

Guest presentation @ University of Strathclyde
**"Working together on energy transition planning
with the open data and open source initiative
PyPSA meets Earth"**



25.07.2022, Maximilian Parzen

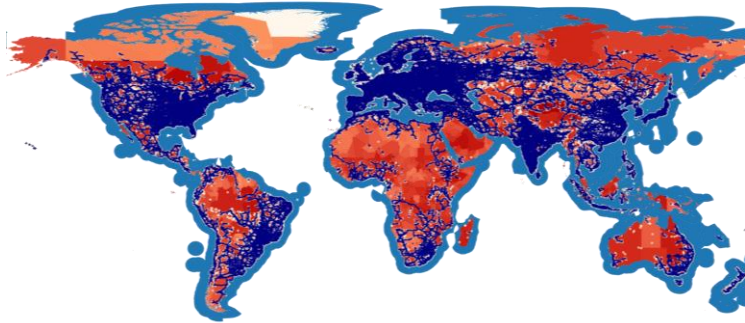


WHO IS MAX?

Bored PhD student
Winter 20/21



PyPSA-Earth & Co.



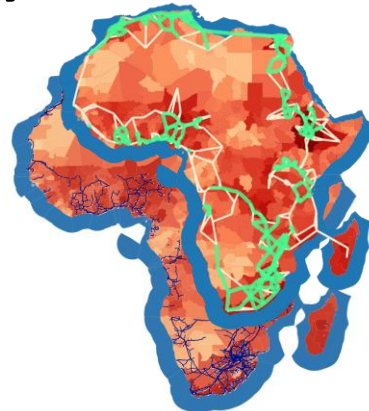
Started activities
on global scale



PyPSA
meets Earth

Extended the
initiative

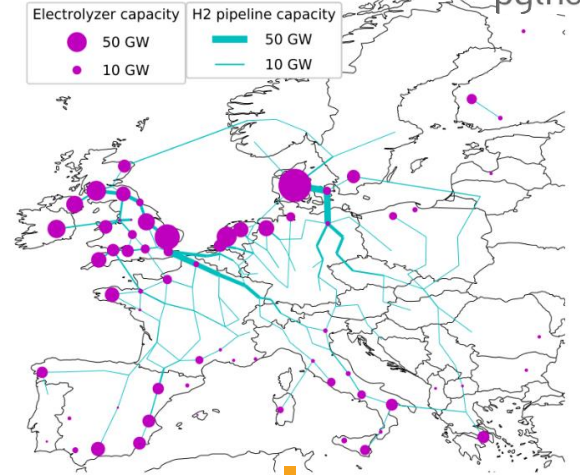
PyPSA-Africa & Co.



Built a model.
Release
Q4 2021

Used it & loved it

PyPSA-Eur



Created an
initiative



PyPSA
meets Africa

Why Open Source?

...Many ways to tweak models
& to introduce bugs.

- **Changing inputs.** Costs, weather years, resource potential, physics...
- **Changing methodologies.** Top-down vs bottom-up demand predictions...
- **Resolution.** Aggregation of space, time and technologies...
- **Changing constraints.** Interconnectability, regional energy independence...
- **Changing problem formulation.** Including flexibility of operation (UC), line losses, AC vs DC power flow formulation....

GO GREEN 
GO NUCLEAR



GO 100%
RENEWABLE ENERGY

GREEN
HYDROGEN
FUTURE

USE CASES & USERS



COAL-EXIT
PLANS



SUPPLY DIVERSI.
PLANS



ENERGY-
TRANSITION
PLANS



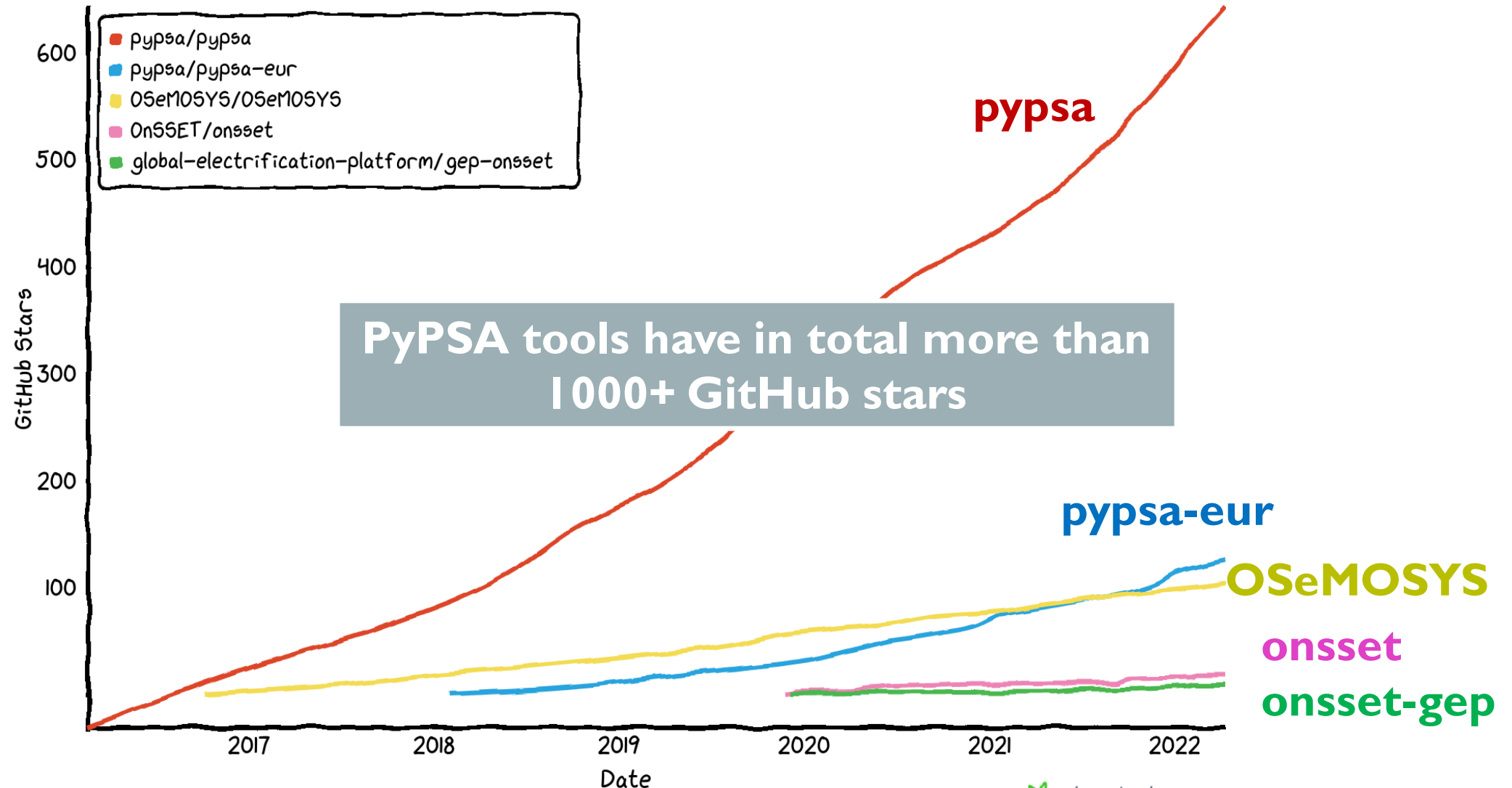
MINI-VS-
GRID
STUDIES

"Energiewende - Energy transition" by florianric is marked
with CC BY-SA 2.0.

"Hybrid solar PV diesel mini-grids for 32 villages in Mali, selected for
funding in the first cycle," by International Renewable Energy
Agency (IRENA) is licensed under [CC BY-NC-ND 2.0](#).

Is PyPSA popular?

GitHub stars – indicating the user popularity

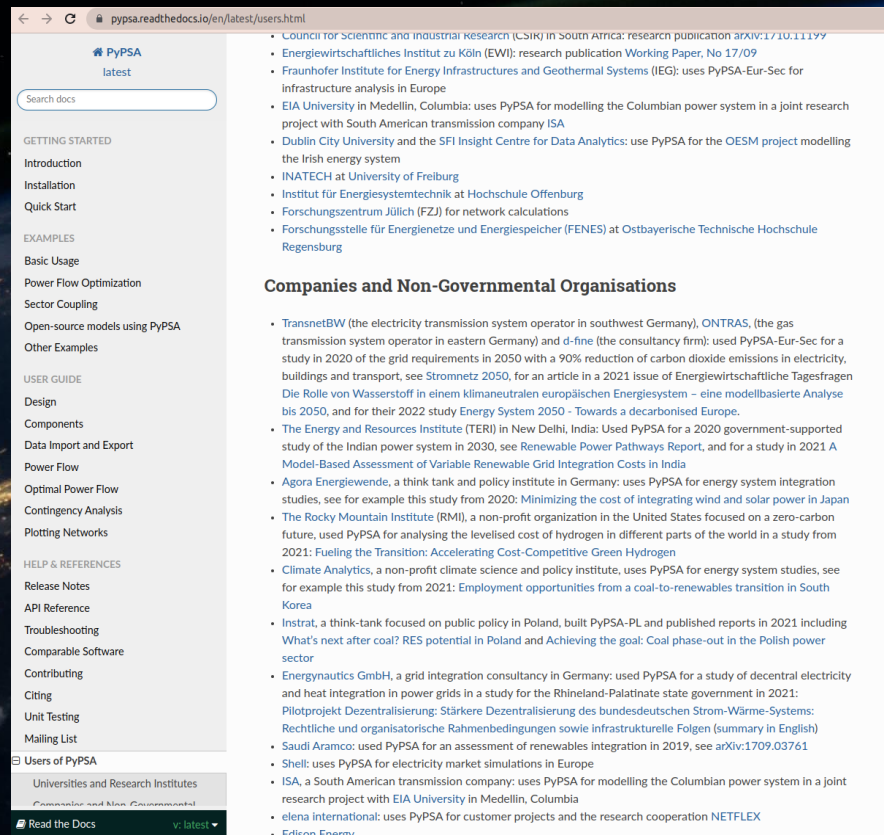


USE CASES & USERS

Extensive list of known users and more use cases:

<https://pypsa.readthedocs.io/en/latest/users.html>

A FEW USERS
ASSOCIATED TO:



The screenshot shows the PyPSA documentation website. The left sidebar contains a navigation menu with sections: GETTING STARTED (Introduction, Installation, Quick Start), EXAMPLES (Basic Usage, Power Flow Optimization, Sector Coupling, Open-source models using PyPSA, Other Examples), USER GUIDE (Design, Components, Data Import and Export, Power Flow, Optimal Power Flow, Contingency Analysis, Plotting Networks), and HELP & REFERENCES (Release Notes, API Reference, Troubleshooting, Comparable Software, Contributing, Citing, Unit Testing, Mailing List). Below the menu is a section for 'Users of PyPSA' with sub-sections for 'Universities and Research Institutes' and 'Companies and Non-Governmental Organisations'. The main content area lists various users and organizations, including the Council for Scientific and Industrial Research (CSIR) in South Africa, Energiewirtschaftliches Institut zu Köln (EWI), Fraunhofer Institute for Energy Infrastructures and Geothermal Systems (IEG), EIA University in Medellín, Columbia, Dublin City University, INATECH at University of Freiburg, Institut für Energiesystemtechnik at Hochschule Offenburg, Forschungszentrum Jülich (FZJ), and Forschungsstelle für Energienetze und Energiespeicher (FENES) at Ostbayerische Technische Hochschule Regensburg.

Companies and Non-Governmental Organisations

- TransnetBW (the electricity transmission system operator in southwest Germany), ONTRAS, (the gas transmission system operator in eastern Germany) and d-fine (the consultancy firm): used PyPSA-Eur-Sec for a study in 2020 of the grid requirements in 2050 with a 90% reduction of carbon dioxide emissions in electricity, buildings and transport, see Stromnetz 2050, for an article in a 2021 Issue of Energiewirtschaftliche Tagesfragen Die Rolle von Wasserstoff in einem klimaneutralen europäischen Energiesystem – eine modellbasierte Analyse bis 2050, and for their 2022 study Energy System 2050 - Towards a decarbonised Europe.
- The Energy and Resources Institute (TERI) in New Delhi, India: Used PyPSA for a 2020 government-supported study of the Indian power system in 2030, see Renewable Power Pathways Report, and for a study in 2021 A Model-Based Assessment of Variable Renewable Grid Integration Costs in India
- Agora Energiewende, a think tank and policy institute in Germany: uses PyPSA for energy system integration studies, see for example this study from 2020: Minimizing the cost of integrating wind and solar power in Japan
- The Rocky Mountain Institute (RMI), a non-profit organization in the United States focused on a zero-carbon future, used PyPSA for analysing the levelised cost of hydrogen in different parts of the world in a study from 2021: Fueling the Transition: Accelerating Cost-Competitive Green Hydrogen
- Climate Analytics, a non-profit climate science and policy institute, uses PyPSA for energy system studies, see for example this study from 2021: Employment opportunities from a coal-to-renewables transition in South Korea
- Instrat, a think-tank focused on public policy in Poland, built PyPSA-PL and published reports in 2021 including What's next after coal? RES potential in Poland and Achieving the goal: Coal phase-out in the Polish power sector
- Energynautics GmbH, a grid integration consultancy in Germany: used PyPSA for a study of decentral electricity and heat integration in power grids in a study for the Rhineland-Palatinate state government in 2021: Pilotprojekt Dezentralisierung: Stärkere Dezentralisierung des bundesdeutschen Strom-Wärme-Systems: Rechtliche und organisatorische Rahmenbedingungen sowie infrastrukturelle Folgen (summary in English)
- Saudi Aramco: used PyPSA for an assessment of renewables integration in 2019, see arXiv:1709.03761
- Shell: uses PyPSA for electricity market simulations in Europe
- ISA, a South American transmission company: uses PyPSA for modelling the Colombian power system in a joint research project with EIA University in Medellín, Columbia
- elena international: uses PyPSA for customer projects and the research cooperation NETFLEX
- Edison Energy



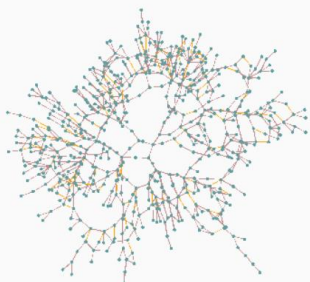
“PyPSA meets Earth's vision is to create together the most compelling open data and open source planning tool to accelerate the world's sustainable energy transition.”

PyPSA is a framework. We build tools on top. **MODEL = Data+Framework**



FRAMEWORK

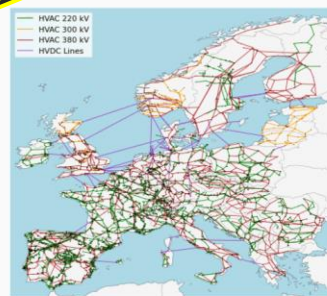
PyPSA



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

MODEL

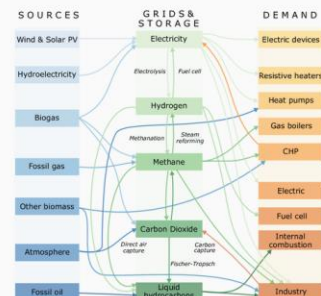
PyPSA-Eur



An open optimisation model of the European transmission system.

MODEL

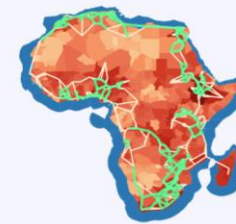
PyPSA-Eur-Sec



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

MODEL

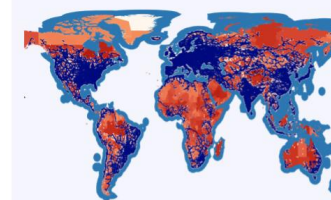
PyPSA-Africa



An open optimization model of the African transmission system

MODEL

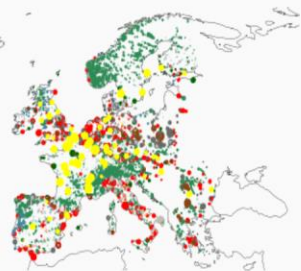
PyPSA-Earth



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

DATA

Powerplantmatching



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

DATA

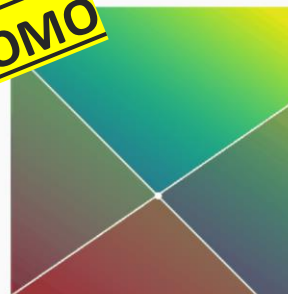
Atlite



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

BETTER PYOMO

Linopy



Linear optimization interface for N-D labeled variables.

DATA

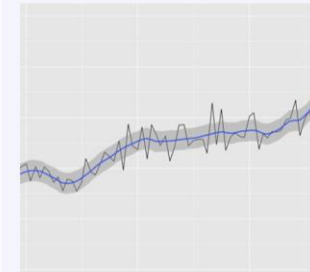
Detect-Energy



A machine learning framework to detect energy assets from satellites

DATA

Demand-Creator



A general framework to create demand timeseries in subnational resolution

WHAT IS PyPSA?

Purpose:

- A tool that can do both **economic analysis** and **grid analysis (load flow studies)**
- Developed for **large scale optimization** and
- Studies in **high spatial resolution**

		Grid Analysis						Economic Analysis								
		Software	Version	Citation	Free Software	Power Flow	Continuation Power Flow	Dynamic Analysis	Transport Model	Linear OPF	SCLOPF	Nonlinear OPF	Multi-Period Optimisation	Unit Commitment	Investment Optimisation	Other Energy Sectors
Power system tools	MATPOWER	6.0	[6]	✓	✓	✓			✓	✓		✓				
	NEPLAN	5.5.8	[2]		✓			✓	✓	✓	✓	✓				✓
	pandapower	1.4.0	[9]	✓	✓				✓	✓		✓				
	PowerFactory	2017	[1]		✓			✓		✓	✓	✓				
	PowerWorld	19	[3]		✓			✓	✓	✓	✓	✓				
	PSAT	2.1.10	[7]	✓	✓	✓		✓	✓		✓	✓	✓	✓		
	PSS/E	33.10	[4]		✓			✓	✓	✓	✓	✓				
	PSS/SINCAL	13.5	[5]		✓			✓				✓				✓
	PYPOWER	5.1.2	[8]	✓	✓				✓	✓		✓				
	PyPSA	0.11.0		✓	✓				✓	✓	✓		✓	✓	✓	✓
Energy system tools	calliope	0.5.2	[11]	✓					✓				✓		✓	✓
	minpower	4.3.10	[12]	✓					✓	✓			✓	✓		
	MOST	6.0	[13]	✓	✓	✓			✓	✓	✓	✓	✓	✓		
	oemof	0.1.4	[14]	✓					✓				✓	✓	✓	✓
	OSeMOSYS	2017	[15]	✓					✓				✓		✓	✓
	PLEXOS	7.400	[16]						✓	✓	✓		✓	✓	✓	✓
	PowerGAMA	1.1	[17]	✓					✓	✓			✓			
	PRIMES	2017	[18]						✓	✓			✓	✓	✓	✓
	TIMES	2017	[19]						✓	✓			✓	✓	✓	✓
	urbs	0.7	[20]	✓					✓				✓	✓	✓	✓

Classical models. 1 or slightly more aggregation nodes per county

This map illustrates the distribution of aggregation nodes for classical models in Texas, where there is 1 or slightly more node per county. A large red circle is positioned in the center of the state. Orange 'X' marks are located on the northern border. Blue dots are concentrated in the southern tip, with a few purple dots scattered nearby.

PyPSA models. Up to 1000 nodes per region of interest fetched automatically. (resolution limits are improving continuously)

REPUBLIC OF BENIN

REPUBLIC OF CAMEROON

ATLANTIC OCEAN

NOTE: IPP Plants are in RED text

HOW DO WE DESIGN OUR DATABASE ?



HOW DO WE DESIGN OUR DATABASE ?

**(WE DON'T HAVE ONE
FOR EVERYTHING)**

1. Provide data extraction scripts for primary open databases

e.g. OpenStreetMap, Era-5 (environment+weather)

- By default global & GIS-based
- Do you have better local country data? Contributions are welcome. Be a part of our community.

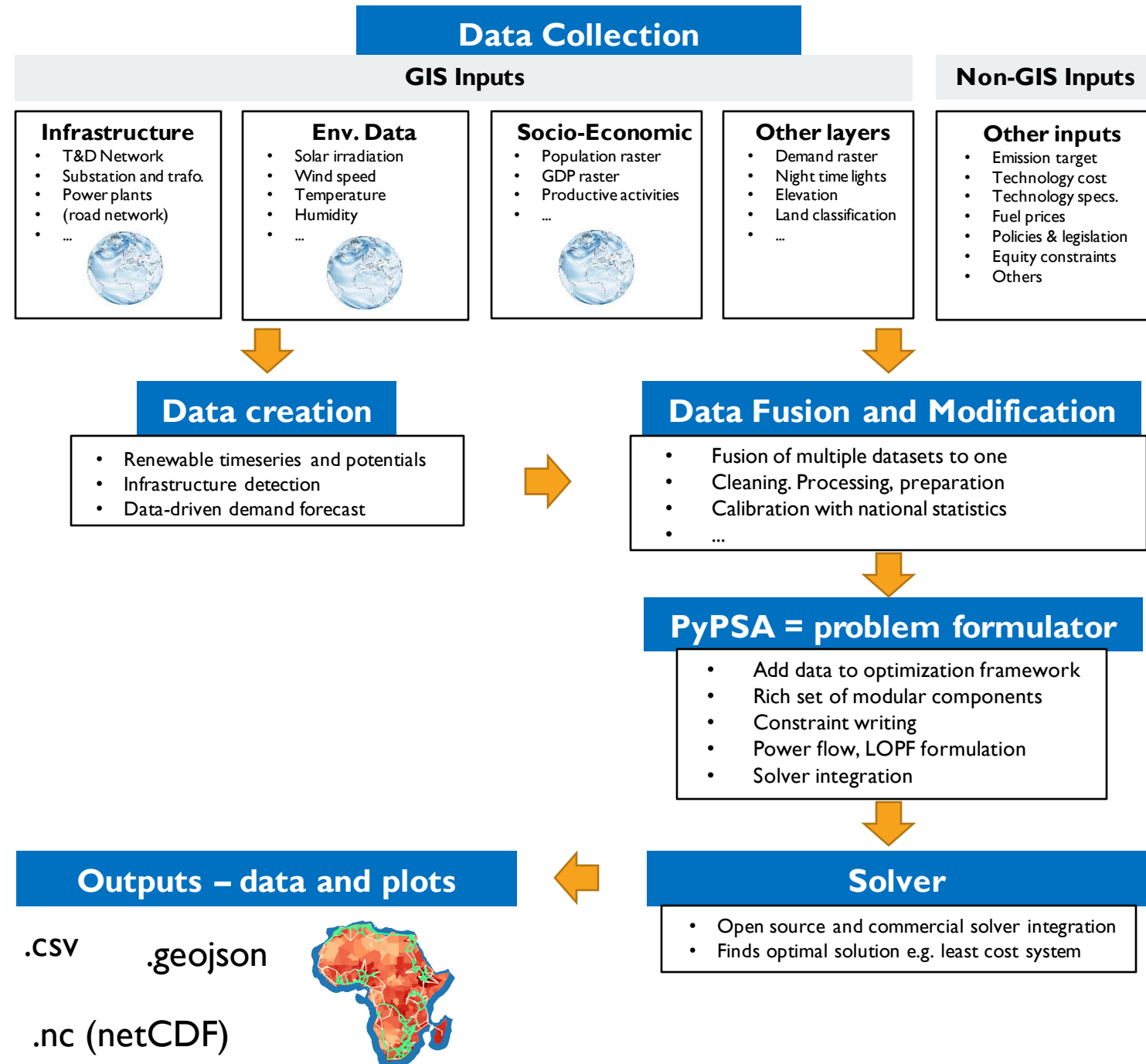
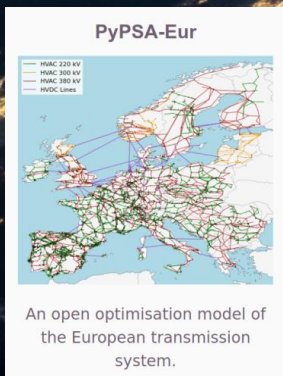
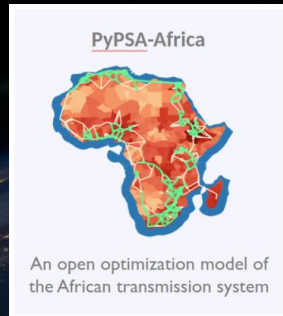
2. Provide data manipulation scripts

e.g. to convert wind speed (m/s) to wind power (MW) or building meshed OpenStreetMap network

3. Provide data validation scripts

e.g. compare results to research or institutional studies (IRENA etc.)

Example of automated workflow I/O



Example of automated workflow

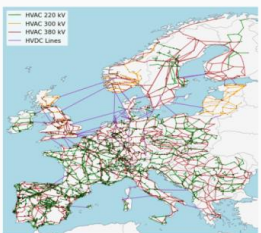
I/O

PyPSA-Africa

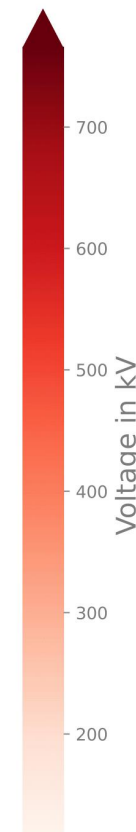
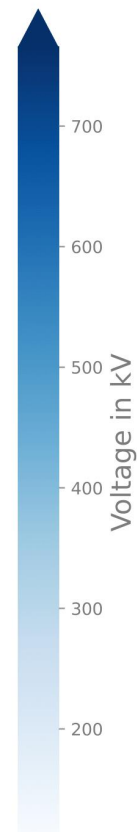


An open optimization model of
the African transmission system

PyPSA-Eur

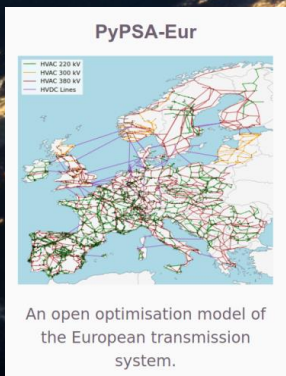
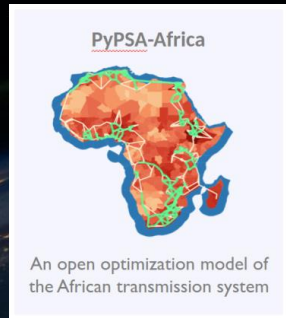


An open optimisation model of
the European transmission
system.



Example of automated workflow

I/O



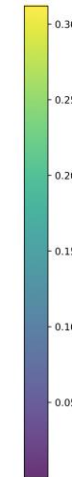
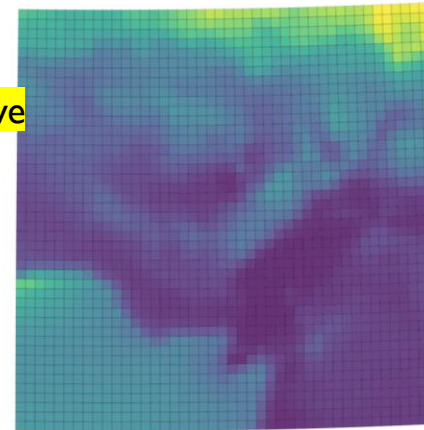
20x20km resolution
Wind speed



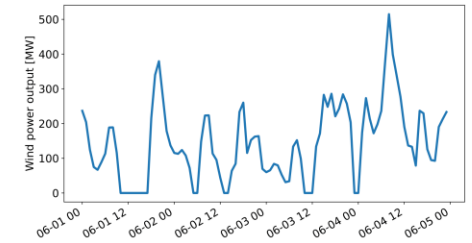
Power curve



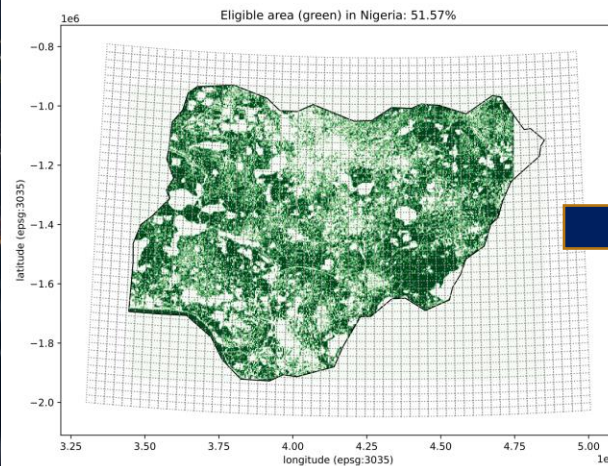
20x20km resolution
Capacity factor calc. from
[pu] timeseries



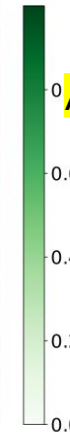
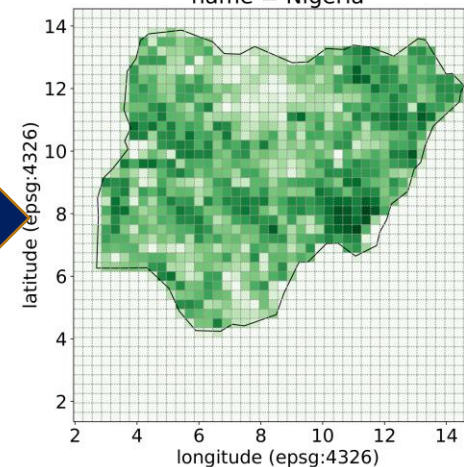
Technical available wind
potential per cell



100x100m resolution.
Eligible area for wind



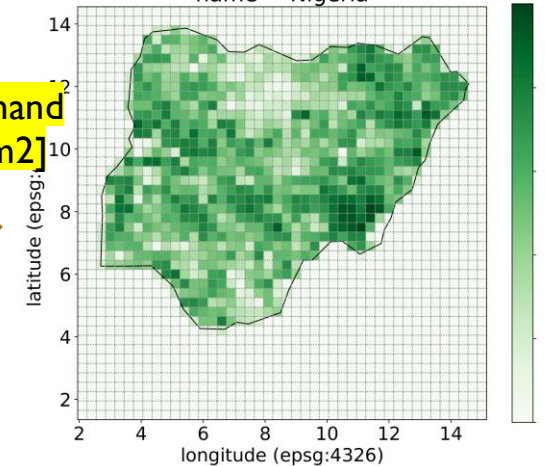
20x20km resolution
Downsampled
name = Nigeria



Area demand
[MW/km2]



20x20km resolution
Installable capacity [MW]
name = Nigeria



WHY THIS STRUGGLE? WHY NOT PROVIDING MODEL-READY DATA?



Photo by [christopher lemercier](https://unsplash.com/photos/I2yvdCiLaVE) <https://unsplash.com/photos/I2yvdCiLaVE>



WHY THIS STRUGGLE?

WHY NOT PROVIDING MODEL-READY DATA?

Data creation, manipulation and validation:

- **needs to be transparent**
- **needs to be reproducible**
- **needs to be editable**

**... because big risk of cheating or mistakes.
We also want to continuously improve.**

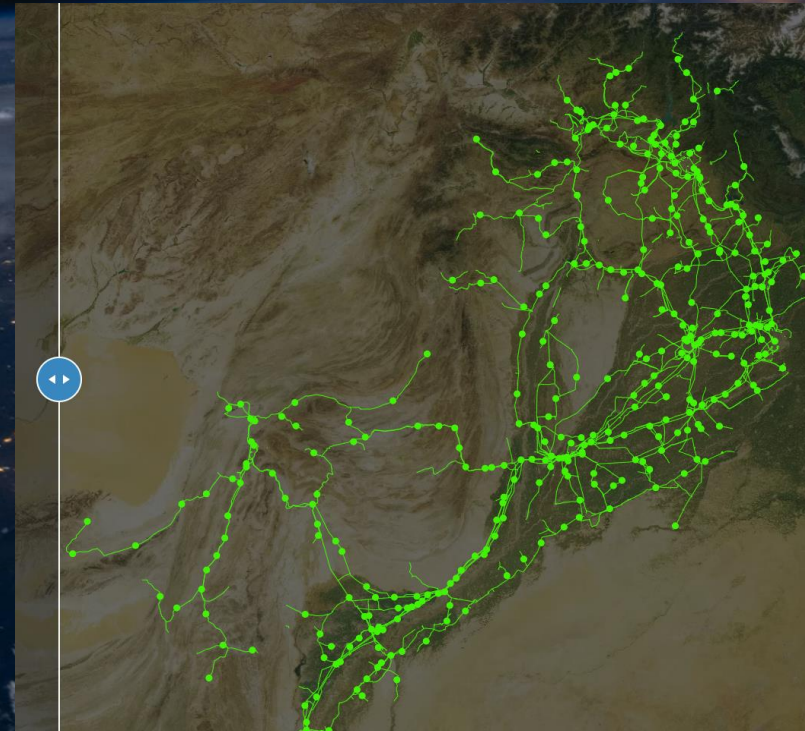
WHAT ABOUT REMOTE SENSING ?

Infrastructure detection:

Before



After



<http://devseed.com/ml-grid-docs/results/mapping-output-and-speed/>



NEW:

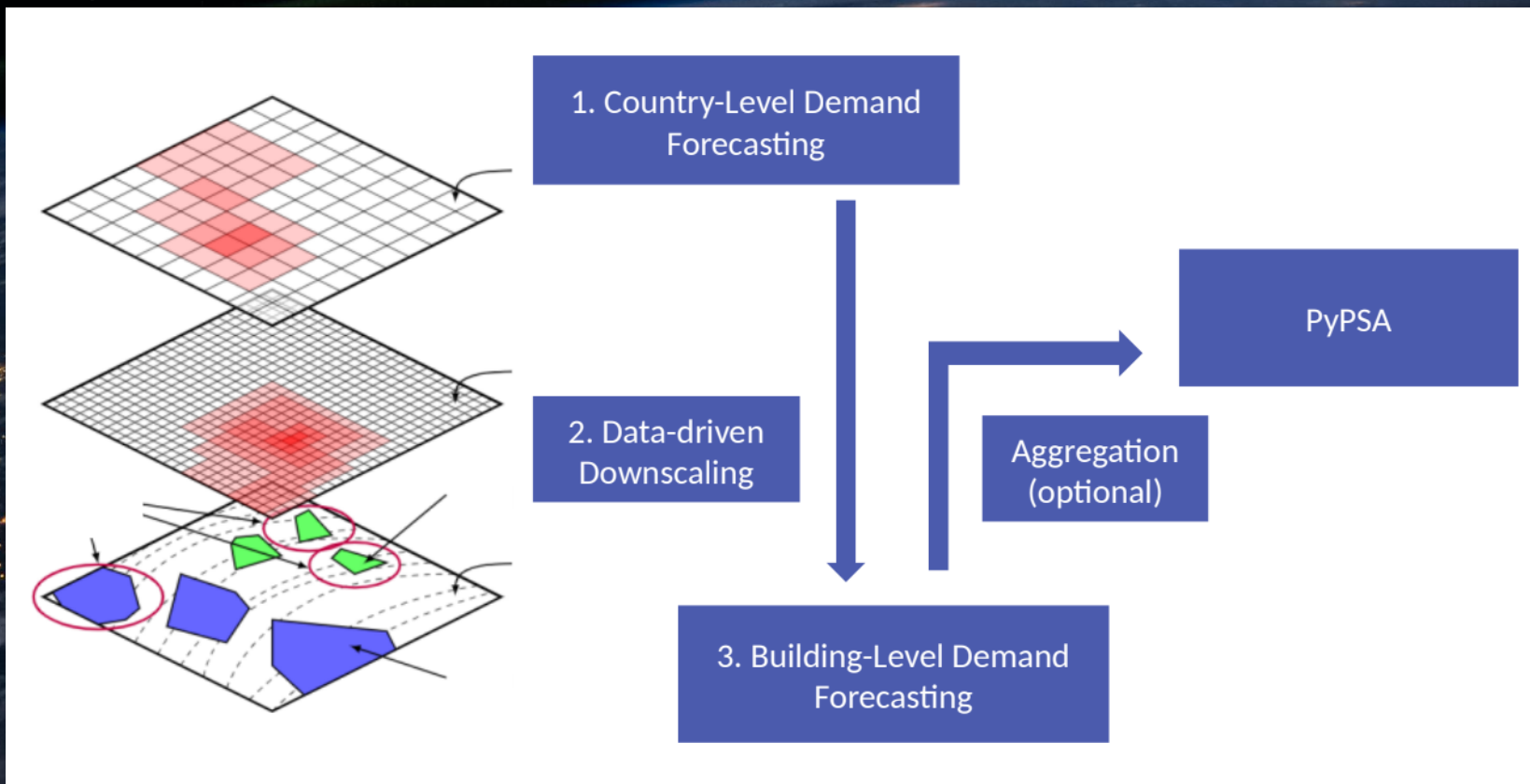
1. Cycle-GAN to
use multiple data sources



2. Reproduceable workflow
to **detect infrastructure**
across the world

Demand forecasts:

VISION: high-resolution demand data around the world



An aerial photograph of a winding asphalt road through a dense green forest. The road has several sharp turns and is surrounded by lush vegetation. A semi-transparent blue horizontal band is overlaid across the middle of the image, containing the text "WHAT'S NEXT?".

WHAT'S NEXT ?

OPEN Global Independent Research Initiative



SOLVER

Help
sustaining

Support
developers

Reveal
bottlenecks

Initiate new
paths

ENERGY SYSTEM MODELS

Features

High resolution

performant

Problem
formulator

Modular

DATA

Creating open
data

Predicting
data

Data
workflow

High
resolution

USER AND DEVELOPER COMMUNITY

Open

Collaborative

Training

Empower

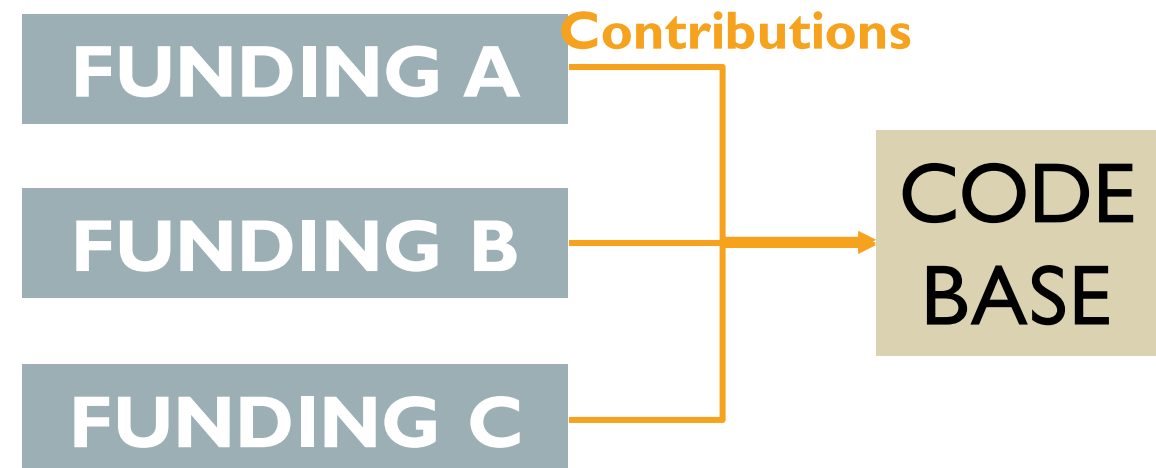
Dialogue

WORK TOGETHER



"I Found The Sun Under The Umbrella" by [Ariza](#) is licensed under [CC BY 2.0](#)

WHAT WE WANT



PyPSA-EARTH

- 1 MODEL 1 EARTH COMMUNITY -

"Provide an alternative to commercial tools such as PLEXOS and alike"

"Model your province, your country, your continent or the whole planet in one model"

"Accelerate innovation/time, support quality, make meaningful impact"

TEAM

Professors

Professional

Researchers

PhD students

Undergrads...



JOIN?

LEAD

IMPROVE

PARTICIPATE

USE

UNDERSTAND

Open Community!

PyPSA-Earth 0/2 Boosts >

- Events
- general** + ⚙
- # moderator-only
- # moderator-exchange
- + CO-WORKING SPACE +
- # MARIE-CURIE
- # TESLA
- # EDISON
- The PyPSA-Earth Stage
 - 1 listening
- + MEETING ROOMS +
- # EINSTEIN
- # NEWTON
- # MAXWELL
- + COMMUNITY +
- # -discussion
- # -news
- # -funding
- # -github
- # -help
- # papers

general The purpose of this channel is to provide guidance on how to use the PyPSA-Earth discord server.

PyPSA-Earth

This is the beginning of this server.

November 20, 2021

MaxParzen 11/20/2021
Please read this first.

Welcome to our PyPSA-Earth discord server - *A platform where we exchange, team up and organize to create energy system planning tools for our planet.* If you are wondering why it is PyPSA-Earth and not PyPSA-meets-Africa, than you probably just found out that we are not only aim to empower Africa. The problem of poor energy planning is a global issue. Together with people around the world we are building open source tools that are scalable, detailed and inclusive. #PyPSA-Earth

Be careful. Some content ins better suited at other places:

- Ask *usability questions* please on: <https://stackoverflow.com/questions/ask> and share in #deleted-channel a link to it
- Report *bugs* or *feature request*, please on: <https://github.com/pypsa-meets-africa/pypsa-africa> as issue

Do.

- Exchange in any of the text channels
- Join voice channels for "co-hacking", meetings or similar

Useful links:

- Our website: <https://pypsa-meets-africa.github.io/>
- PyPSA-meets-Africa Documentations <https://pypsa-meets-africa.readthedocs.io/en/latest/index.html>
- GitHub repository: <https://github.com/pypsa-meets-africa/pypsa-africa>
- Google drive (invitation necessary): <https://drive.google.com/drive/folders/13Z8Y9zgsh5IZaDNkkRyo1wkoMgbdUxT5?usp=sharing>
- LinkedIn: <https://www.linkedin.com/company/pypsa-meets-africa>
- Youtube: <https://www.youtube.com/channel/UCKKnlgWikF3hg4rwwucsQTA>
- Meeting agenda and links <https://github.com/pypsa-meets-africa/pypsa-africa#get-involved> (edited)

November 23, 2021

★ **MaxParzen** pinned a message to this channel. See all **pinned messages**. 11/23/2021

MODERATION — 4

- davidsf
- Lukas Franken
- MaxParzen
- YoTwo

ONLINE — 12

- cesacap
- eyorat
- fabianhofmann
- fneum
- gecki
- hazem
- Iclal Cetin Tas
- Koen
- Leon S
- meki21
- Sir-Wentemi
- Tony Tuo, ZHANG

LET'S OPEN UP THE BLACK BOX

+ MAKE THE "OPEN BOX" THE STANDARD





MAXIMILIAN PARZEN

Co-steering the PyPSA meets Earth initiative

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+49 176 70889068

Contact:



<https://pypsa-meets-africa.github.io/>



max.parzen@ed.ac.uk

OPEN Global Independent Research Initiative



SOLVER

**ENERGY
SYSTEM
MODELS**

DATA

**USER AND
DEVELOPER
COMMUNITY**

APPENDIX

DONATE NOW.
WE RAISE 100+k
FOR DEVELOPING
10-100x FASTER OPEN-
SOURCE SOLVER

DETAILED PROPOSAL*:

<https://pypsa-meets-africa.github.io/highs.html>

*In collaboration with University of Edinburgh,
TU Berlin and Princeton University

OPEN ENERGY SYSTEM PLANNING



#SUPPORT #HiGHS
TO INCREASE ACCESSIBILITY

- **Investment and dispatch optimization for multiple-horizons**
- **Powerflow optimization** (e.g. AC powerflow, security constrained LOPF, DCOPF)
- **Data-driven constraint formulation** (e.g. renewable potentials, protected areas, climate-change impacts)
- **Machine learning** (Object detection with transfer learning, super resolution, Time-series prediction with DeepML, Bayesian inference for demand prediction..)
- **Graph theory** (for spatial clustering and graph expansion e.g. k-means, steiner-tree, minimum spanning tree,...)
- **Statistics** (e.g. data-driven disaggregation, demand predictions)
- **Parallel and cloud computing** (dask and xarray)
- **Workflow management system** (snakemake for reproducibility and ease of use)

For Energy Model:

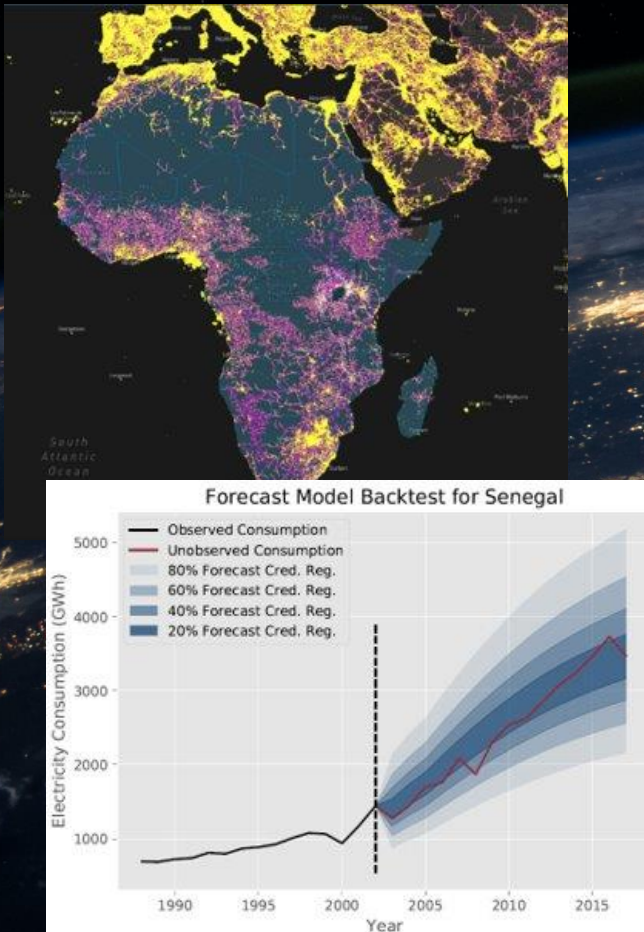
- Powerflow optimization tested against PyPOWER/MATPOWER and pandapower
- Comparison to public accessible stats and reports (e.g. IRENA on existing renewables)
- Comparison to other commercial models (e.g. provide same results as PLEXOS)

For Machine Learning:

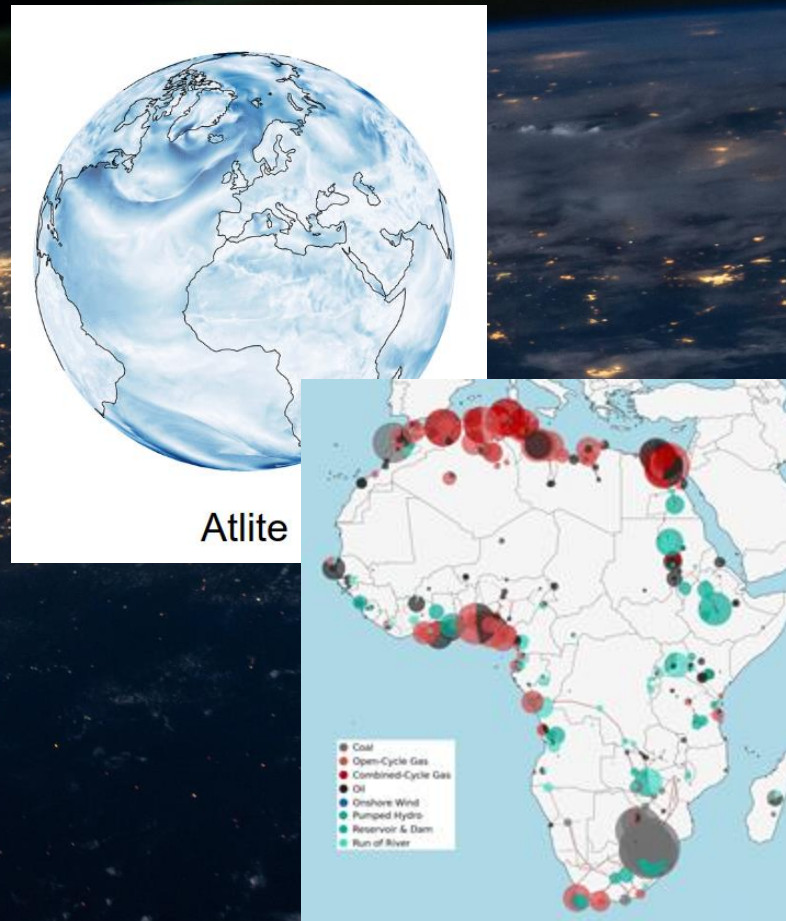
- Back-testing of historic data
- Validation data from manual validation (e.g. satellite detected images) or existing data (e.g. smart meter data)

USE EXISTING DATA TO PLAN THE FUTURE

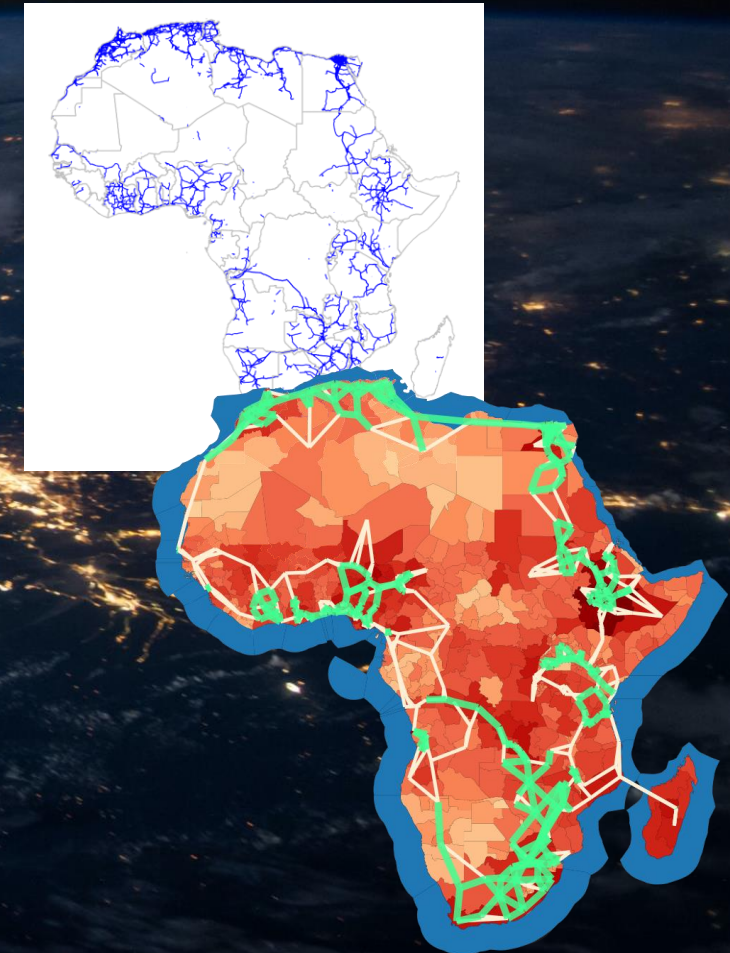
DEMAND

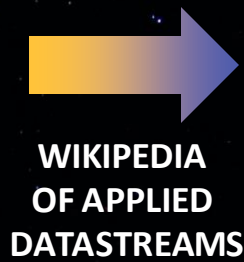


SUPPLY

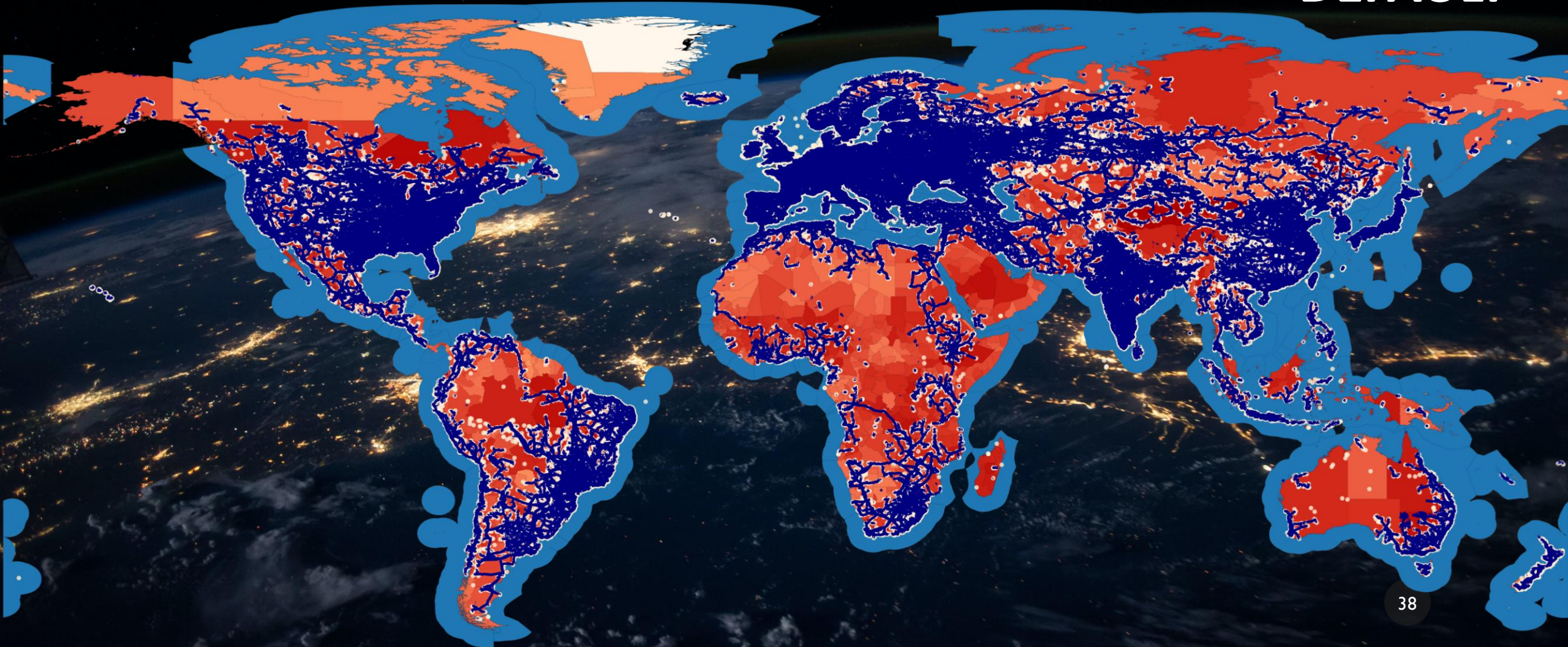


NETWORK





GLOBAL
DATA BY
DEFAULT



WHAT IF YOU ARE MISSING DATA?

I.
**INFRASTRUCTURE
DETECTION**



II.
**DEMAND
PREDICTION**

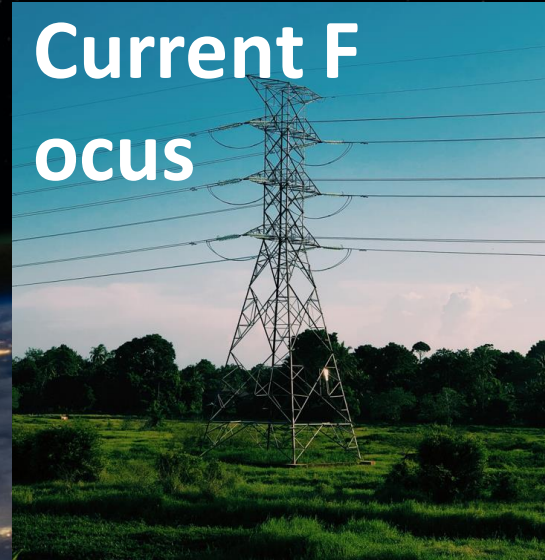
Before



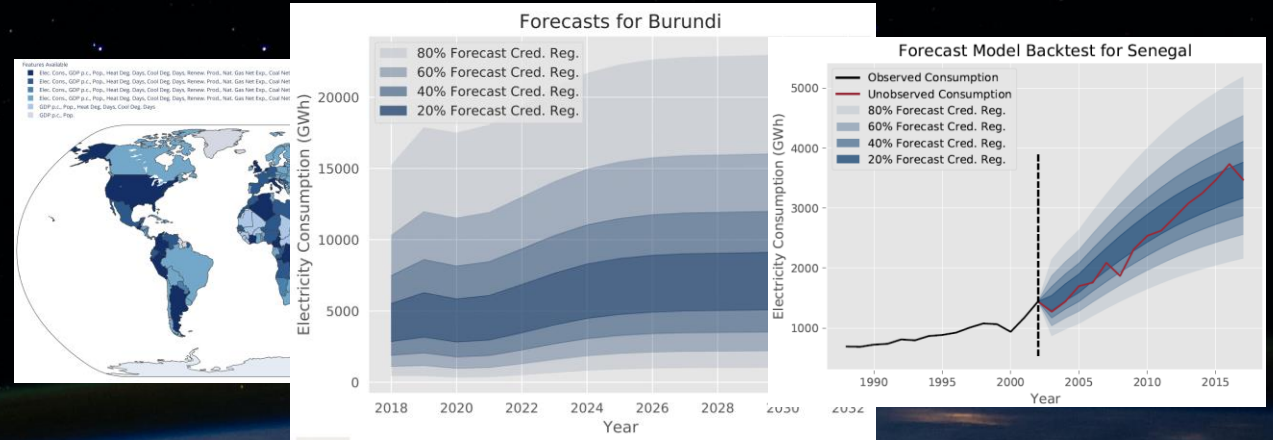
After



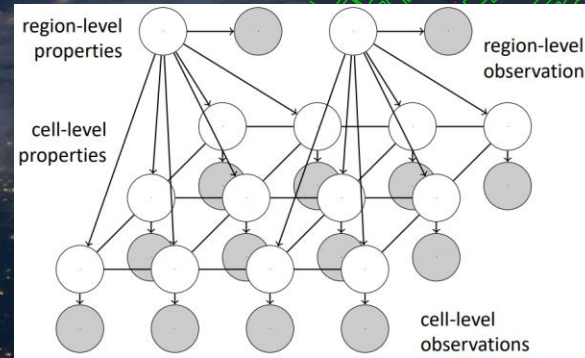
**Current F
ocus**



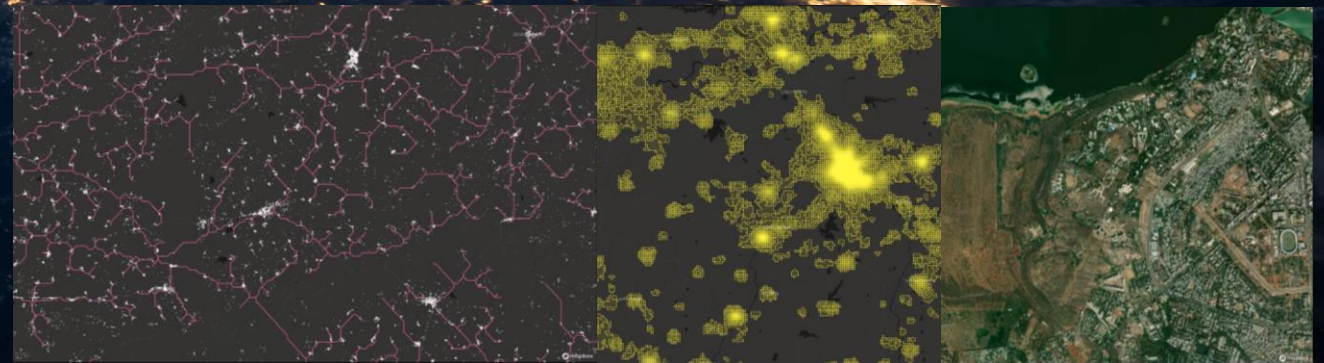
1. Country-Level Demand Forecasting via Bayesian Deep Learning and Others



2. Downscaling via Economics-Informed Probabilistic Models and Others

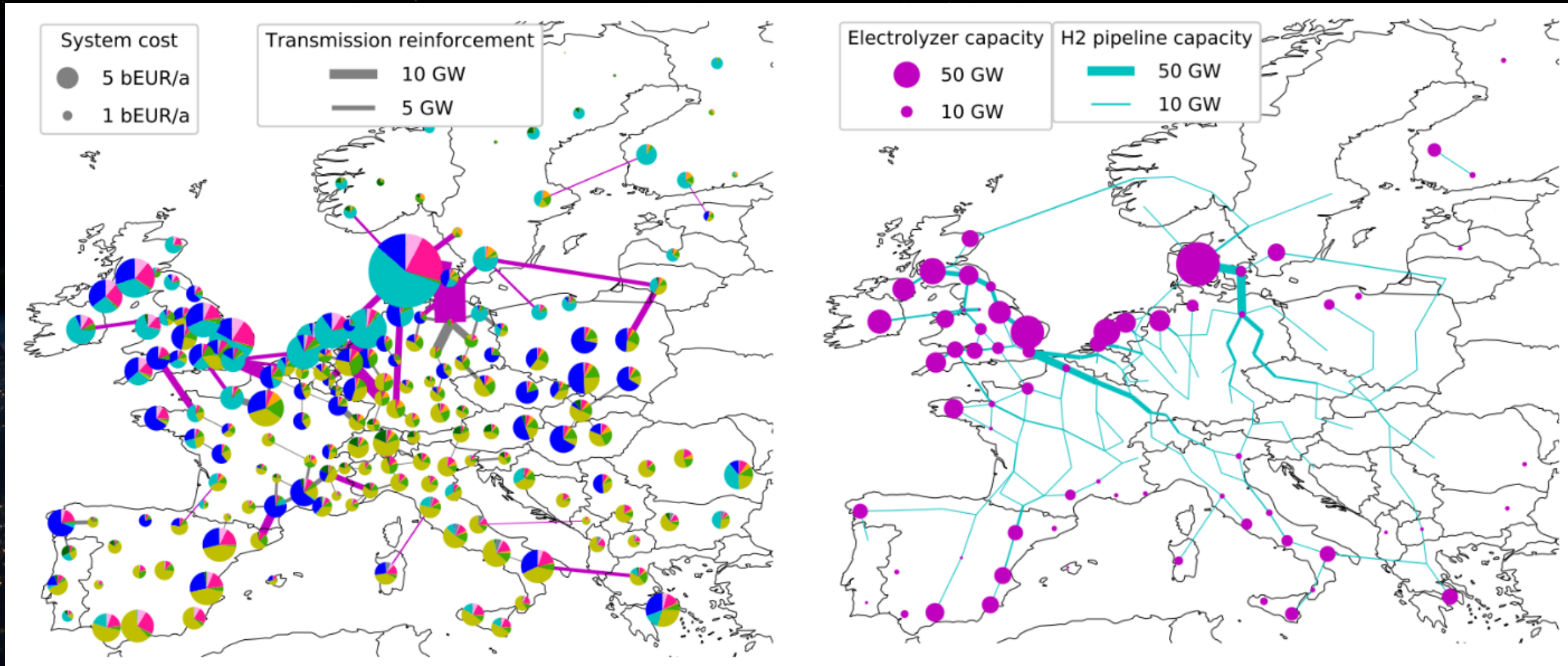


3. Building-Level Demand Forecasting via Bayesian Deep Learning and Others

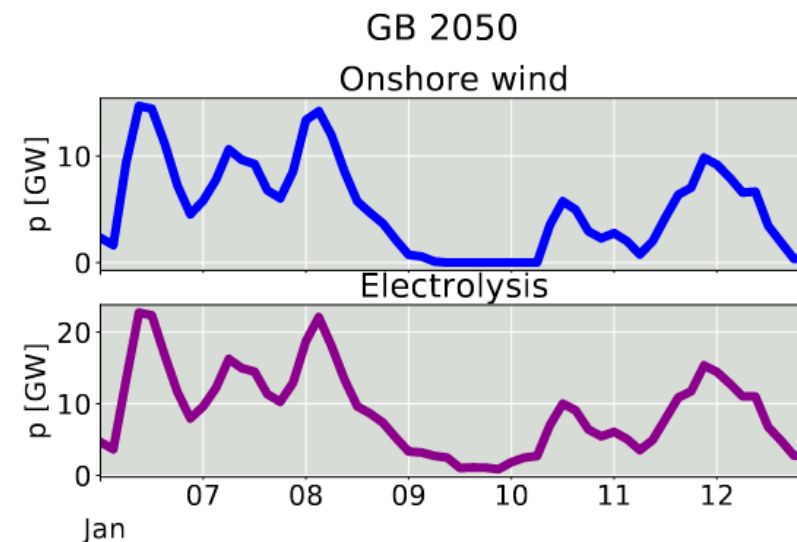
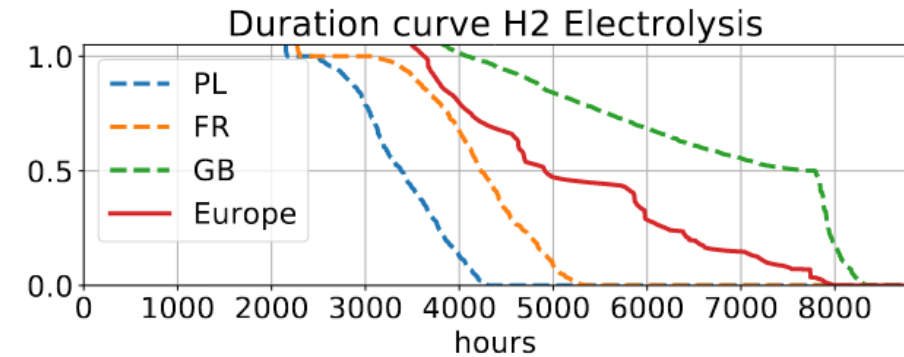
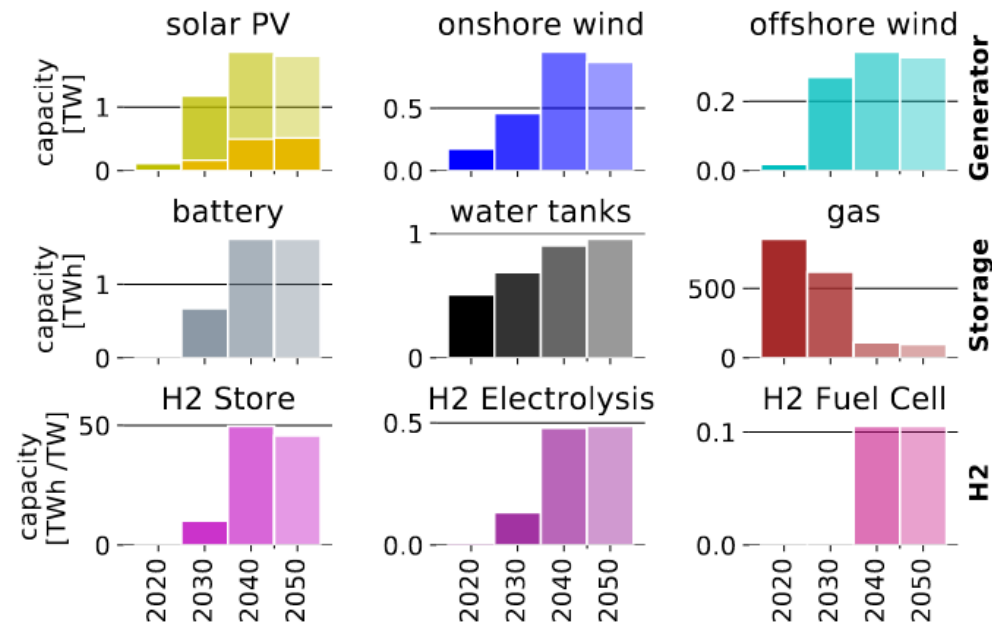


HYDROGEN AND GIS

EXAMPLE OUTPUT: INVESTMENTS FOR 2050 NET ZERO SCENARIOS

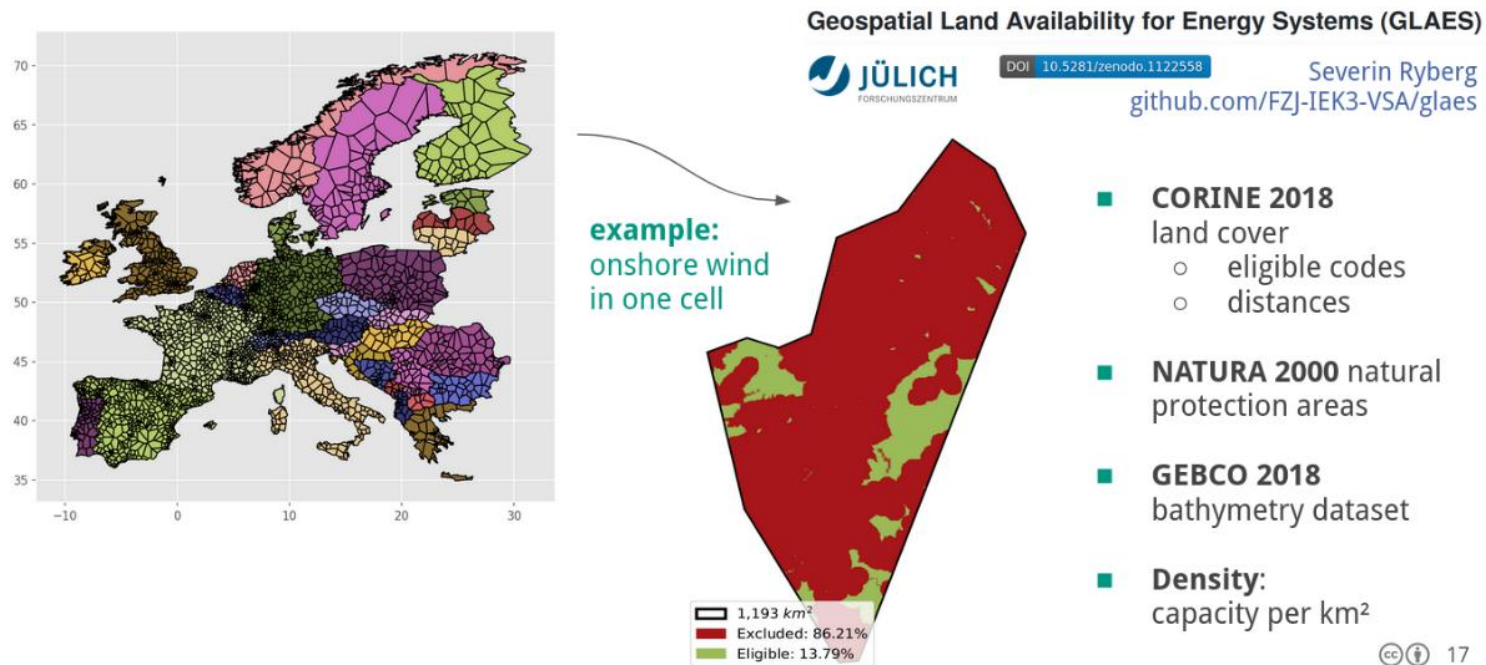


EXAMPLE OUTPUT: INVESTMENTS + OPERATION FOR 2050 NET ZERO SCENARIOS



EXAMPLE OUTPUT: INVESTMENTS + OPERATION FOR 2050 NET ZERO SCENARIOS

Installable Potential and Land Eligibility



5 ACTIVE TEAMS

ATM PYPSA-EARTH
Africa, North Asia, West-Asia
(POWER)

OUTREACH

PYPSA-EARTH-SEC
(SECTOR-COUPLED)

DEMAND
PREDICTION

INFRASTRUCTURE
DETECTION

PYPSA-MINIGRID