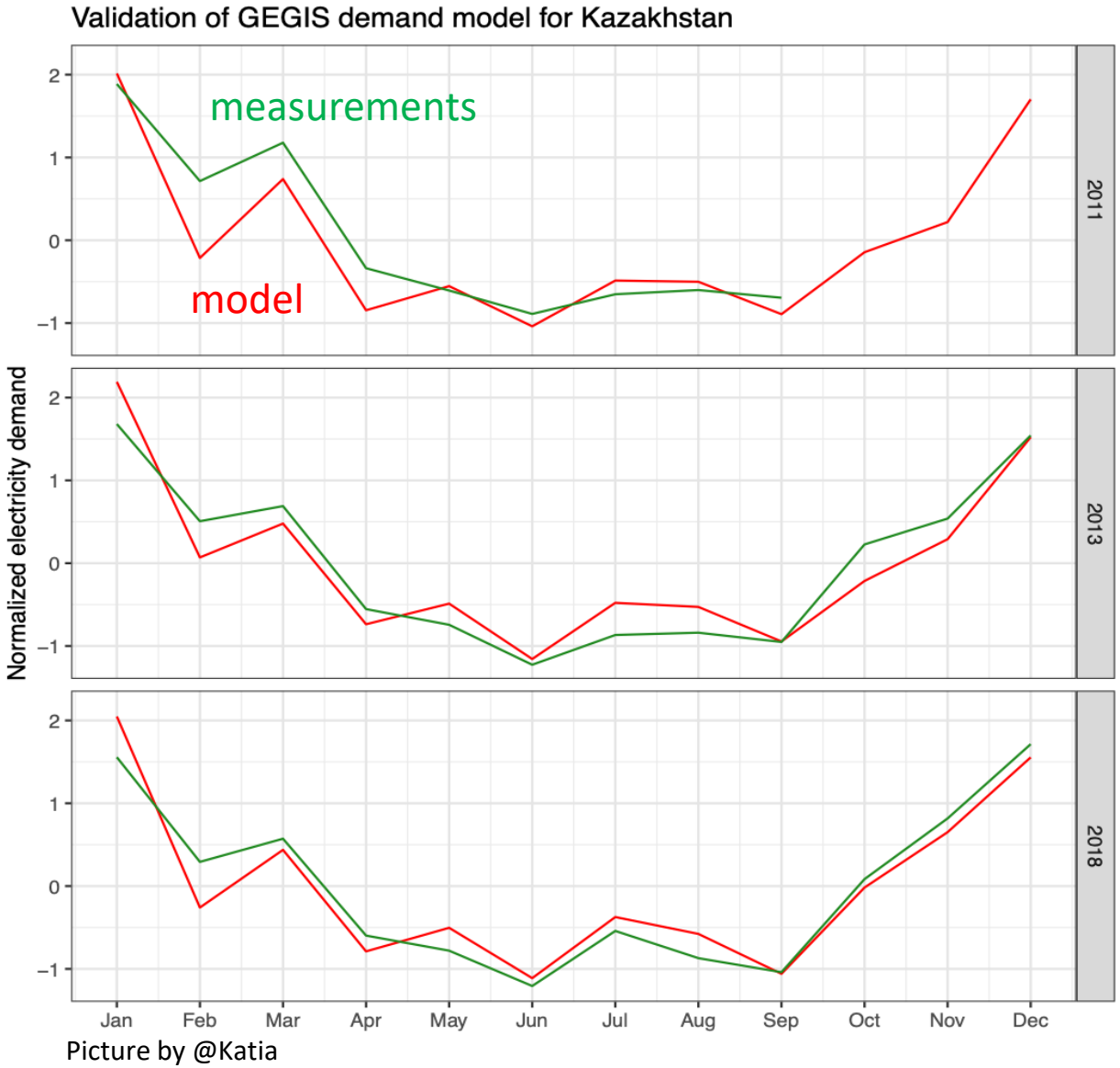
Merge data with powerplantmatching

https://github.com/PyPSA/powerplantmatching



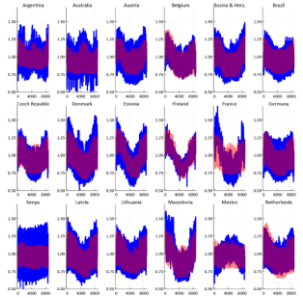
F. Gotzens, H. Heinrichs, J. Hörsch, and F. Hofmann, Performing energy modelling exercises in a transparent way - The issue of data quality in power plant databases, Energy Strategy Reviews, vol. 23, pp. 1–12, Jan. 2019

Estimate the demand (electric, sector-coupled coming)

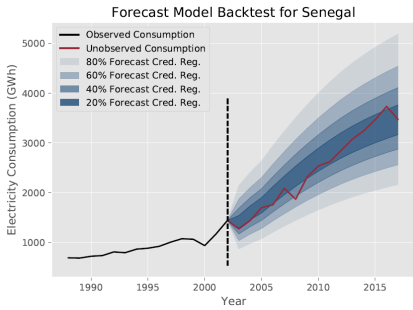


Picture by @Katia

Support multiple models



1) GlobalEnergyGIS
(current)



2) Demand-Creator
(under development)

3) … yours?

JUST ANOTHER ENERGY MODELLING? NO!

PyPSA meets Earth

80% DATA HANDLING

20% ENERGY MODEL

- Build on top of existing tools
- Grow an existing community

PyPSA