

ICTP Summer School

"PyPSA Database & Remote Sensing"



02.06.2022, Maximilian Parzen

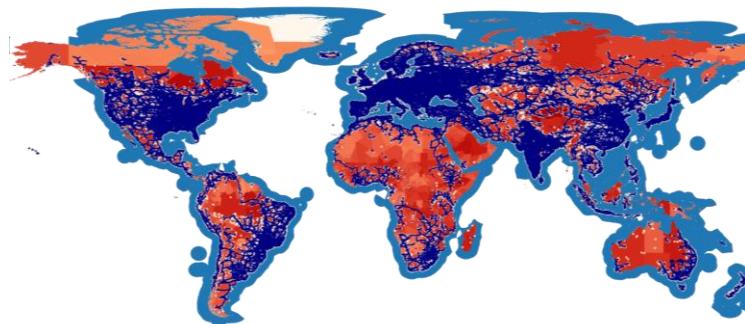


WHO IS MAX?

Bored PhD student
Winter 20/21

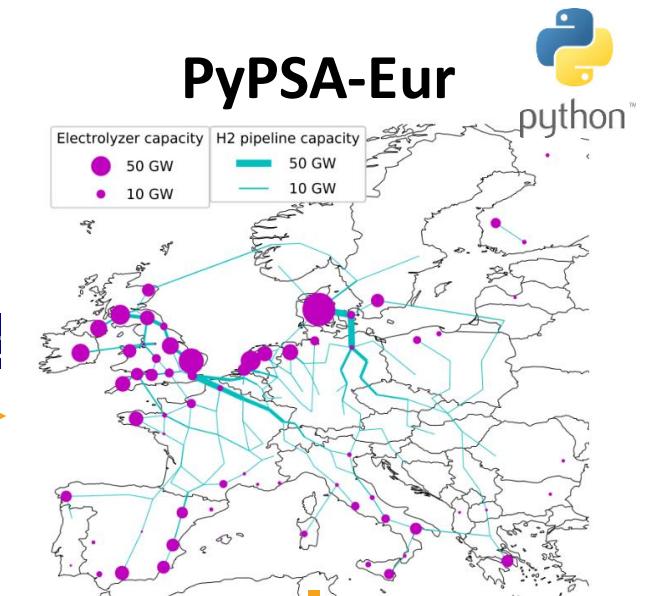


PyPSA-Earth & Co.



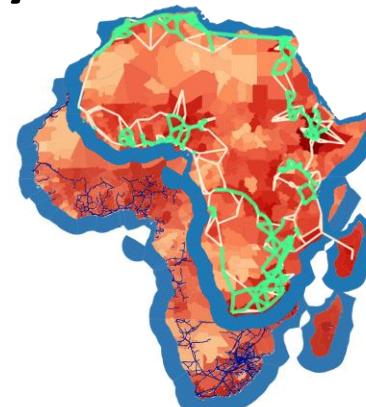
Started activities
on global scale

Used it & loved it



Created an
initiative

PyPSA-Africa & Co.



Extended the
initiative

Built a model.
Release
Q4 2021



PyPSA
meets Earth

PyPSA
meets Africa

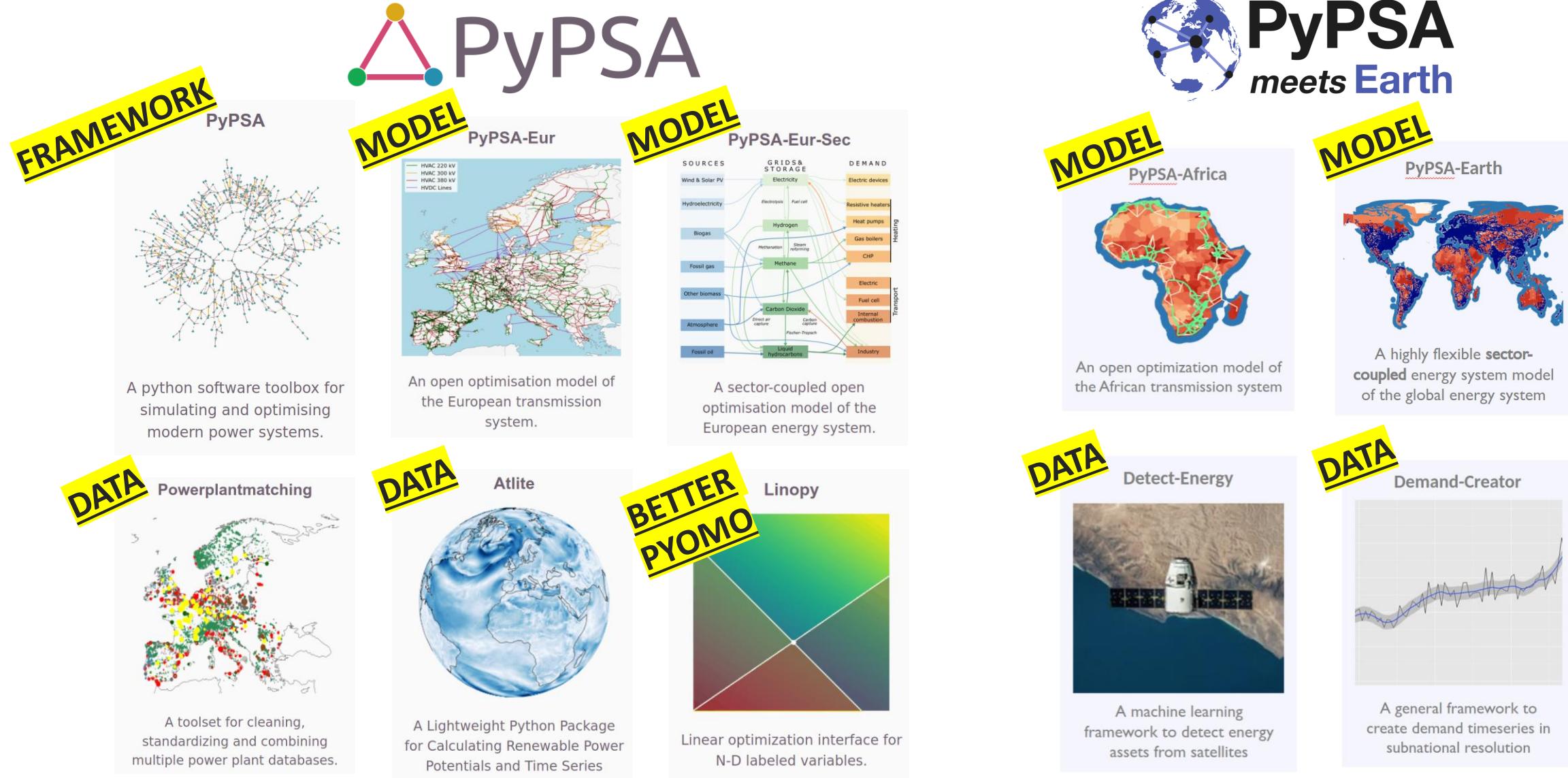




“PyPSA meets Earth’s vision is to create together the most compelling open data and open source planning tool to accelerate the world’s sustainable energy transition.”

PyPSA is a framework. We build tools on top.

MODEL = Data+Framework



WHAT IS PyPSA?

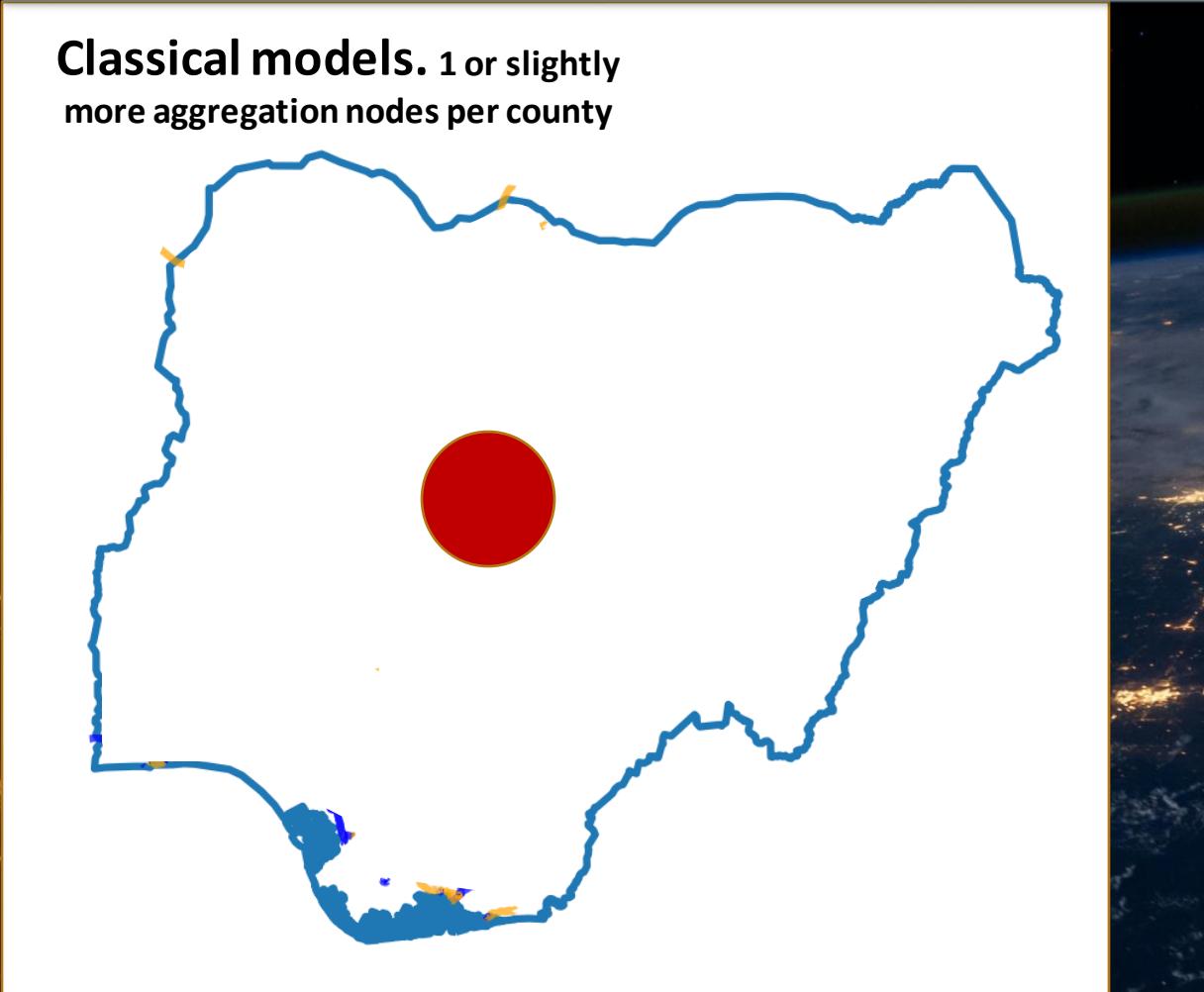
Purpose:

- 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**

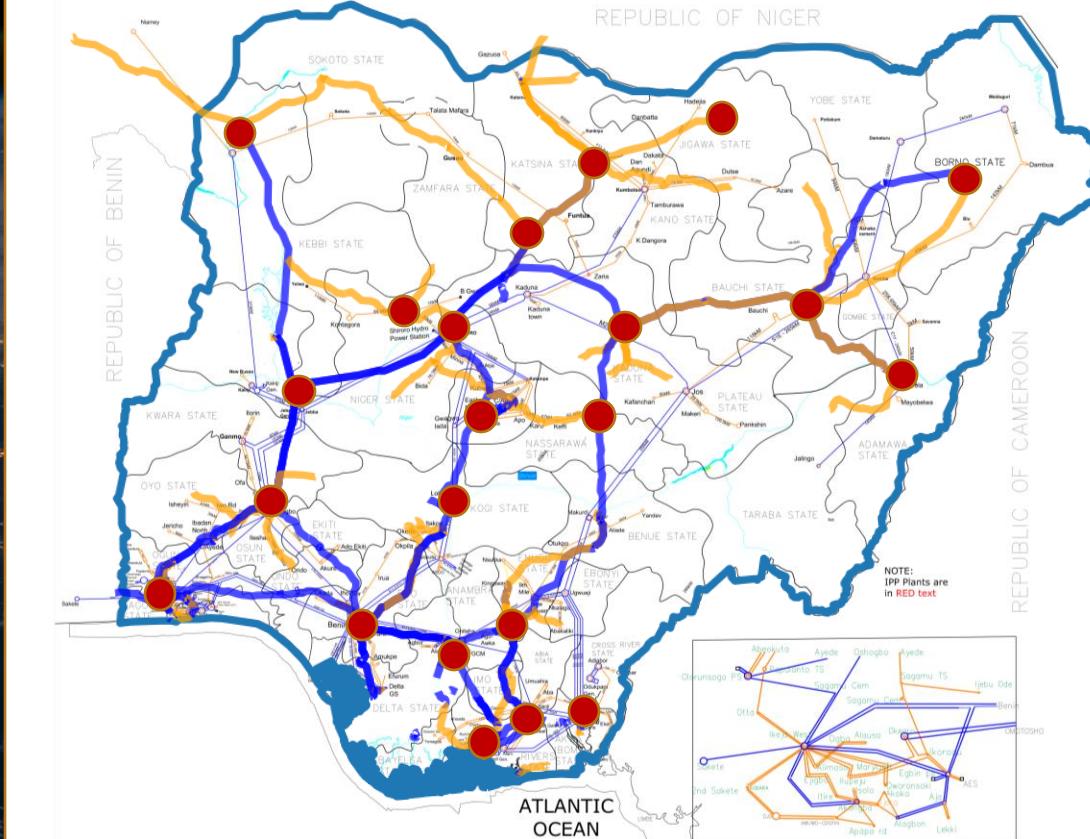
Software	Version	Citation	Free Software	Grid Analysis			Economic Analysis				
				Power Flow	Continuation Power Flow	Dynamic Analysis	Transport Model	Linear OPF	SCLOPF	Nonlinear OPF	Multi-Period Optimisation
MATPOWER	6.0	[6]	✓	✓	✓	✓	✓	✓	✓	✓	✓
NEPLAN	5.5.8	[2]	✓	✓	✓	✓	✓	✓	✓	✓	✓
pandapower	1.4.0	[9]	✓	✓	✓	✓	✓	✓	✓	✓	✓
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		✓	✓		✓	✓	✓	✓	✓	✓
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]	✓			✓			✓	✓	✓

THE SPATIAL RESOLUTION IN ENERGY PLANNING STUDIES

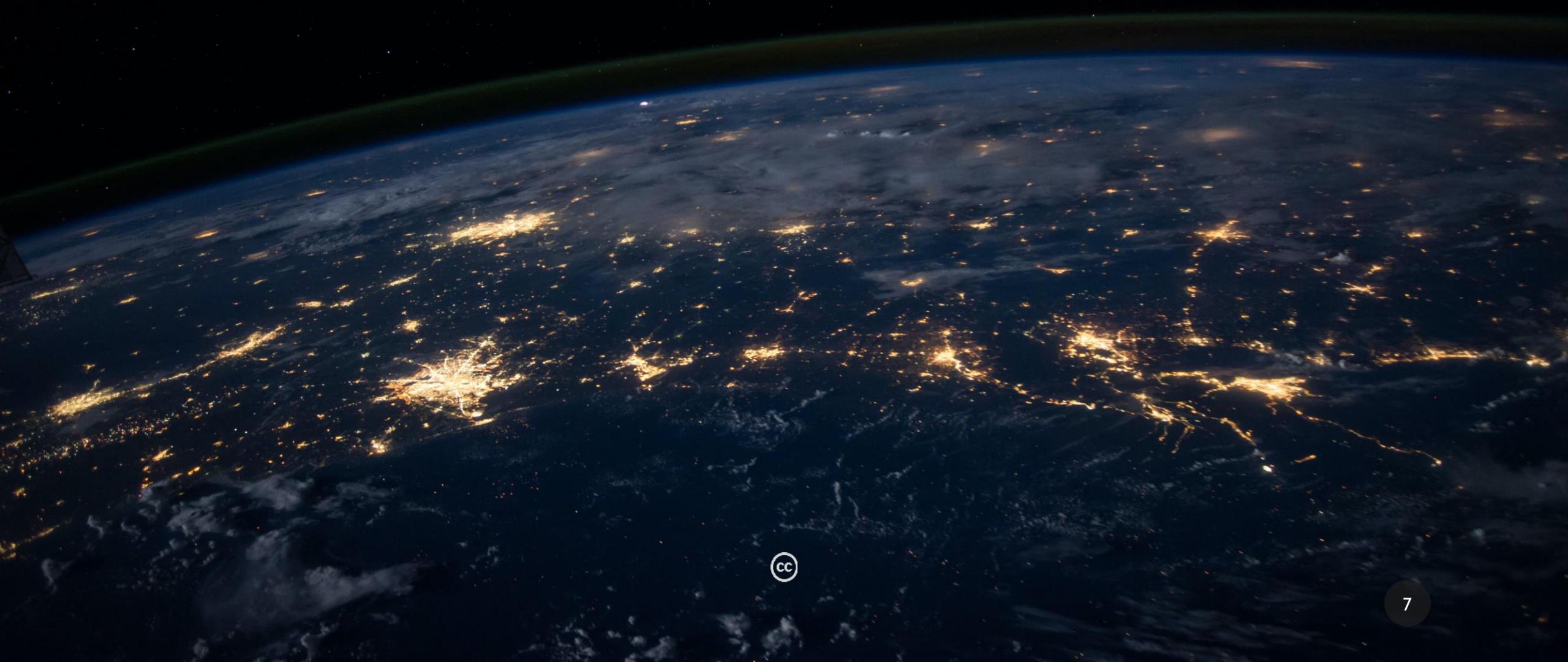
Classical models. 1 or slightly more aggregation nodes per county



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



HOW DO WE DESIGN OUR DATABASE ?



HOW DO WE DESIGN OUR DATABASE ?

(WE DON'T HAVE ONE
FOR EVERYTHING)

I. Provide data extraction scripts for primary open databases

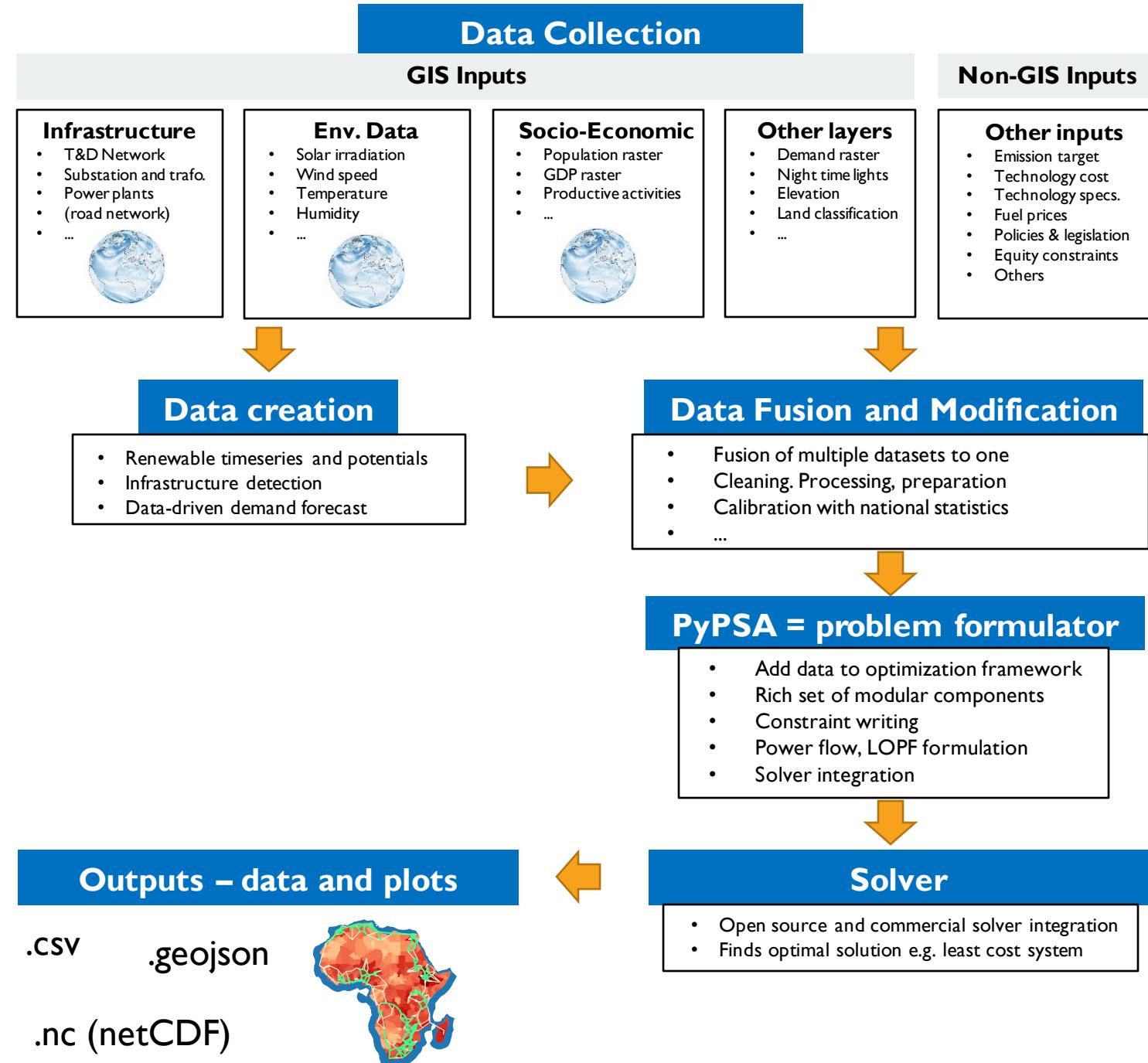
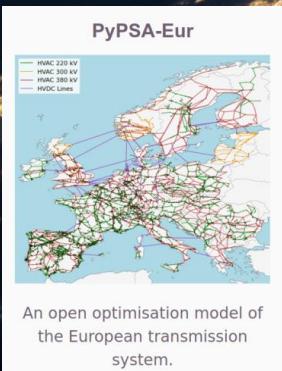
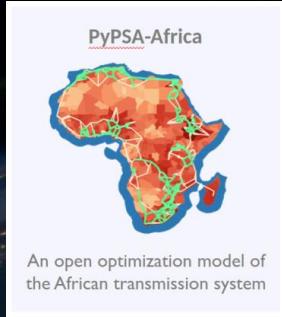
e.g. OpenStreetMap, Era-5 (environment+weather)

- By default global & GIS-based
- Do you have better local country data? Contribution welcome!

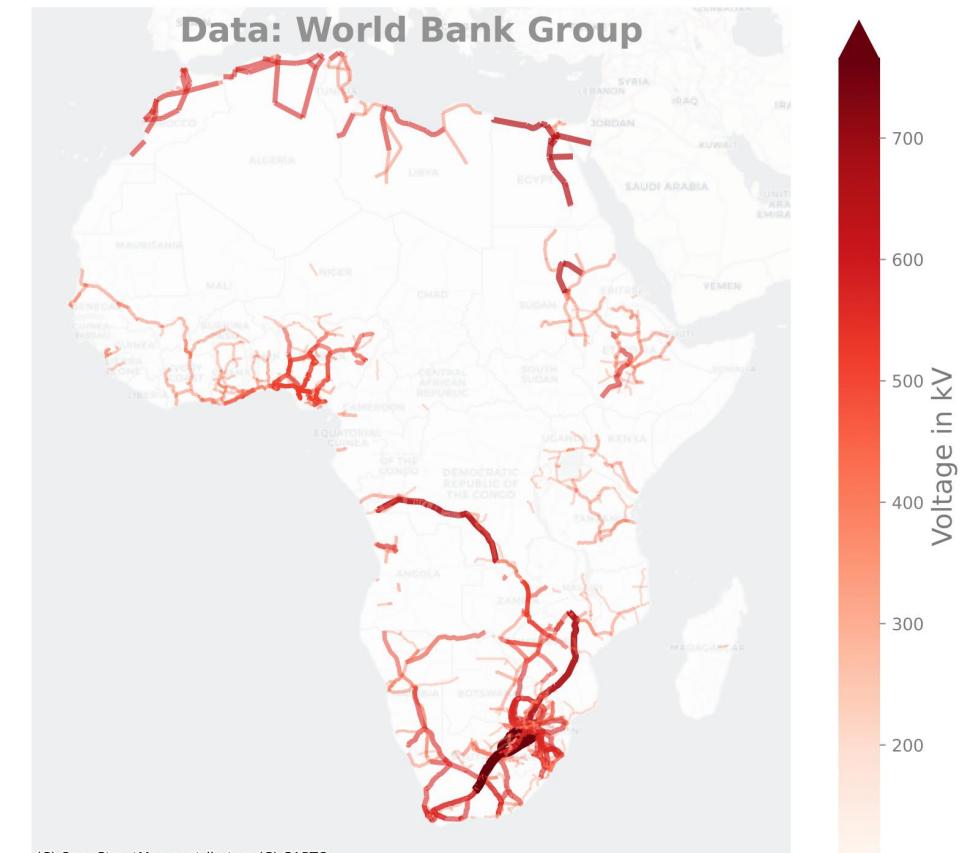
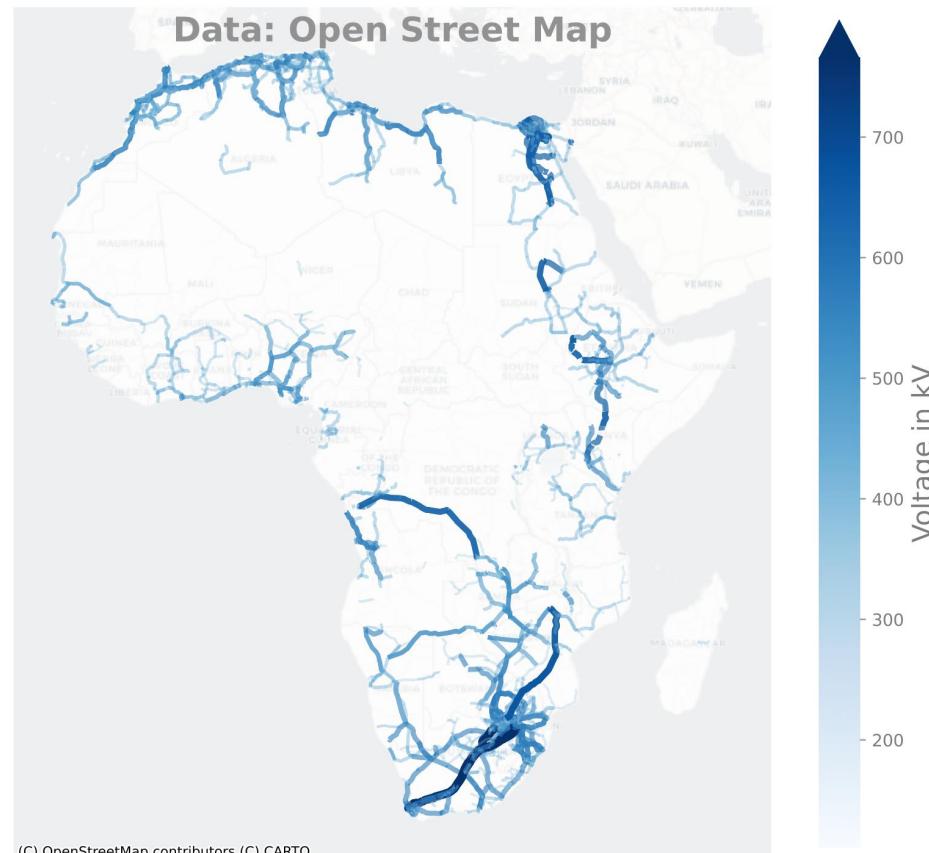
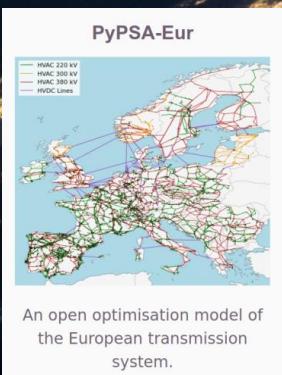
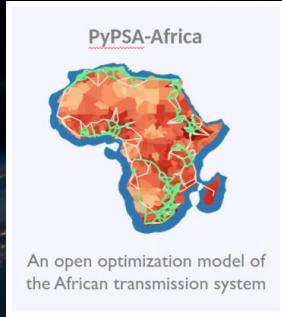
2. Provide data manipulation scripts e.g. to convert wind speed (m/s) to wind power (MW) or building meshed OpenStreetMap network

3. Provide data validation scripts e.g. comparing results to research studies or institutions (IRENA etc.)

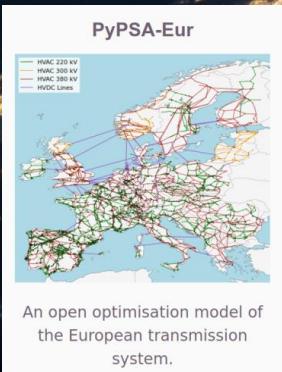
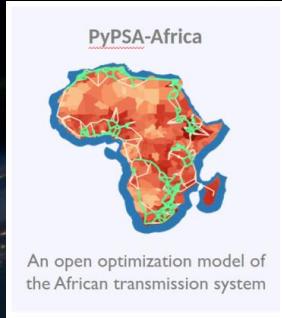
Example of automated workflow I/O



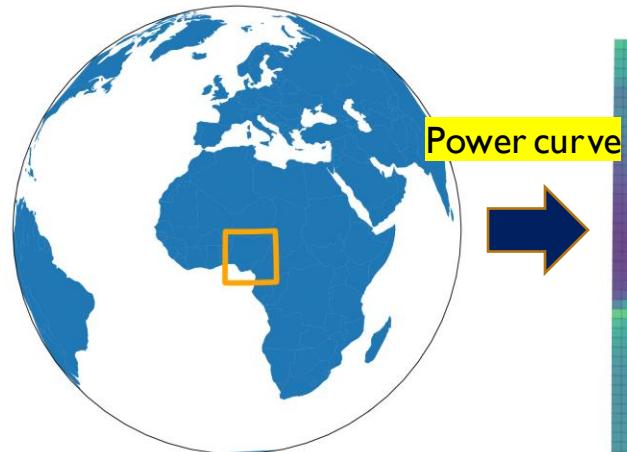
Example of automated workflow I/O



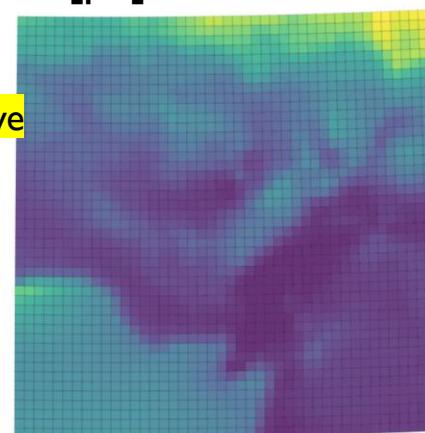
Example of automated workflow I/O



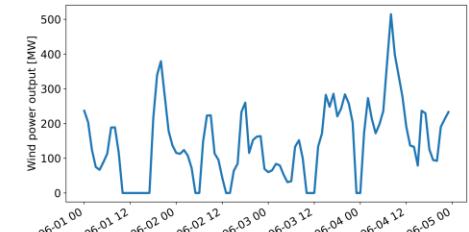
20x20km resolution
Wind speed



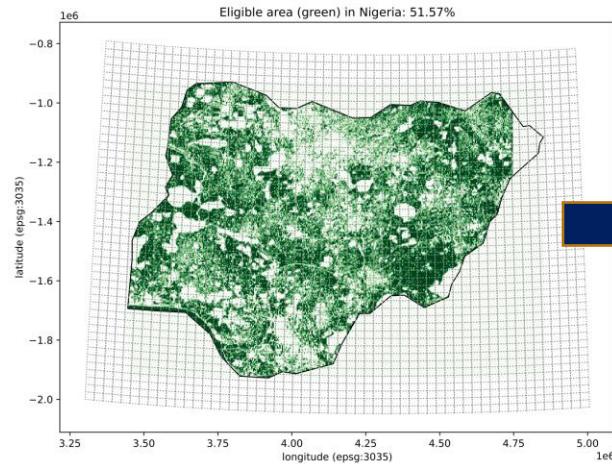
20x20km resolution
Capacity factor calc. from
[pu] timeseries



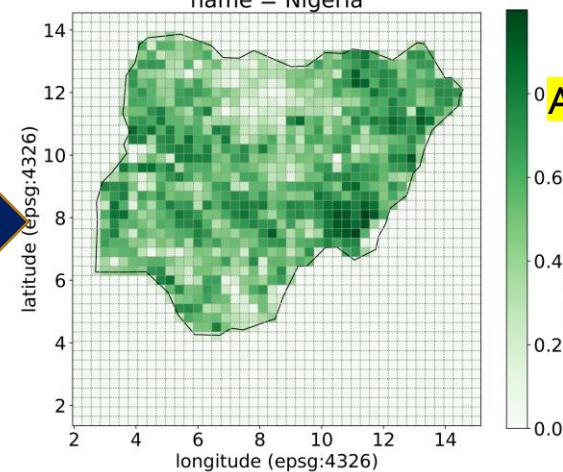
Technical available wind
potential per cell



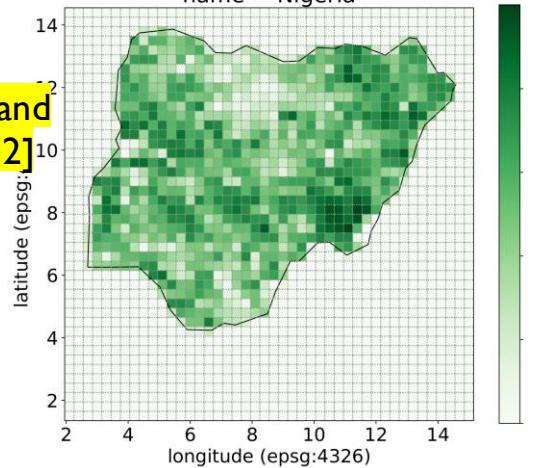
100x100m resolution.
Eligible area for wind



20x20km resolution
Downsampled
name = Nigeria



20x20km resolution
Installable capacity [MW]
name = Nigeria



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



Photo by [christopher_lemercier](https://unsplash.com/photos/l2yvdCiLaVE) <https://unsplash.com/photos/l2yvdCiLaVE>



WHY THIS STRUGGLE? WE 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 and
we want to improve.**

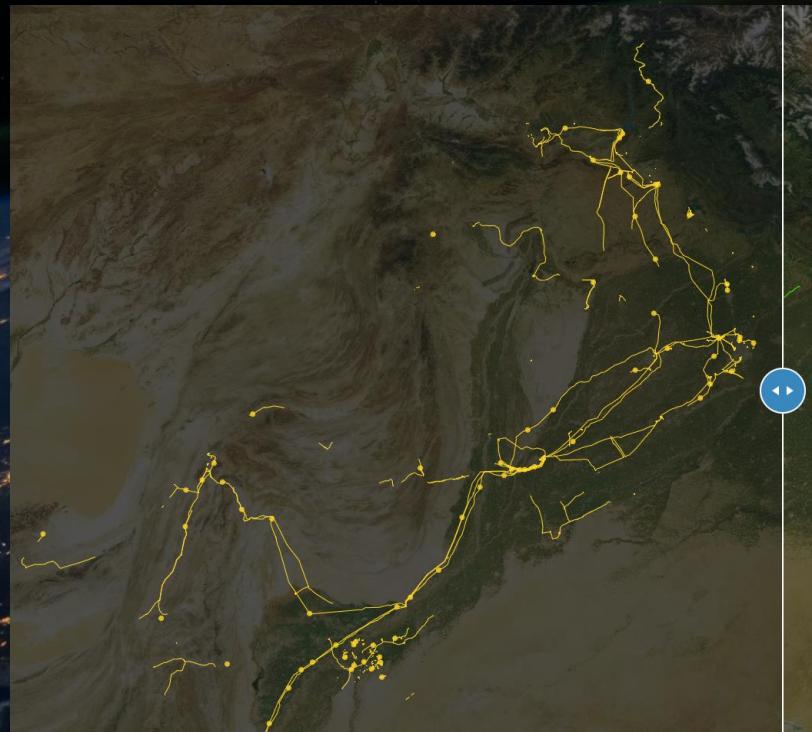
WHAT ABOUT REMOTE SENSING ?



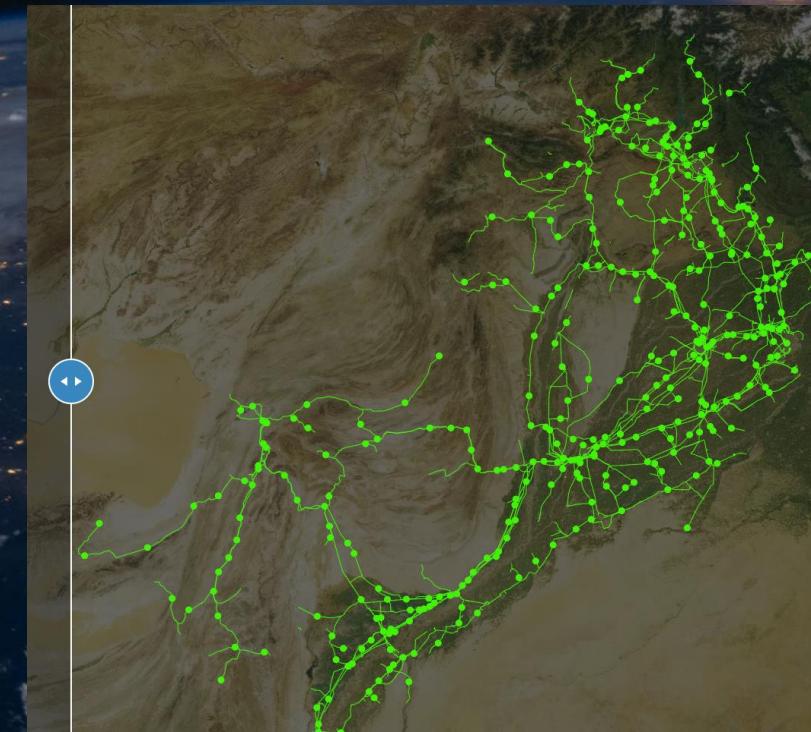
cc

Infrastructure detection:

Before



After

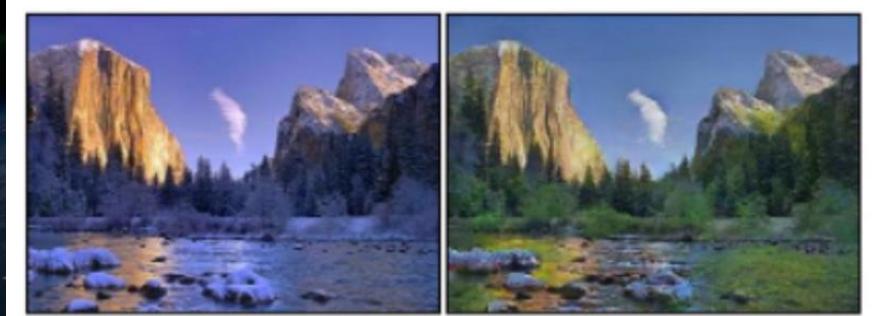


<http://devseed.com/ml-grid-docs/results/mapping-output-and-speed/>

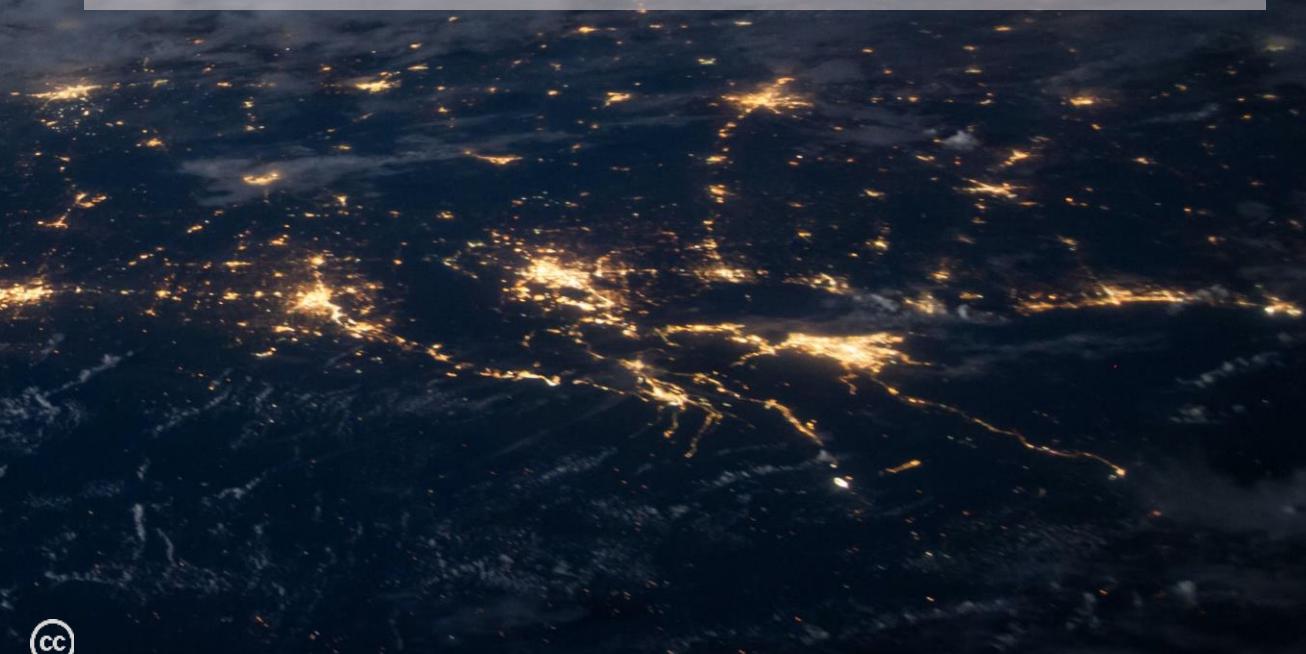


NEW:

I. Cycle-GAN to use multiple data sources

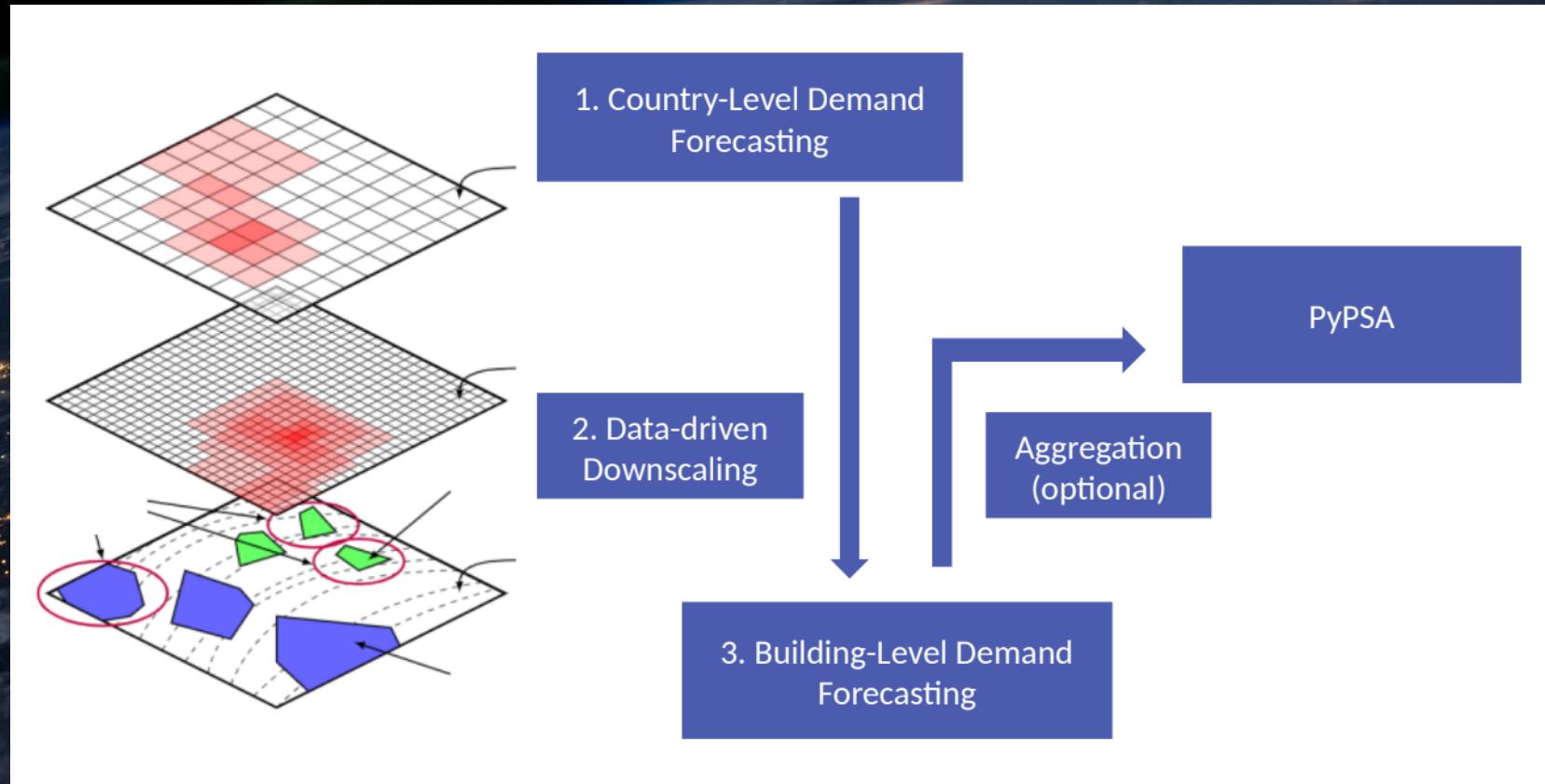


2. Reproduceable workflow to detect infrastructure across the world



Demand forecasts:

VISION: high-resolution demand data around the world





WHAT'S NEXT ?



SOLVER

ENERGY
SYSTEM
MODELS

DATA

USER AND
DEVELOPER
COMMUNITY

PyPSA-EARTH

- 1 MODEL 1 EARTH COMMUNITY -

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

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

TEAM





MAXIMILIAN PARZEN

Co-steering the PyPSA meets Earth initiative

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University of Edinburgh
Kings Building
EH9 3JL Edinburgh, UK
+49 176 70889068

Contact:  <https://pypsa-meets-africa.github.io/>
 max.parzen@ed.ac.uk



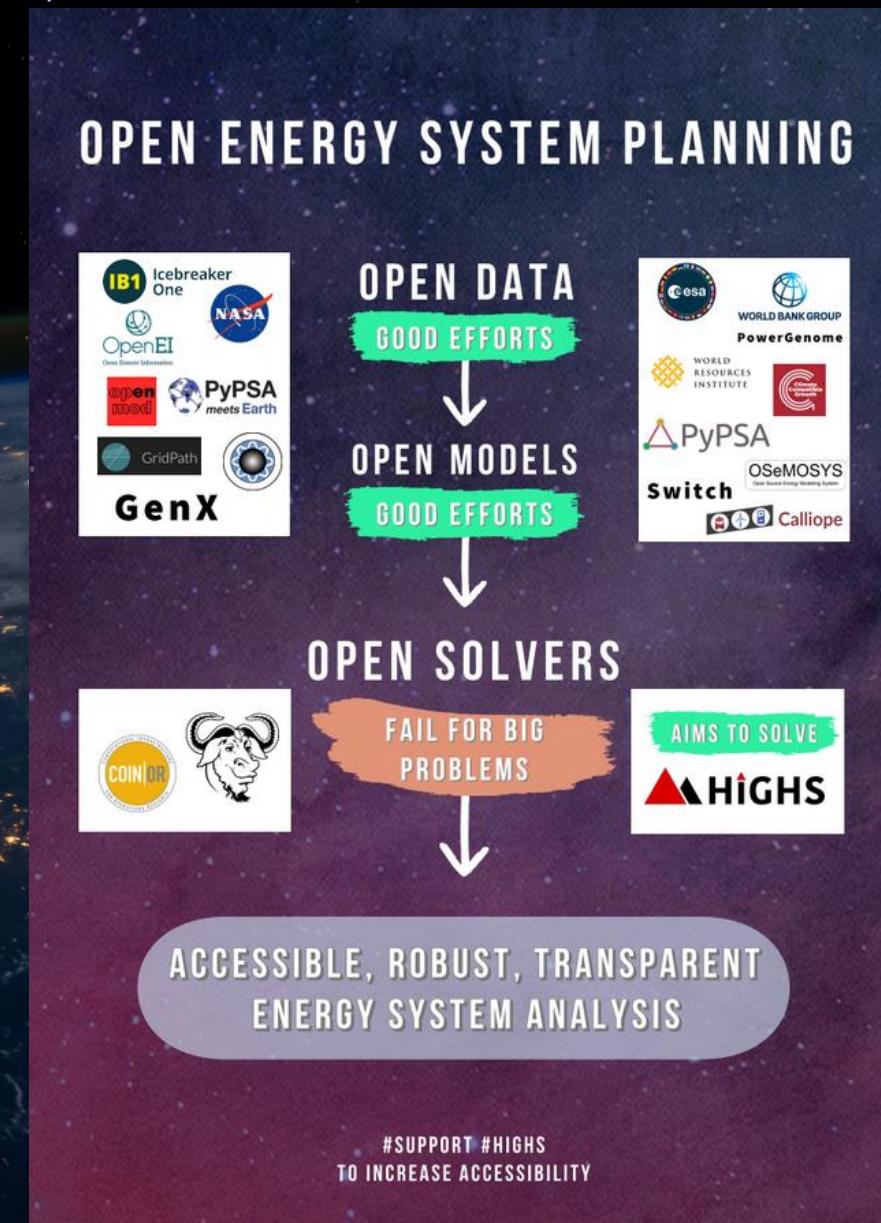
THE UNIVERSITY *of* EDINBURGH

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



LET'S OPEN UP THE BLACK BOX

+ MAKE THE "OPEN BOX" THE STANDARD



Applied Methods

- **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)

Validation approaches

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)

OPEN Global Independent Research Initiative

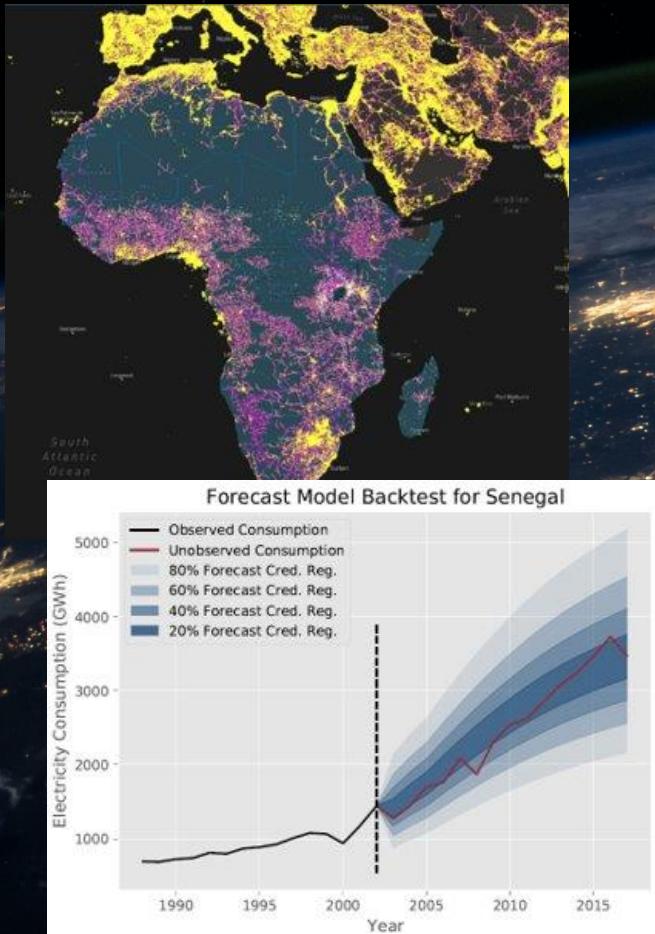


A collage of text elements on a background image of Earth from space, illustrating various components and features of the PyPSA initiative:

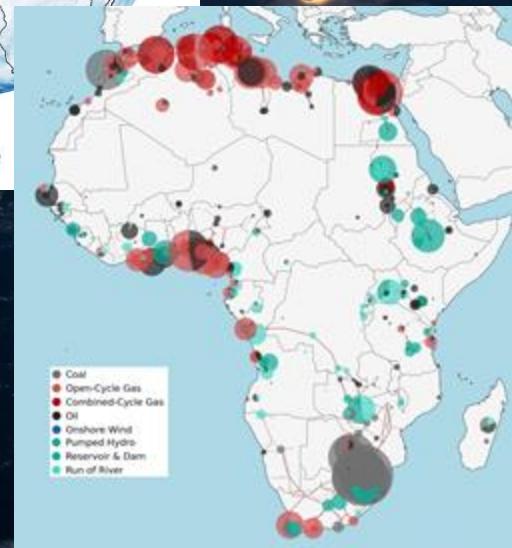
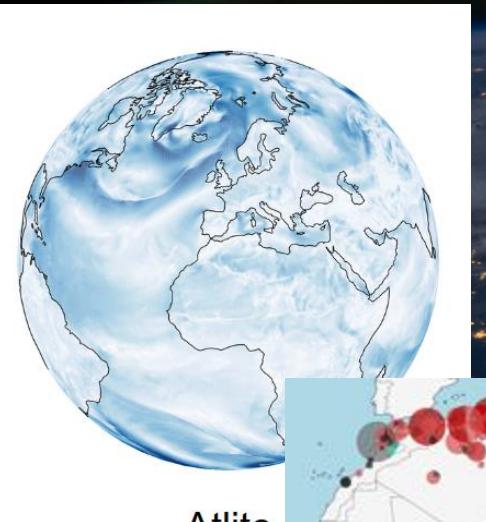
- SOLVER**: Help sustaining, Support developers, Reveal bottlenecks, Initiate new paths
- ENERGY SYSTEM MODELS**: High resolution, Features, Problem formulator, Modular, Performance
- DATA**: Creating open data, Predicting data, Data workflow, High resolution
- USER AND DEVELOPER COMMUNITY**: Open, Collaborative, Dialogue, Training, Empower

USE EXISTING DATA TO PLAN THE FUTURE

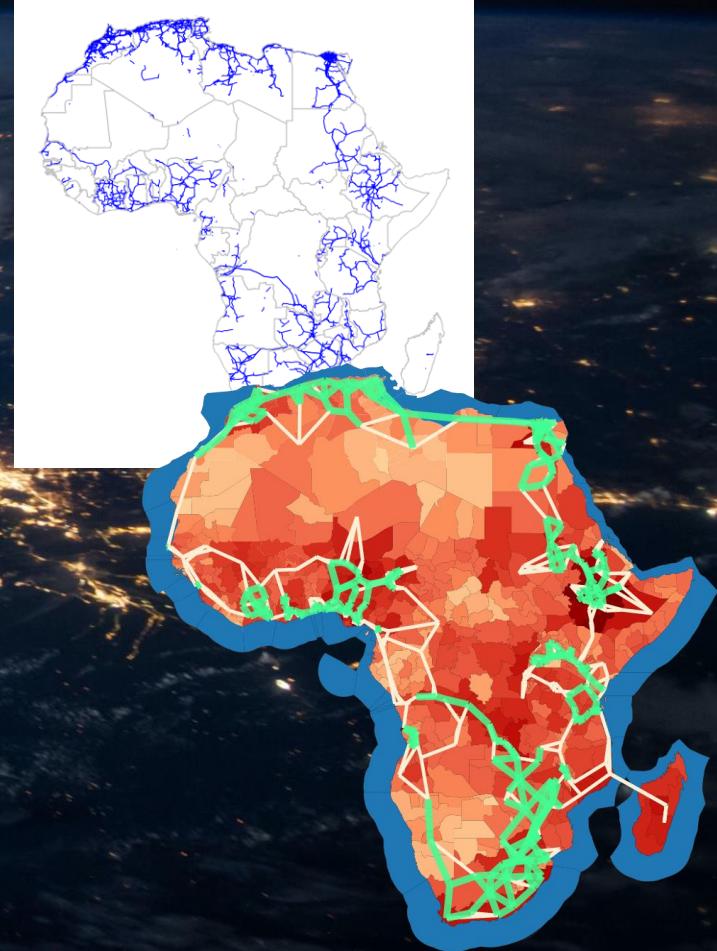
DEMAND

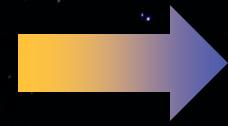


SUPPLY



NETWORK

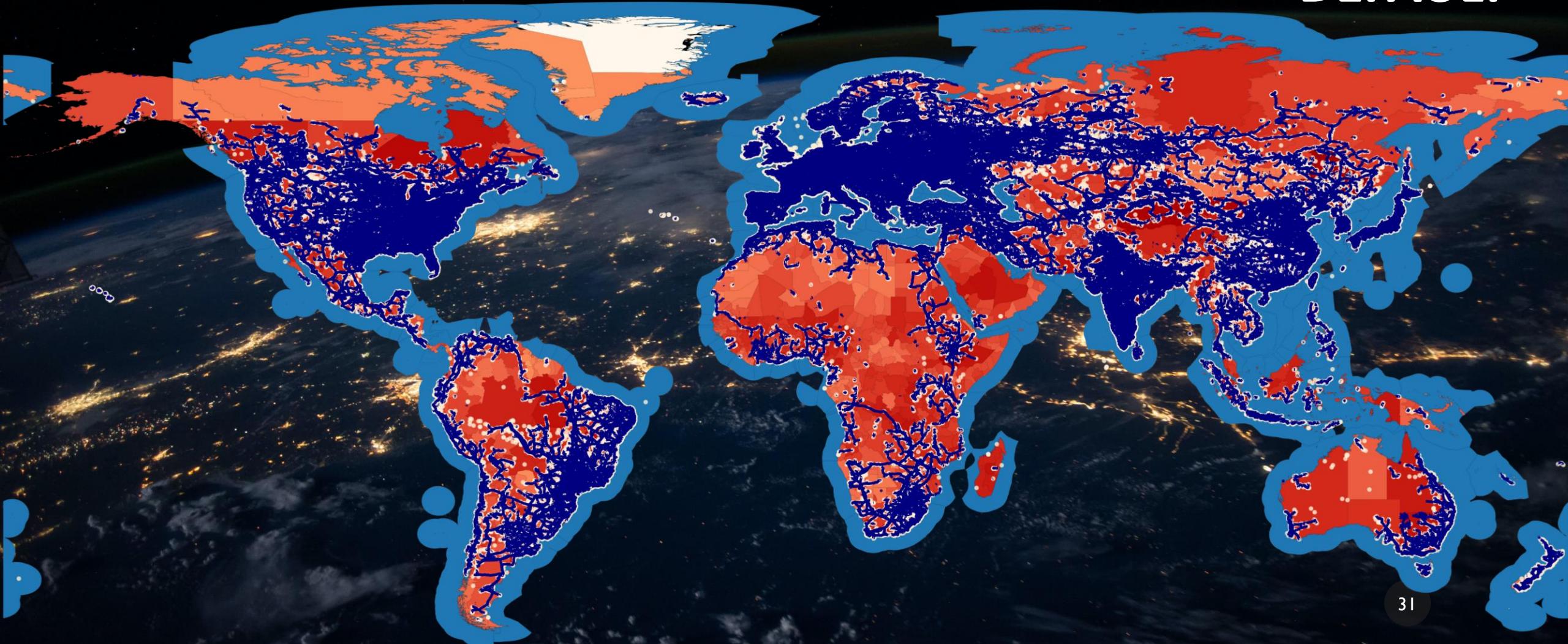




WIKIPEDIA
OF APPLIED
DATASTREAMS



GLOBAL
DATA BY
DEFAULT



WHAT IF YOU ARE MISSING DATA?

I.

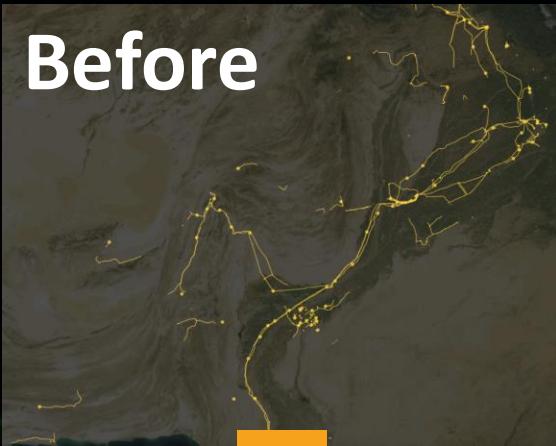
**INFRASTRUCTURE
DETECTION**



II.

**DEMAND
PREDICTION**

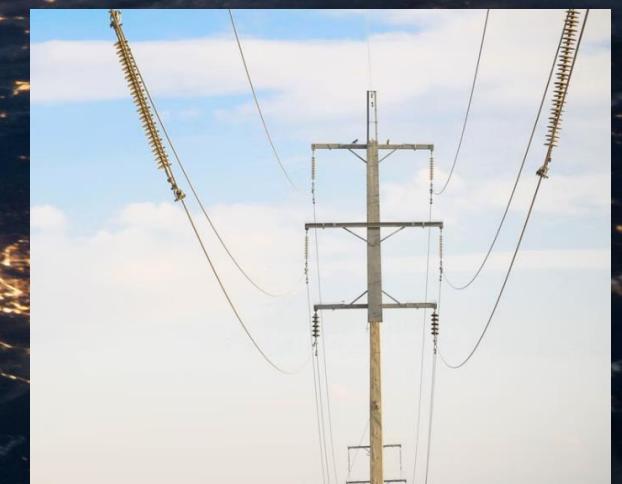
Before



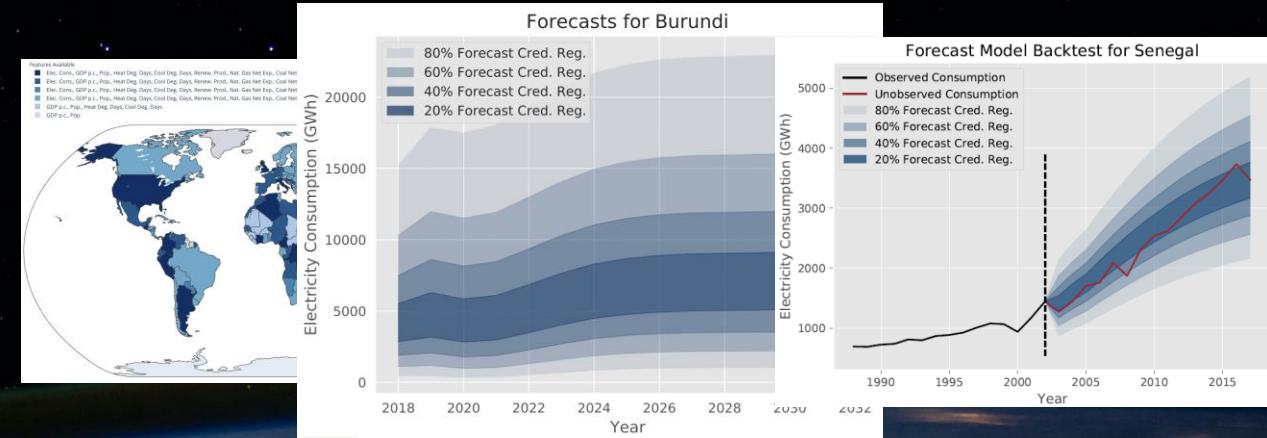
After



**Current F
ocus**



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



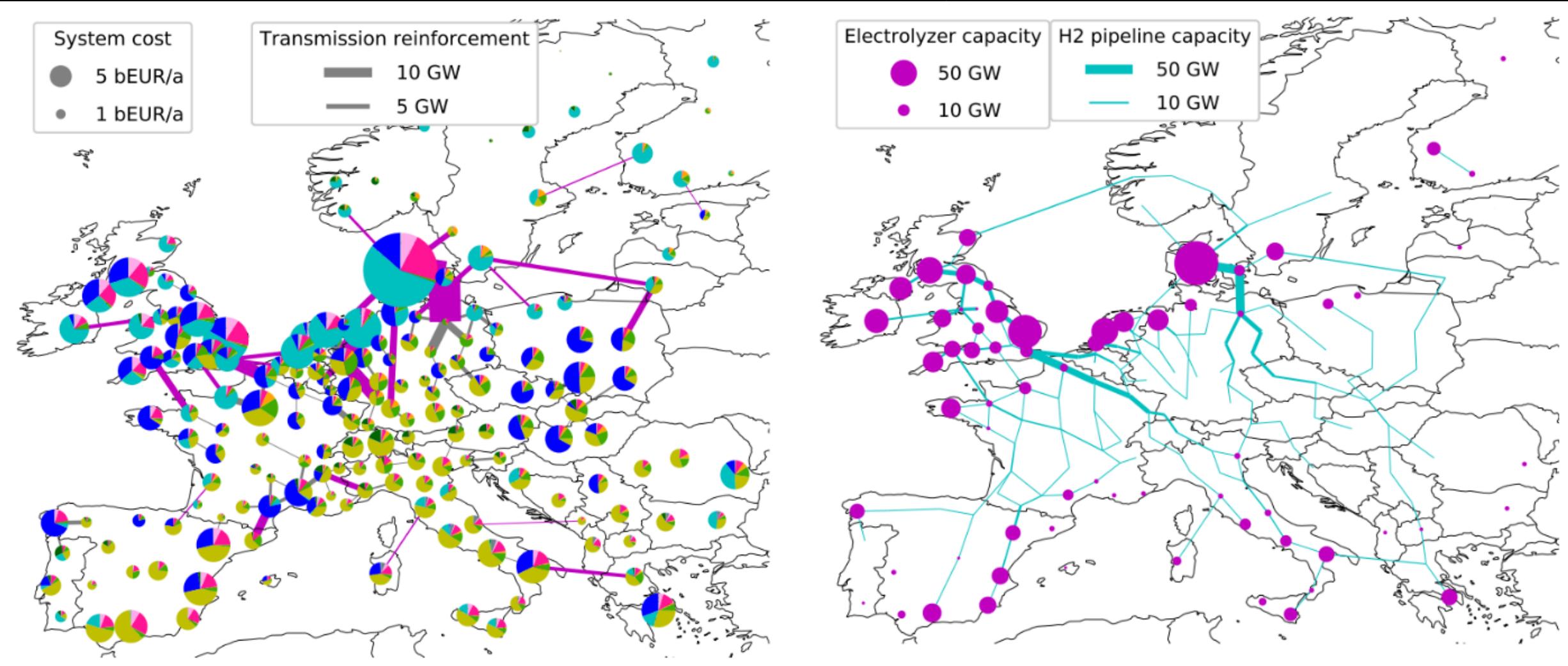
2. Downscaling via Economics-Informed Probabilistic Models and Others



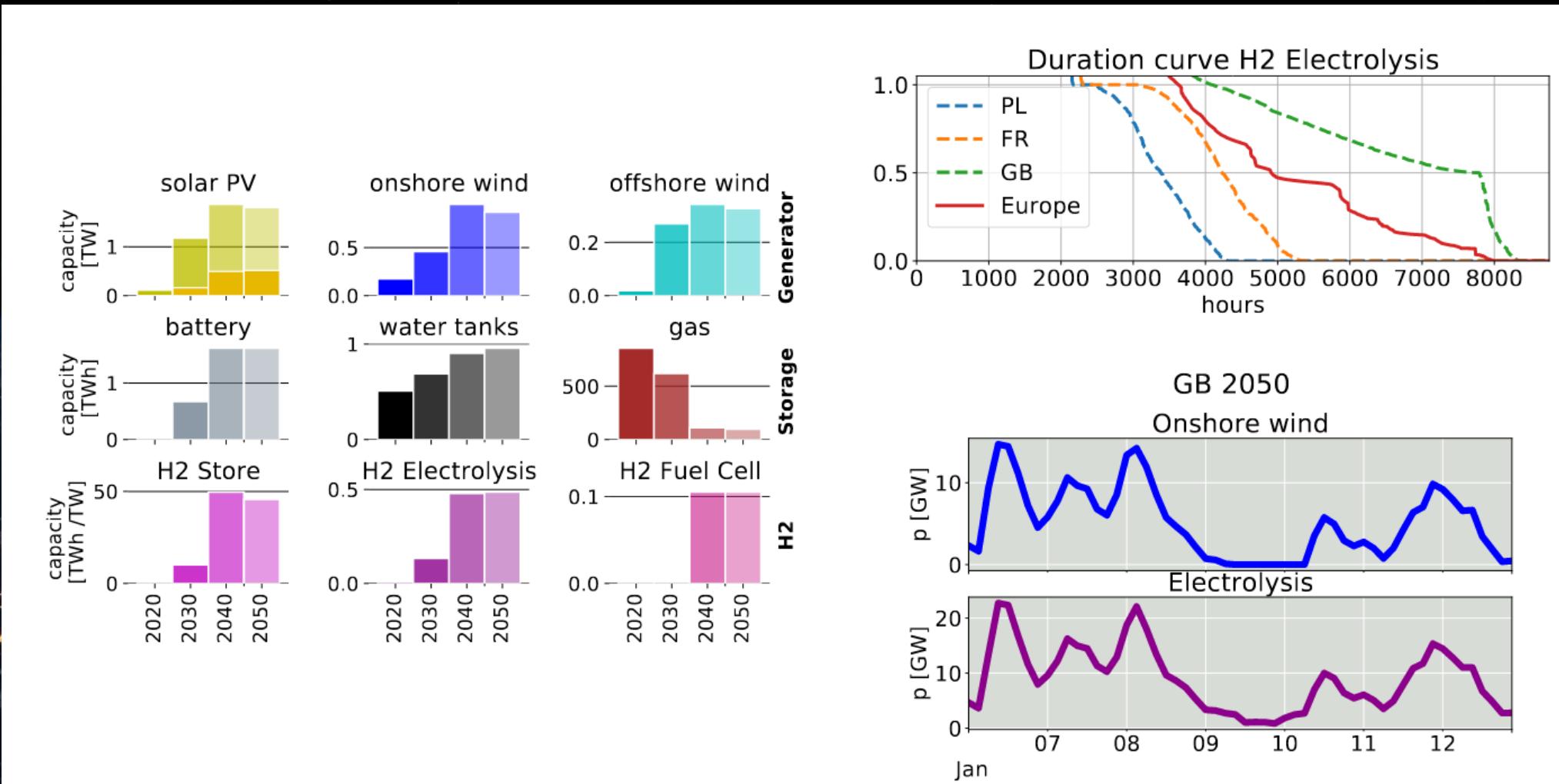
3. Building-Level Demand Forecasting via Bayesian Deep Learning and Others

HYDROGEN AND GIS

EXAMPLE OUTPUT: INVESTMENTS FOR 2050 NET ZERO SCENARIOS

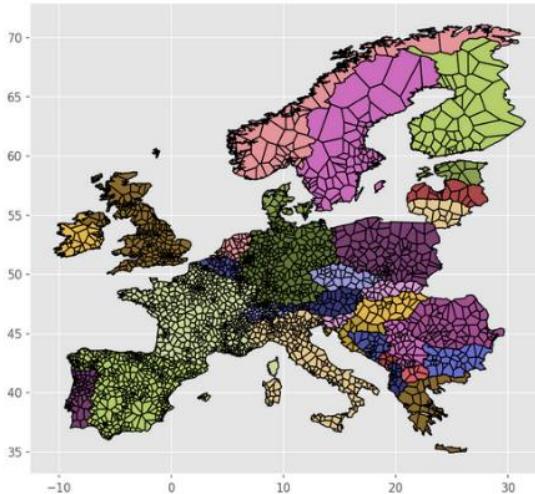


EXAMPLE OUTPUT: INVESTMENTS + OPERATION FOR 2050 NET ZERO SCENARIOS



EXAMPLE OUTPUT: INVESTMENTS + OPERATION FOR 2050 NET ZERO SCENARIOS

Installable Potential and Land Eligibility



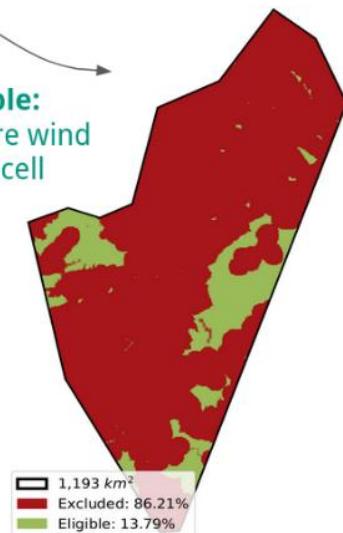
Geospatial Land Availability for Energy Systems (GLAES)



DOI 10.5281/zenodo.1122558

Severin Ryberg
github.com/FZJ-IEK3-VSA/glaes

example:
onshore wind
in one cell



- CORINE 2018
land cover
 - eligible codes
 - distances
- NATURA 2000 natural
protection areas
- GEBCO 2018
bathymetry dataset
- Density:
capacity per km²

CC BY 17

5 ACTIVE TEAMS

ATM
Africa,
North Asia,
West-Asia

PYPSA-EARTH
(POWER)

PYPSA-EARTH-SEC
(SECTOR-COUPLED)

INFRASTRUCTURE
DETECTION

OUTREACH

DEMAND
PREDICTION

PYPSA-MINIGRID

Open Community!

The screenshot shows the PyPSA-Earth Discord server interface. The left sidebar lists channels under categories: GOAL: LVL 1, CO-WORKING SPACE, MEETING ROOMS, and COMMUNITY. The general channel is selected, showing a pinned message from MaxParzen: "Please read this first." The message content welcomes users to the server and provides guidelines for participation. It includes links to the website (<https://pypsa-meets-africa.github.io>), documentation (<https://pypsa-meets-africa.readthedocs.io/en/latest/index.html>), GitHub repository (<https://github.com/pypsa-meets-africa/pypsa-africa>), Google drive (<https://drive.google.com/drive/folders/13Z8Y9zgsh5lZaDNkkRyo1wkoMgbdUxT5?usp=sharing>), LinkedIn (<https://www.linkedin.com/company/pypsa-meets-africa>), YouTube (<https://www.youtube.com/channel/UCKKnlgWikF3hg4rwwucsQTA>), and meeting agenda links (<https://github.com/pypsa-meets-africa/pypsa-africa#get-involved>). The right sidebar shows a list of moderation roles (davidst, Lukas Franken, MaxParzen, YoTwo) and online users (cesacap, eyorat, fabianhofmann, fneum, gecki, hazem, Iclal Cetin Tas, Koen, Leon S, meki21, Sir-Wentemi, Tony Tuo, ZHANG).

general - Discord

PyPSA-Earth

GOAL: LVL 1 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

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 Documentation: <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/13Z8Y9zgsh5lZaDNkkRyo1wkoMgbdUxT5?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>

November 23, 2021

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

MODERATION — 4

davidst

Lukas Franken

MaxParzen

YoTwo

ONLINE — 12

cesacap

eyorat

fabianhofmann

fneum

gecki

hazem

Iclal Cetin Tas

Koen

Leon S

meki21

Sir-Wentemi

Tony Tuo, ZHANG