

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



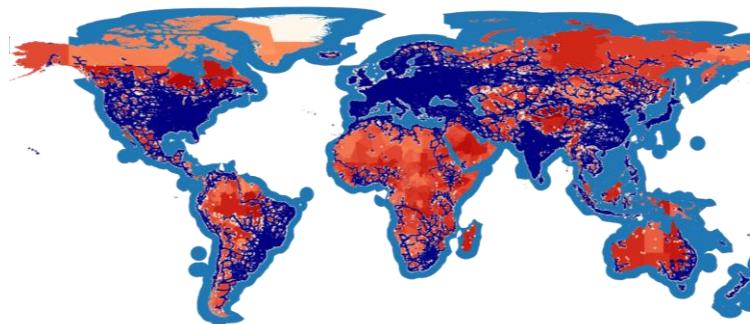
25.07.2022, Maximilian Parzen

WHO IS MAX?

Bored PhD student
Winter 20/21

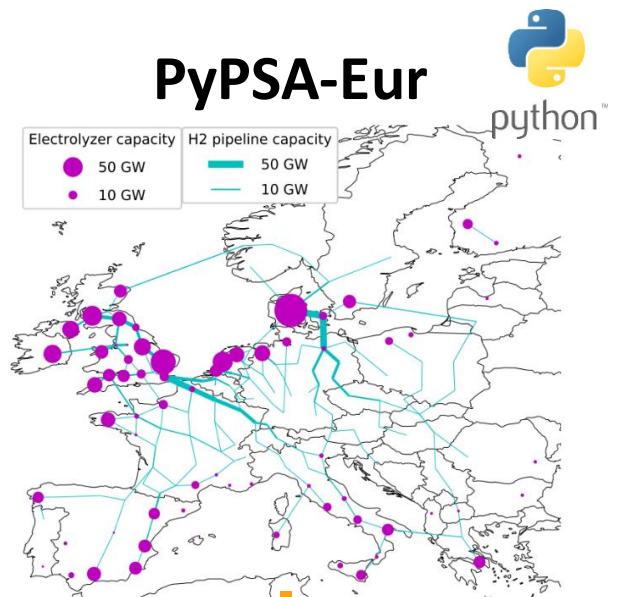


PyPSA-Earth & Co.



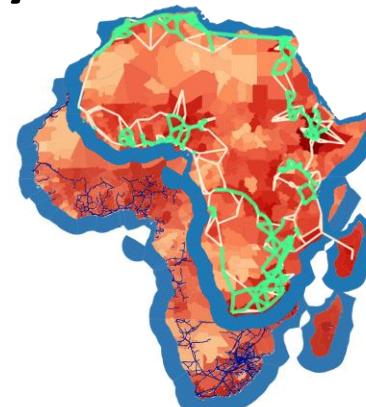
Started activities
on global scale

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

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....



**GREEN
HYDROGEN
FUTURE**

USE CASES & USERS



COAL-EXIT
PLANS



SUPPLY DIVERSI.
PLANS



ENERGY-
TRANSITION
PLANS



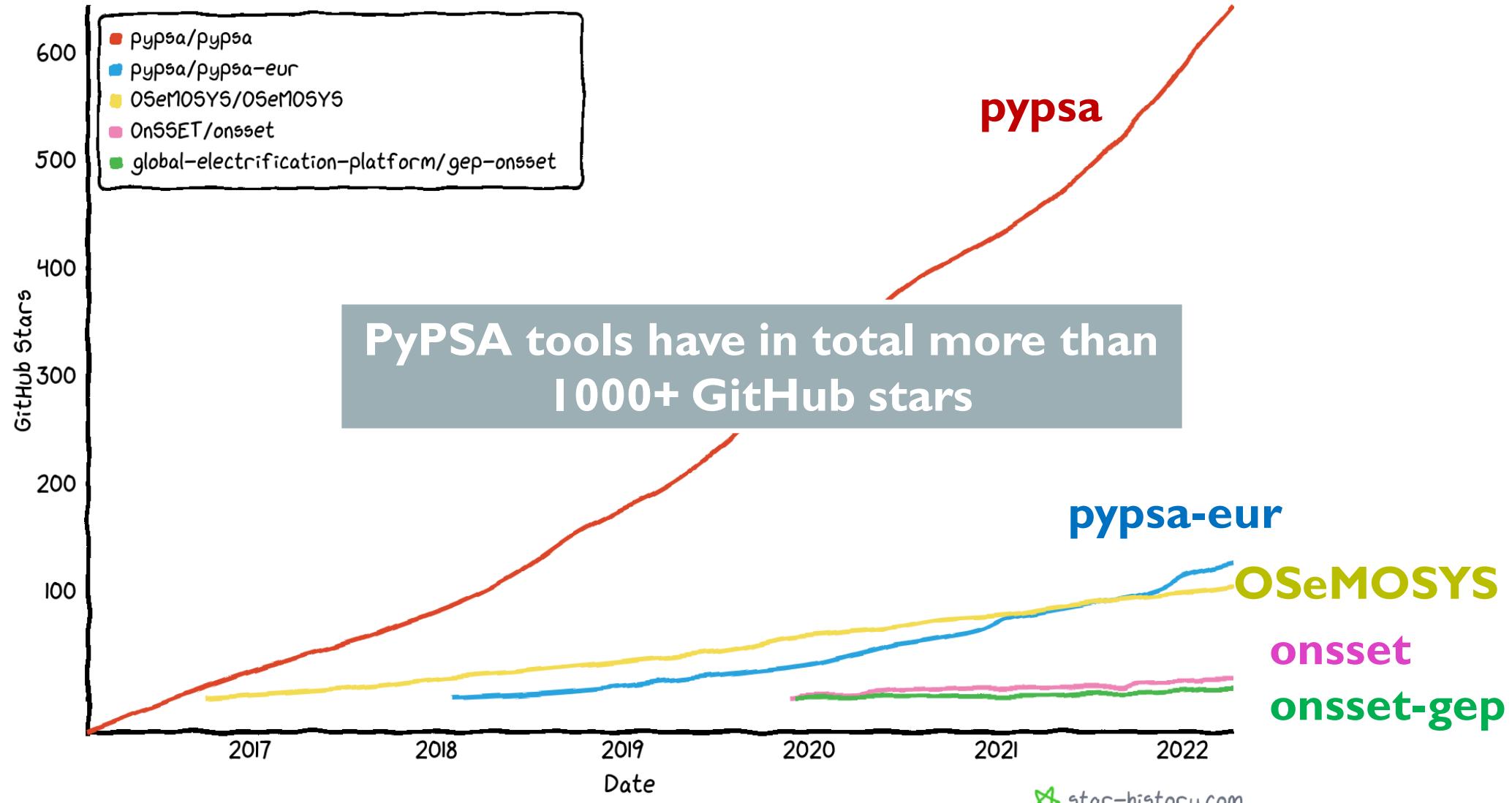
MINI-VS-
GRID
STUDIES

"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](#).

"Energiewende - Energy transition" by [florianric](#) is marked with CC BY-SA 2.0.

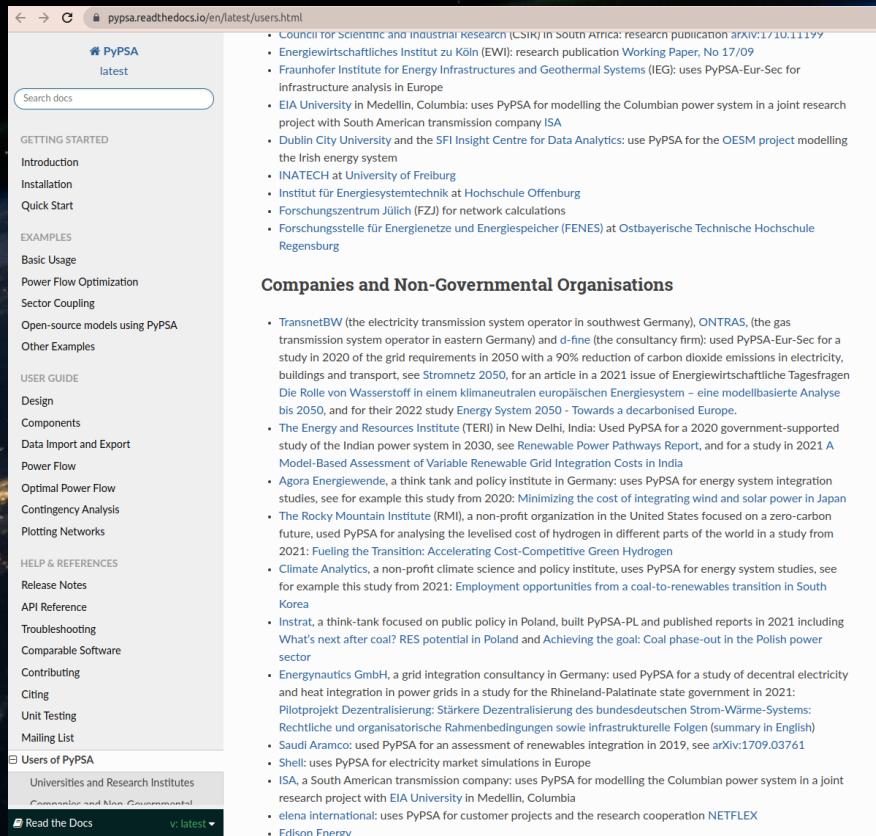
Is PyPSA popular?

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>



The screenshot shows the PyPSA documentation page for the 'Users' section. It lists various organizations and research institutions that have used PyPSA for their work, such as 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 Medellin, Colombia, Dublin City University, SFI Insight Centre for Data Analytics, INATECH at University of Freiburg, Institut für Energiesystemtechnik at Hochschule Offenburg, Forschungszentrum Jülich (FZJ), FENES at Ostbayerische Technische Hochschule Regensburg, TransnetBW, ONTRAS, d-fine, Energy Resources Institute (TERI), Agora Energiewende, Rocky Mountain Institute (RMI), Climate Analytics, Instrat, Energynautics GmbH, Saudi Aramco, Shell, ISA, elena international, and Edison Energy.

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
- ISA, a South American transmission company: uses PyPSA for modelling the Columbian power system in a joint research project with EIA University in Medellin, Colombia
- elena international: uses PyPSA for customer projects and the research cooperation NETFLEX
- Edison Energy

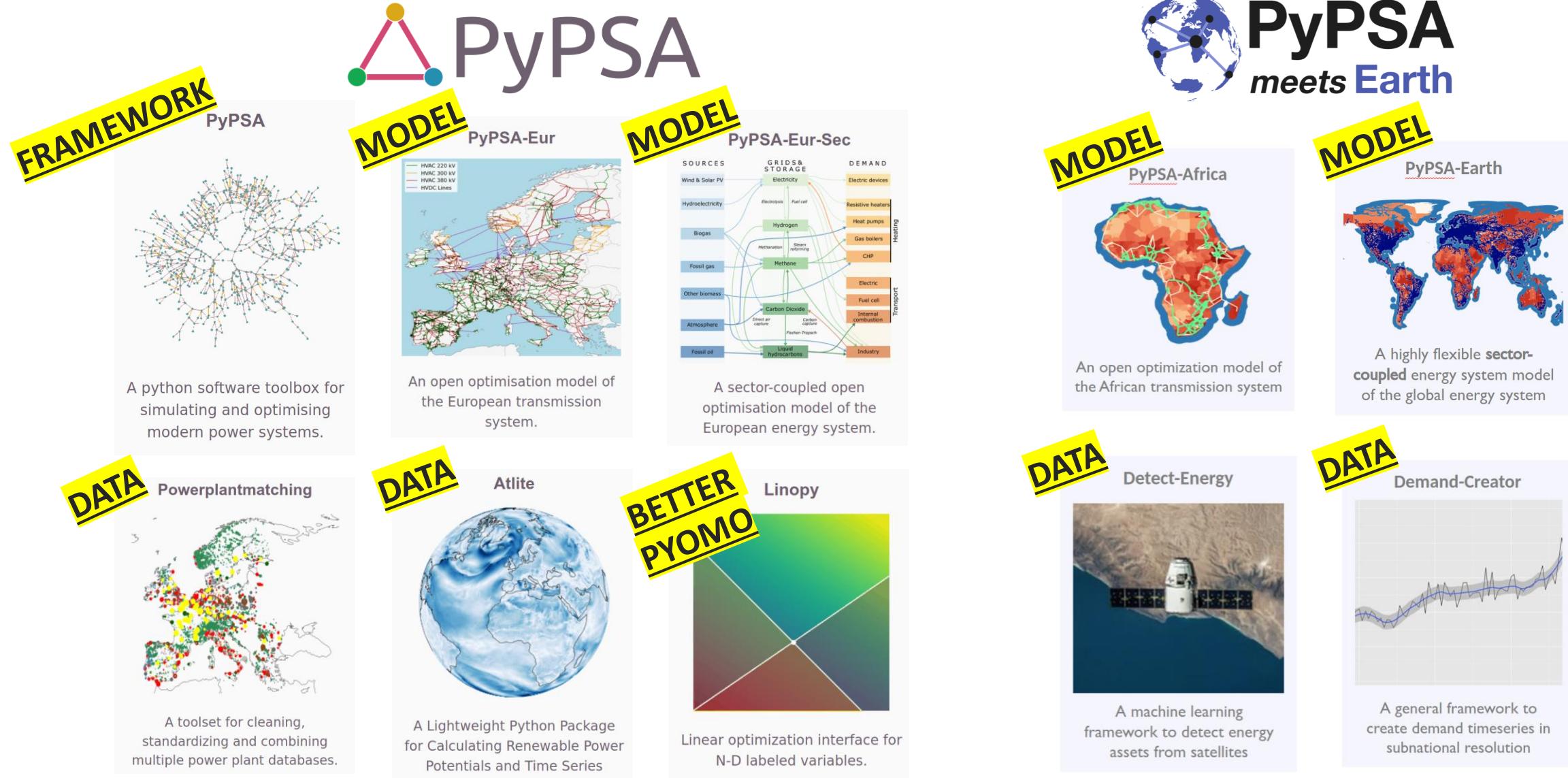
A FEW USERS
ASSOCIATED TO:



“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?



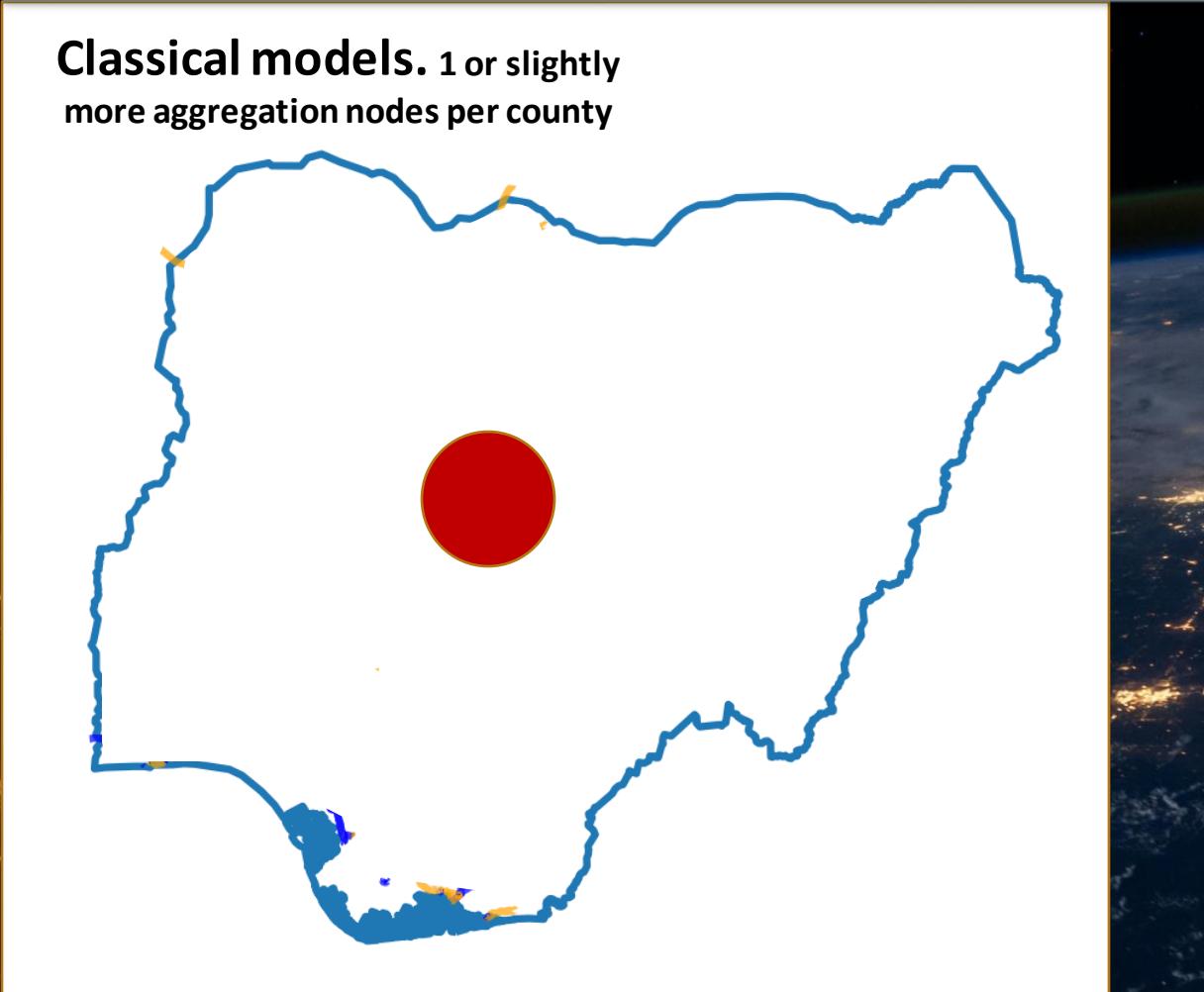
Purpose:

- 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**

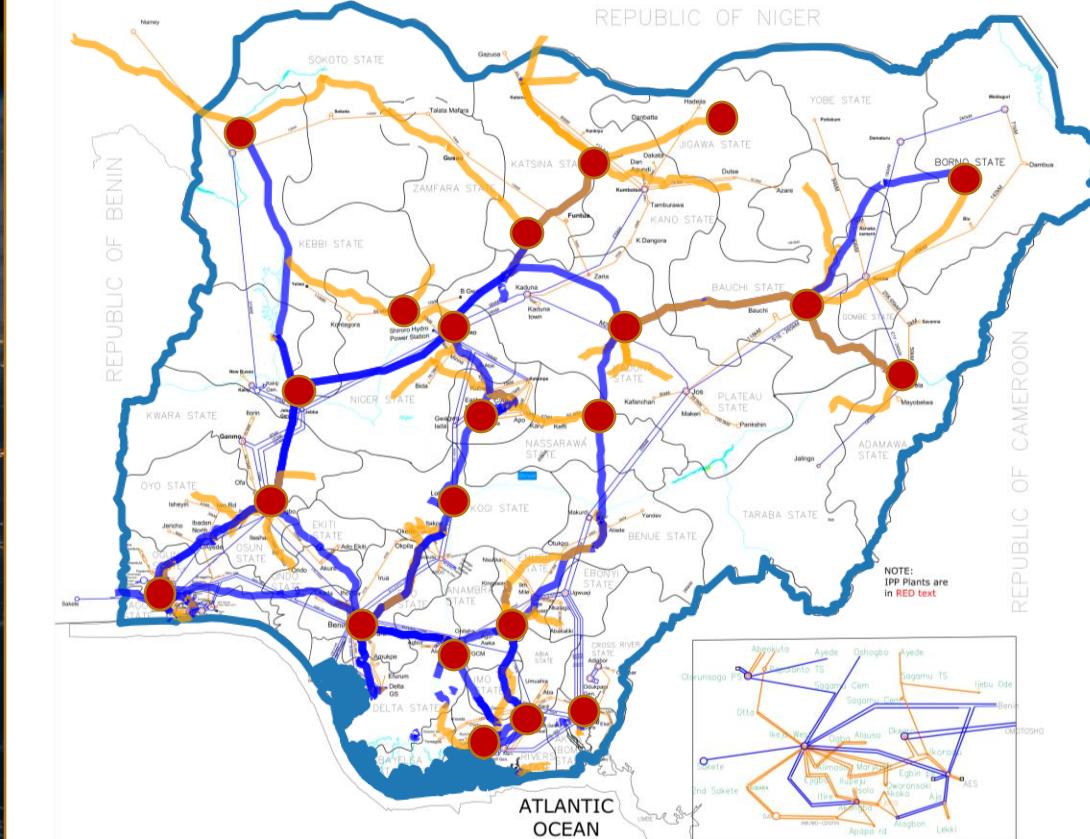
Software	Version	Citation	Free Software	Grid Analysis			Economic Analysis				
				Power Flow	Continuation Power Flow	Dynamic Analysis	Transport Model	Linear OPF	SCLOPF	Nonlinear OPF	Multi-Period Optimisation
MATPOWER	6.0	[6]	✓	✓	✓	✓	✓	✓	✓	✓	✓
NEPLAN	5.5.8	[2]	✓	✓	✓	✓	✓	✓	✓	✓	✓
pandapower	1.4.0	[9]	✓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

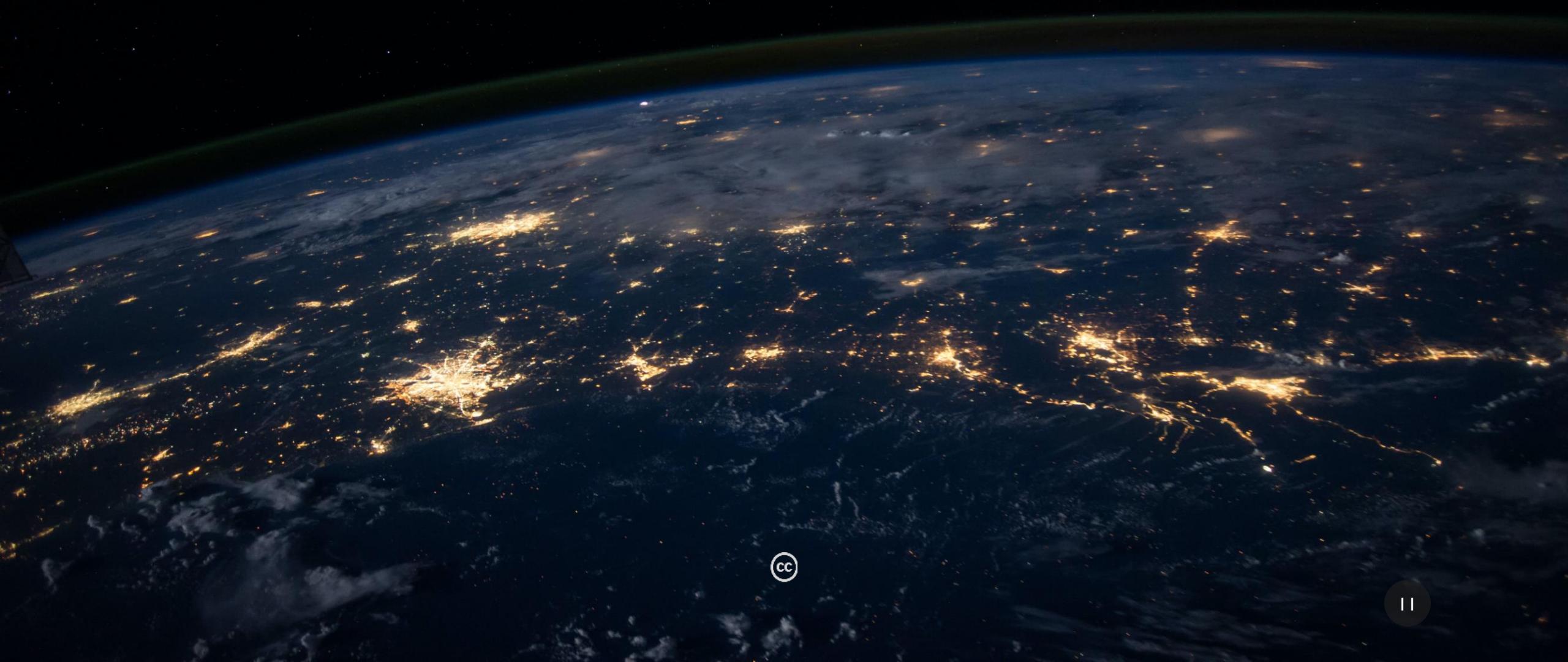
Classical models. 1 or slightly more aggregation nodes per county



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? Contributions are welcome. Be a part of our community.

2. Provide data manipulation scripts

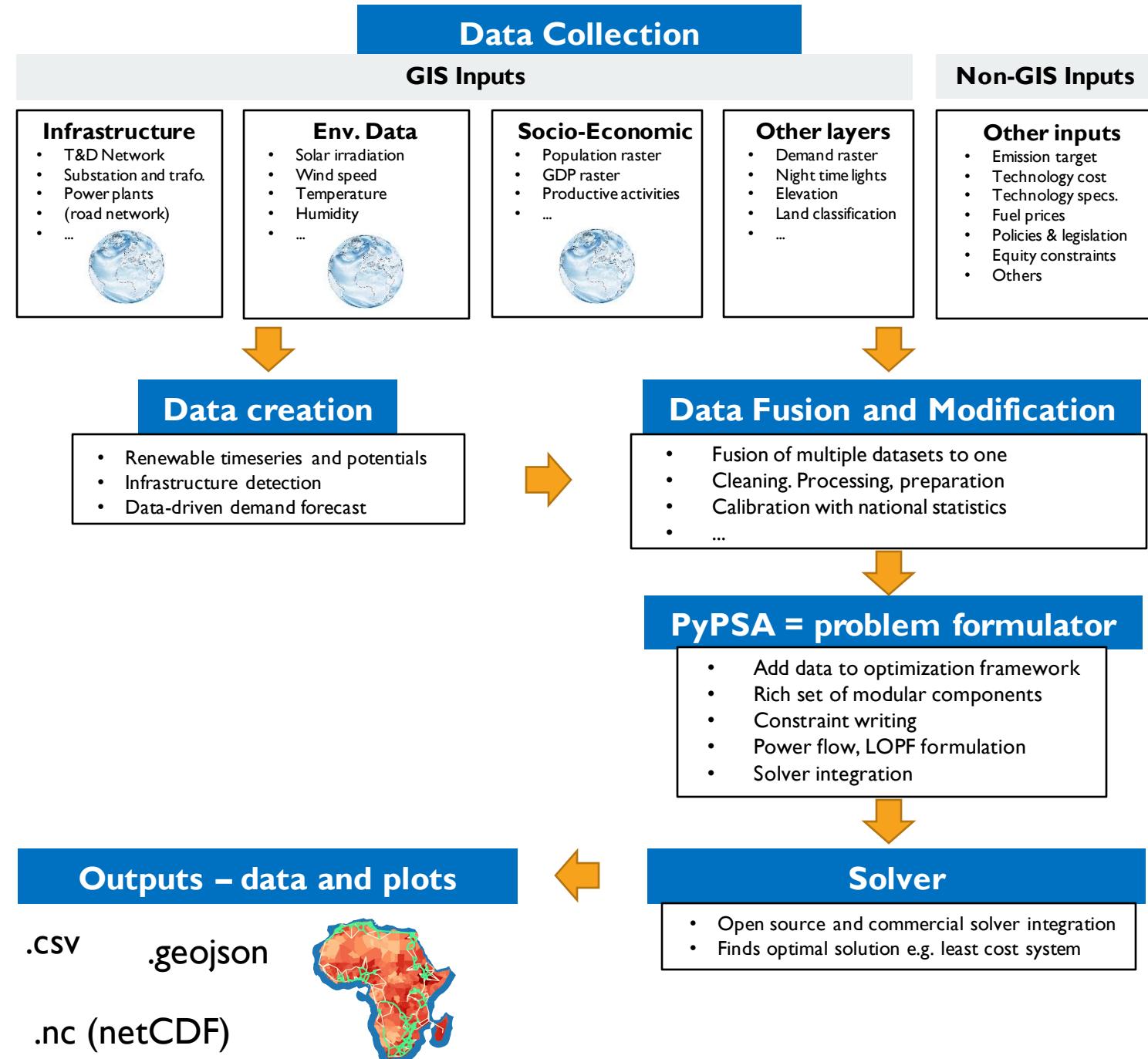
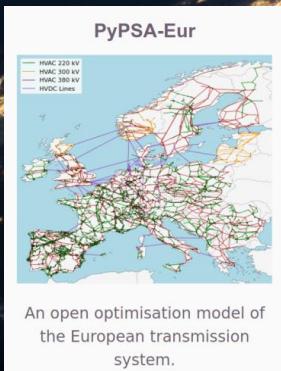
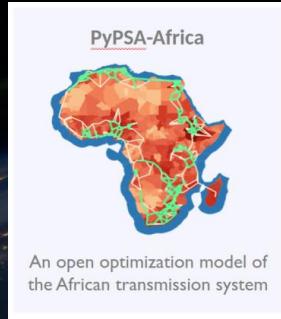
e.g. to convert wind speed (m/s) to wind power (MW) or building meshed OpenStreetMap network

3. Provide data validation scripts

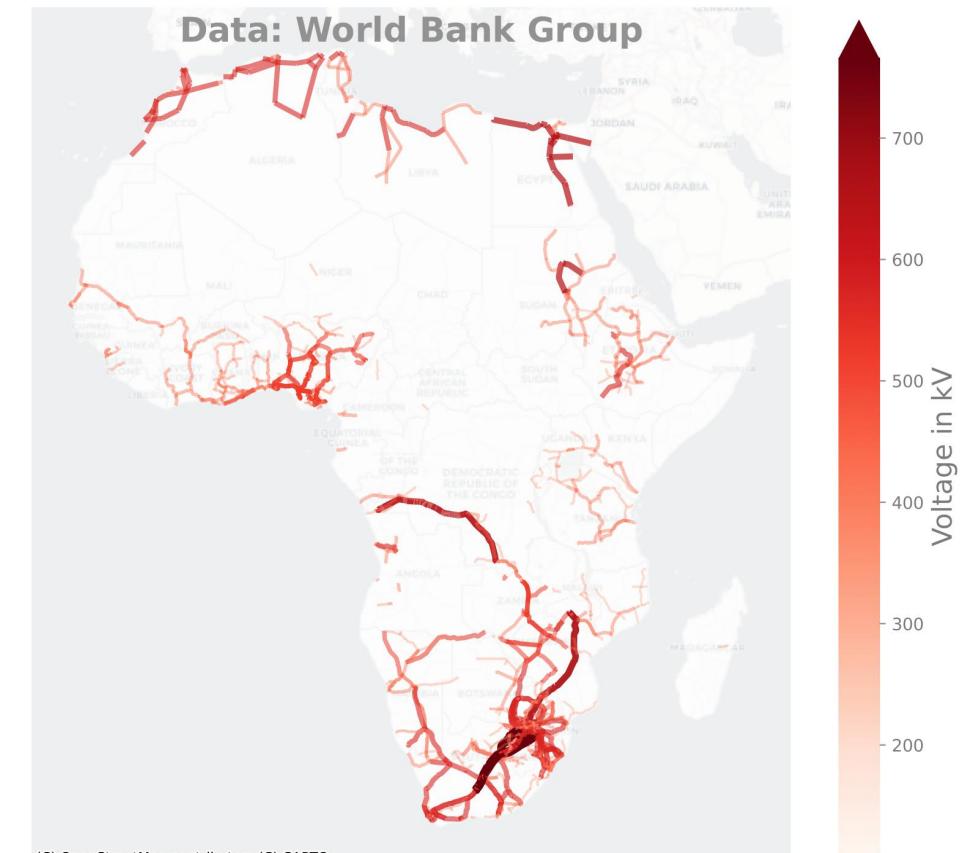
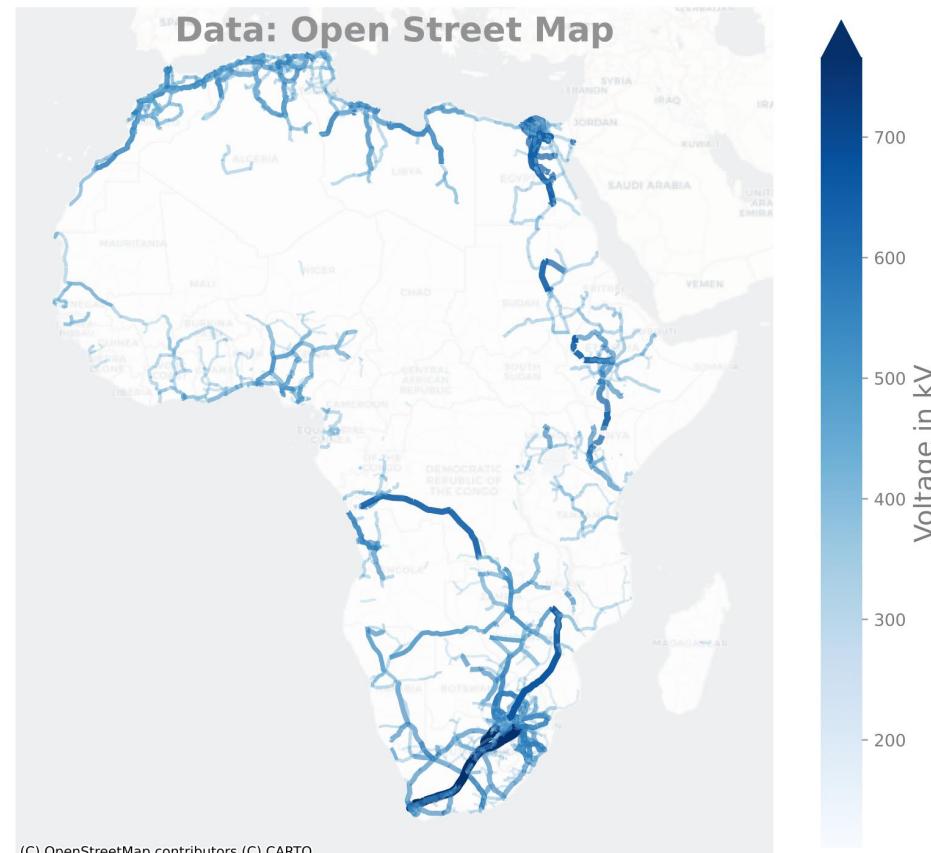
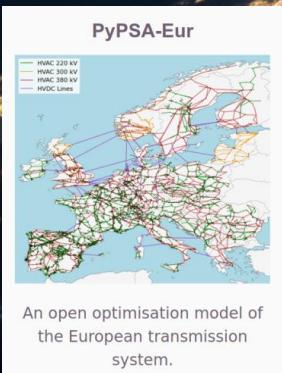
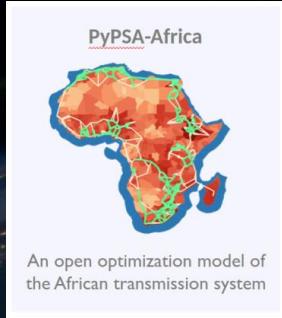
e.g. compare results to research or institutional studies (IRENA etc.)



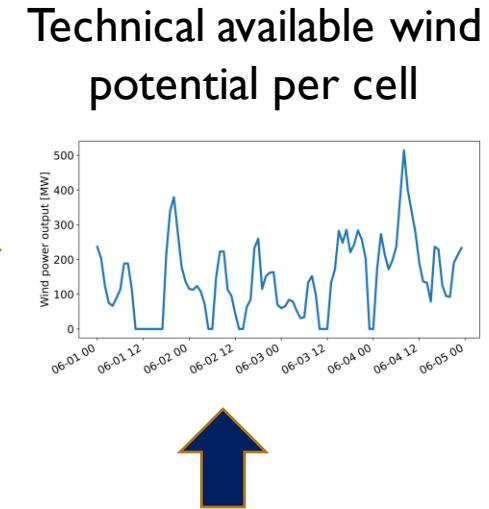
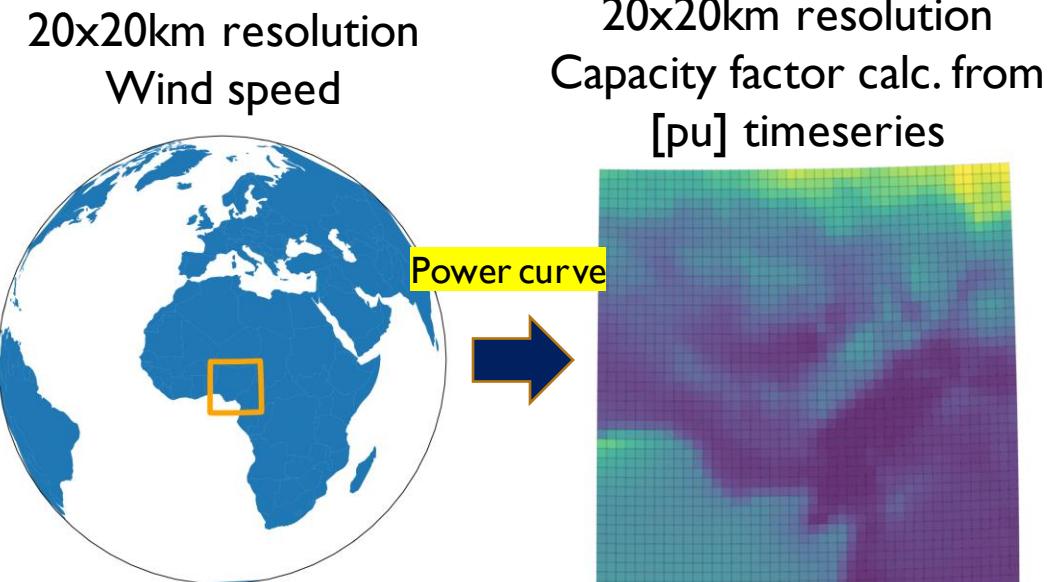
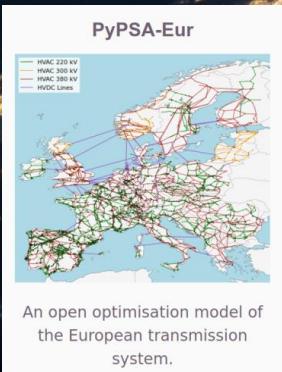
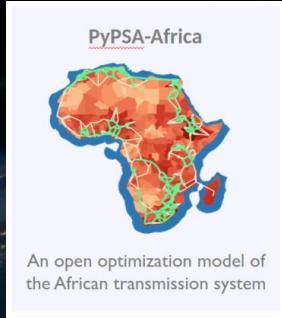
Example of automated workflow I/O



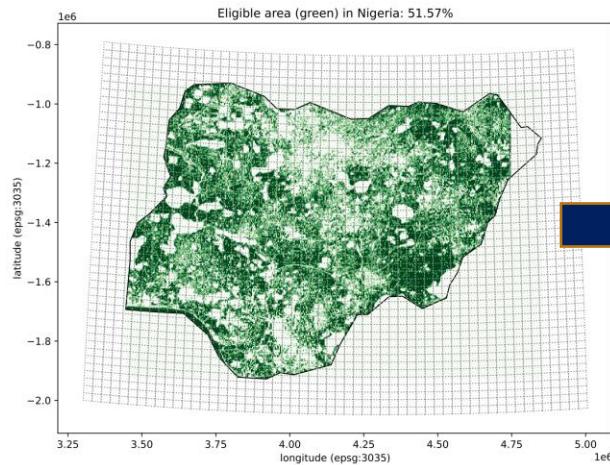
Example of automated workflow I/O



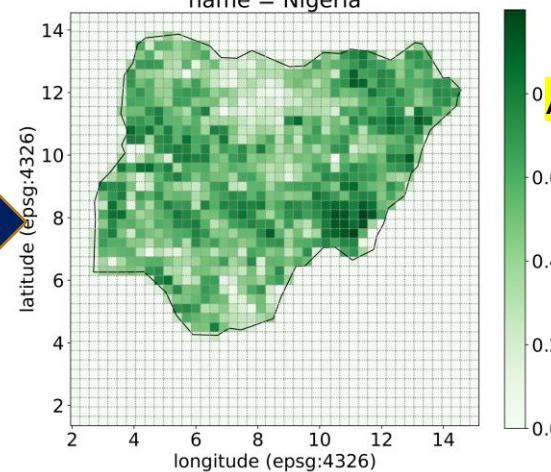
Example of automated workflow I/O



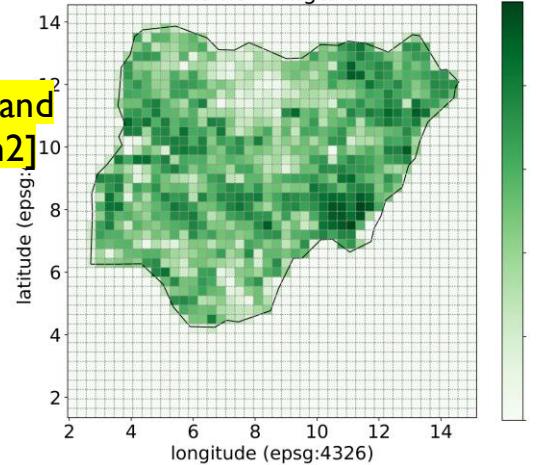
100x100m resolution.
Eligible area for wind



20x20km resolution
Downsampled
name = Nigeria



20x20km resolution
Installable capacity [MW]
name = Nigeria



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



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



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

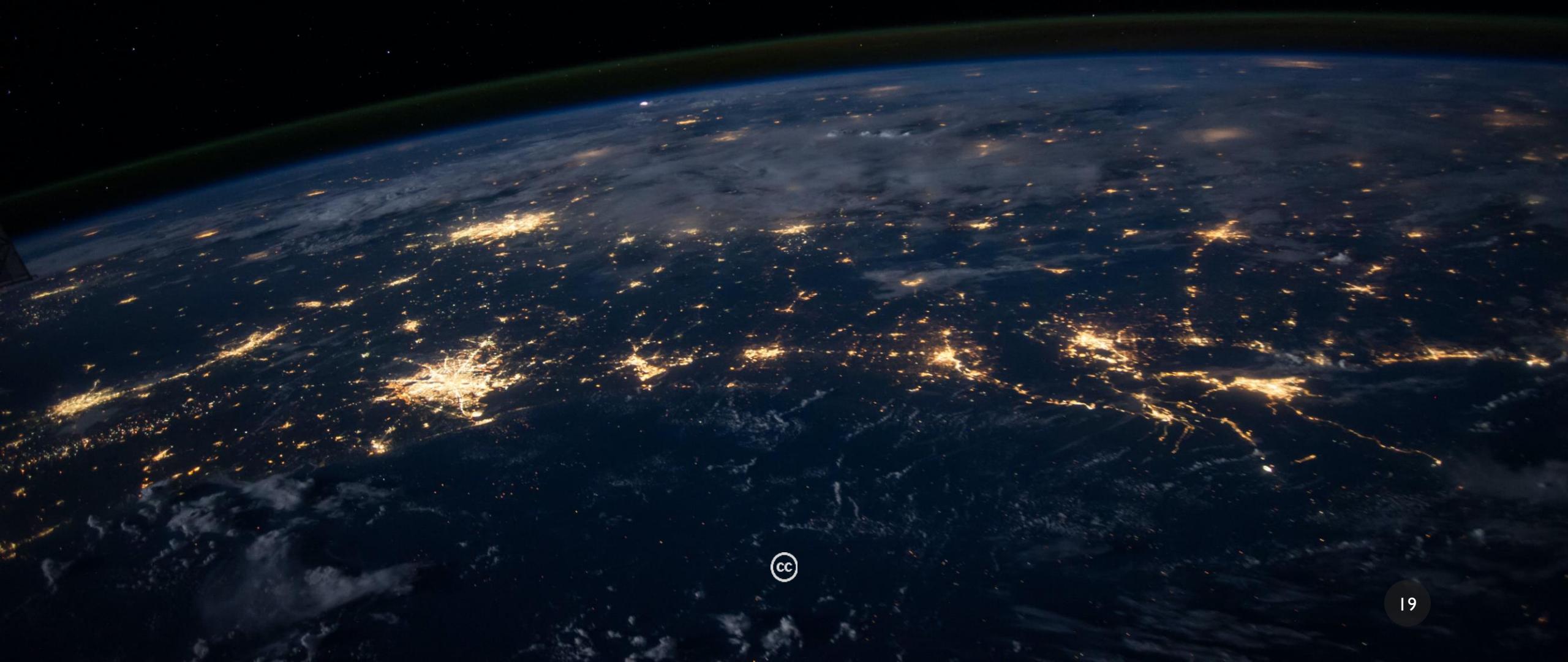
Data creation, manipulation and validation:

- 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.

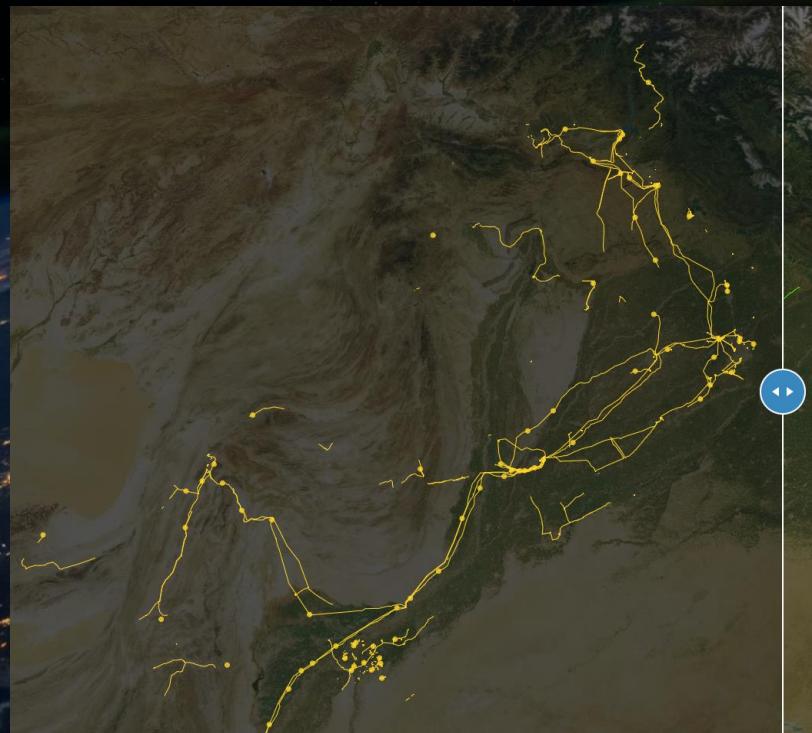
WHAT ABOUT REMOTE SENSING ?



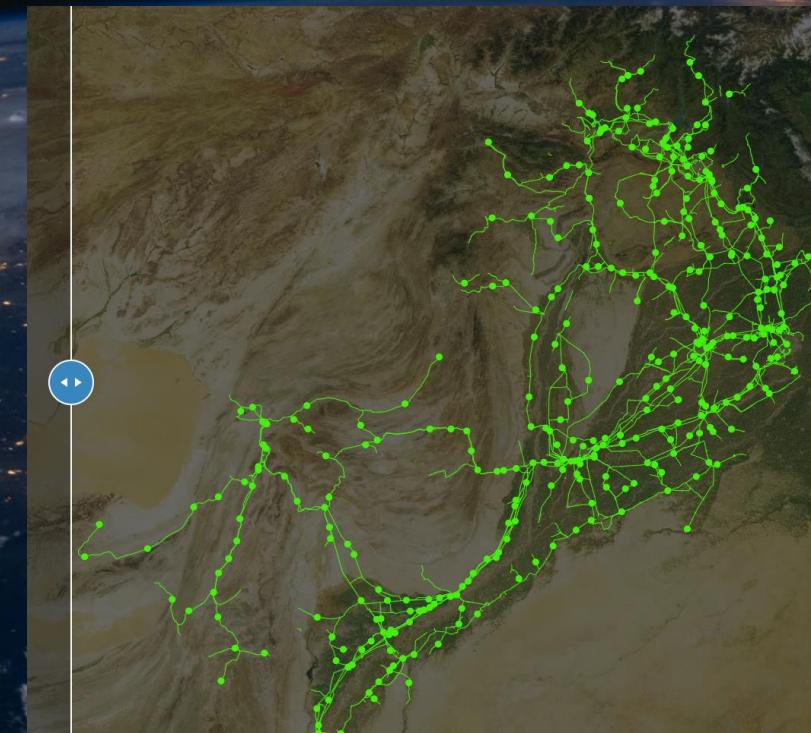
cc

Infrastructure detection:

Before



After



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

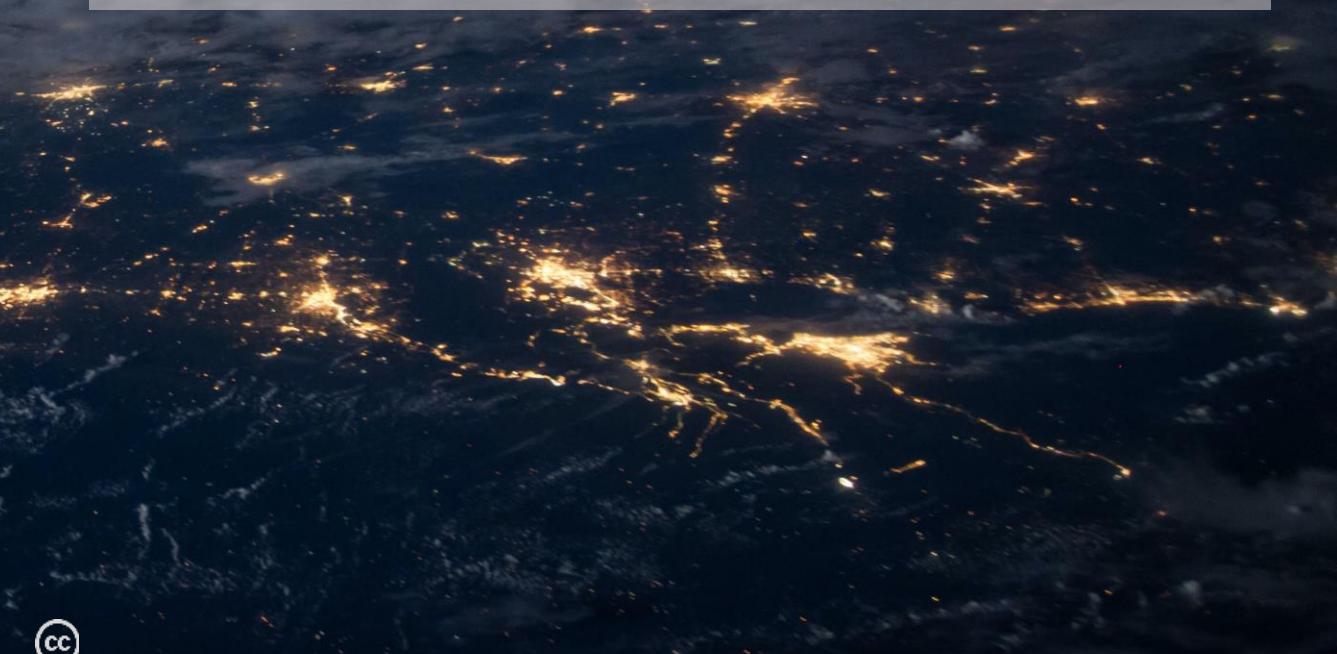


NEW:

I. Cycle-GAN to use multiple data sources



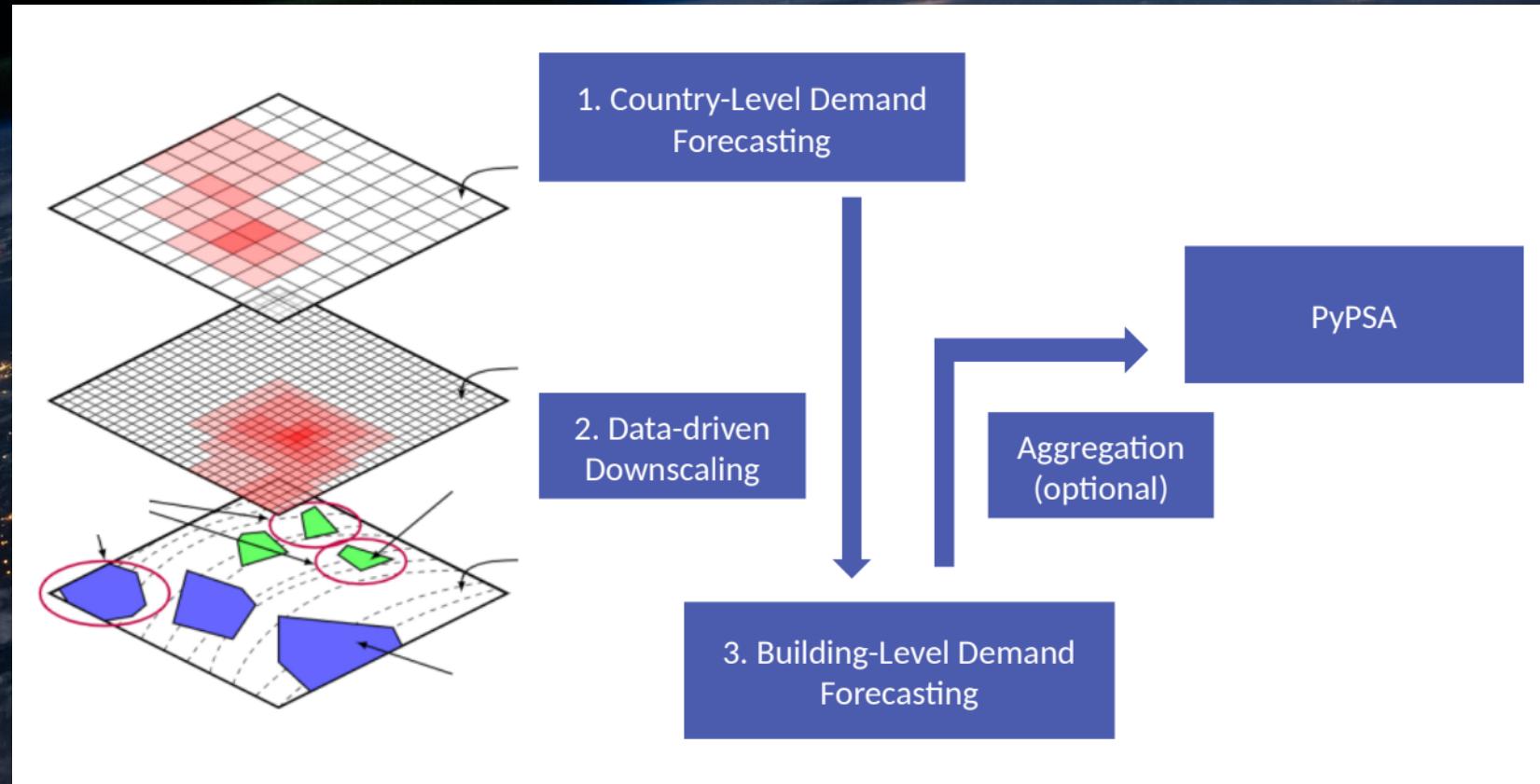
2. Reproduceable workflow to detect infrastructure across the world



cc

Demand forecasts:

VISION: high-resolution demand data around the world





WHAT'S NEXT ?

OPEN Global Independent Research Initiative



A collage of text elements on a background of a night-time satellite view of Earth from space, showing city lights and clouds.

SOLVER

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

ENERGY SYSTEM MODELS

- High resolution
- Features
- Problem formulator
- Modular
- Performance

DATA

- Creating open data
- Data workflow
- High resolution

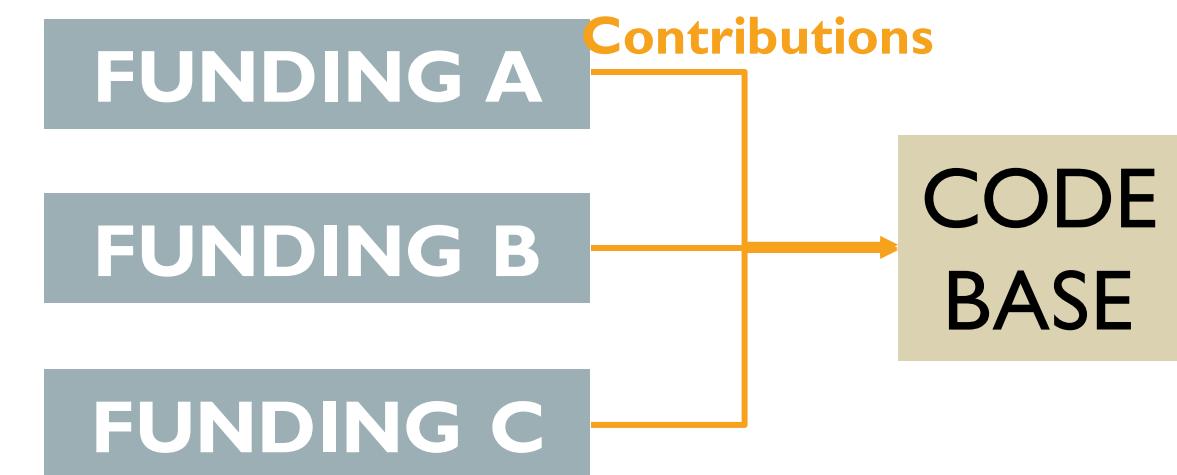
USER AND DEVELOPER COMMUNITY

- Open
- Collaborative
- Training
- Empower
- Dialogue

WORK TOGETHER



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"

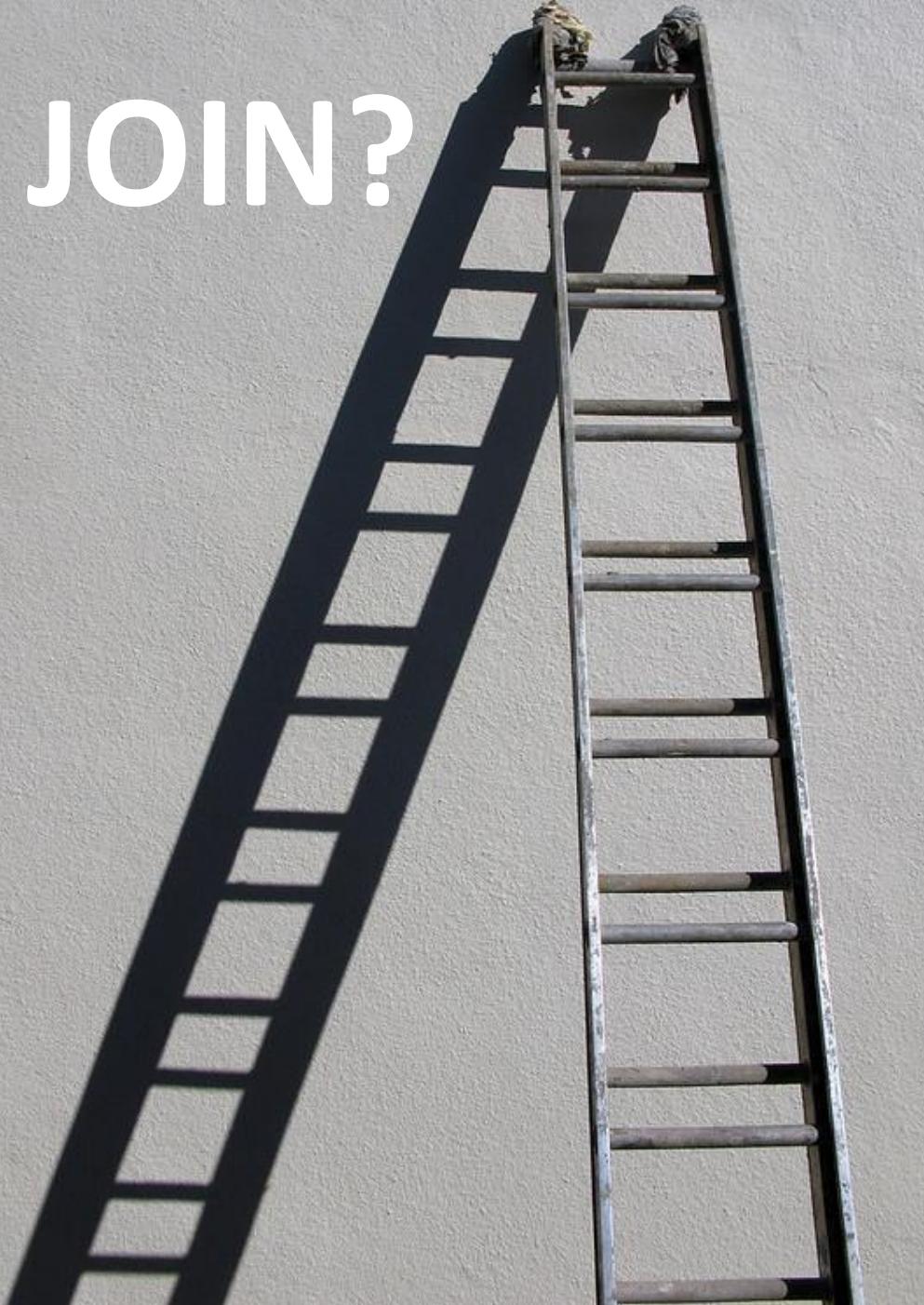
"Accelerate innovation/time, support quality, make meaningful impact"

TEAM



JOIN?

"[up and down the ladder](#)" by [Robert Couse-Baker](#) is licensed under [CC BY 2.0](#)



LEAD

IMPROVE

PARTICIPATE

USE

UNDERSTAND

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. The right sidebar shows a list of moderation roles (davidst, Lukas Franken, MaxParzen, YoTwo) and a list of 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/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

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

LET'S OPEN UP THE BLACK BOX

+ MAKE THE "OPEN BOX" THE STANDARD





MAXIMILIAN PARZEN

Co-steering the PyPSA meets Earth initiative

Address: Institute of Energy Systems
University of Edinburgh
Kings Building
EH9 3JL Edinburgh, UK
+49 176 70889068

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



SOLVER

ENERGY
SYSTEM
MODELS

DATA

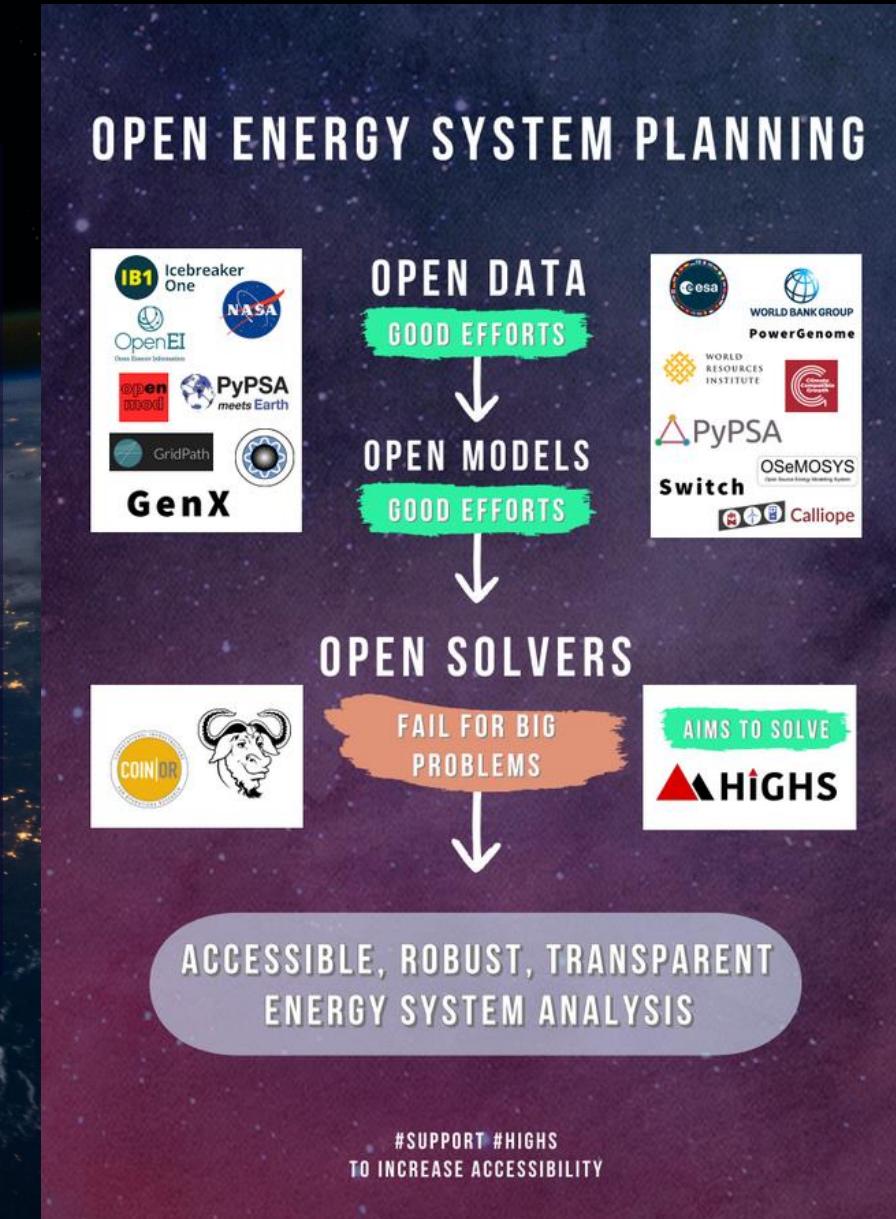
USER AND
DEVELOPER
COMMUNITY

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



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:

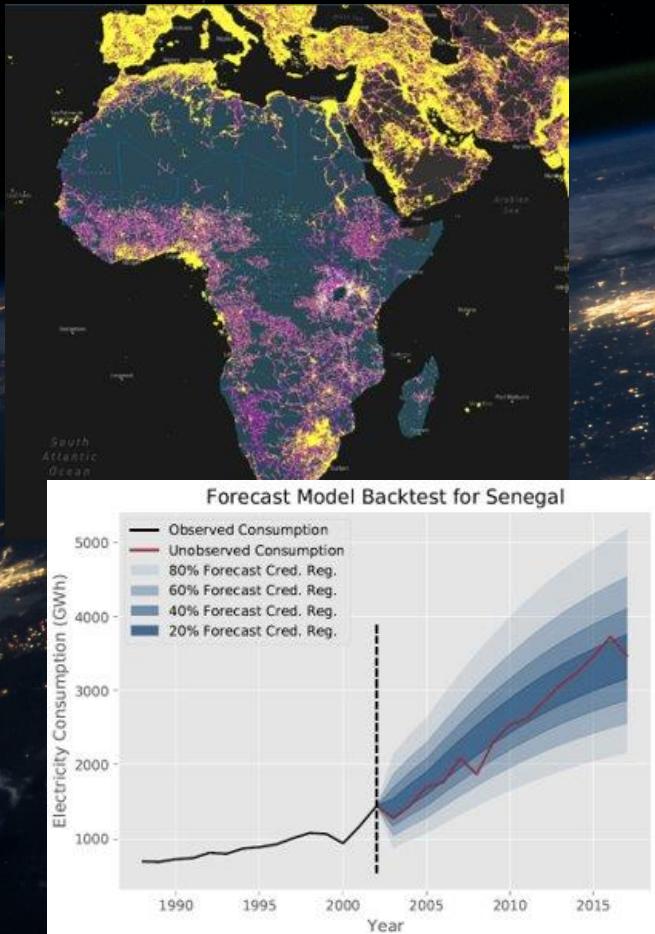
- Powerflow optimization tested against PyPOWER/MATPOWER and pandapower
- Comparison to public accessible stats and reports (e.g. IRENA on existing renewables)
- Comparison to other commercial models (e.g. provide same results as PLEXOS)

For Machine Learning:

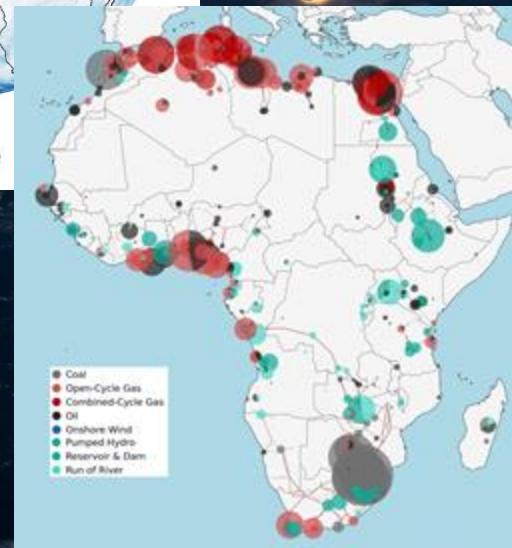
- Back-testing of historic data
- Validation data from manual validation (e.g. satellite detected images) or existing data (e.g. smart meter data)

USE EXISTING DATA TO PLAN THE FUTURE

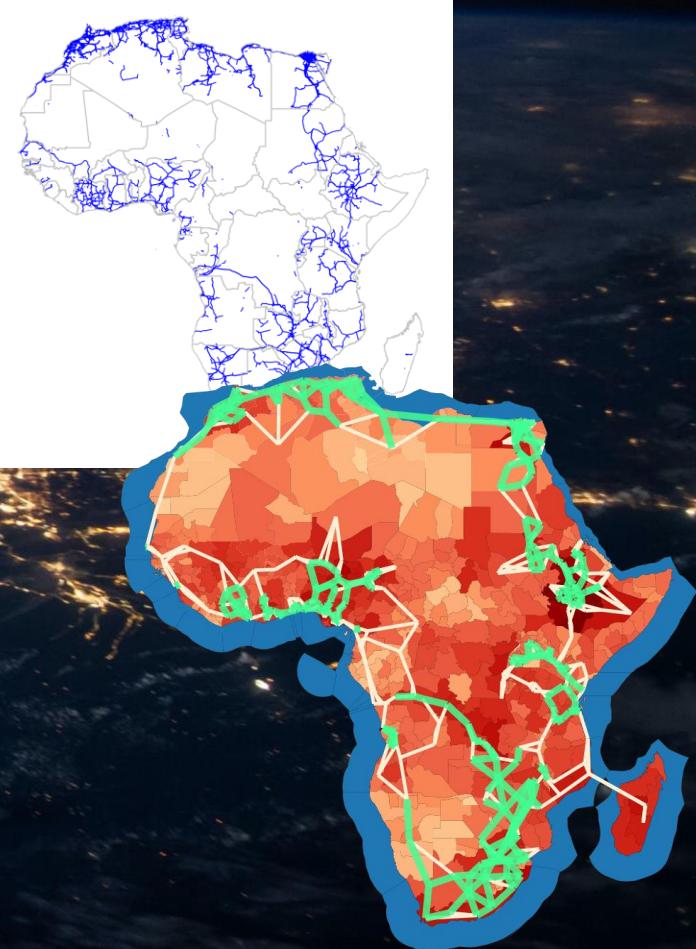
DEMAND

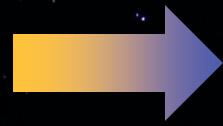


SUPPLY



NETWORK

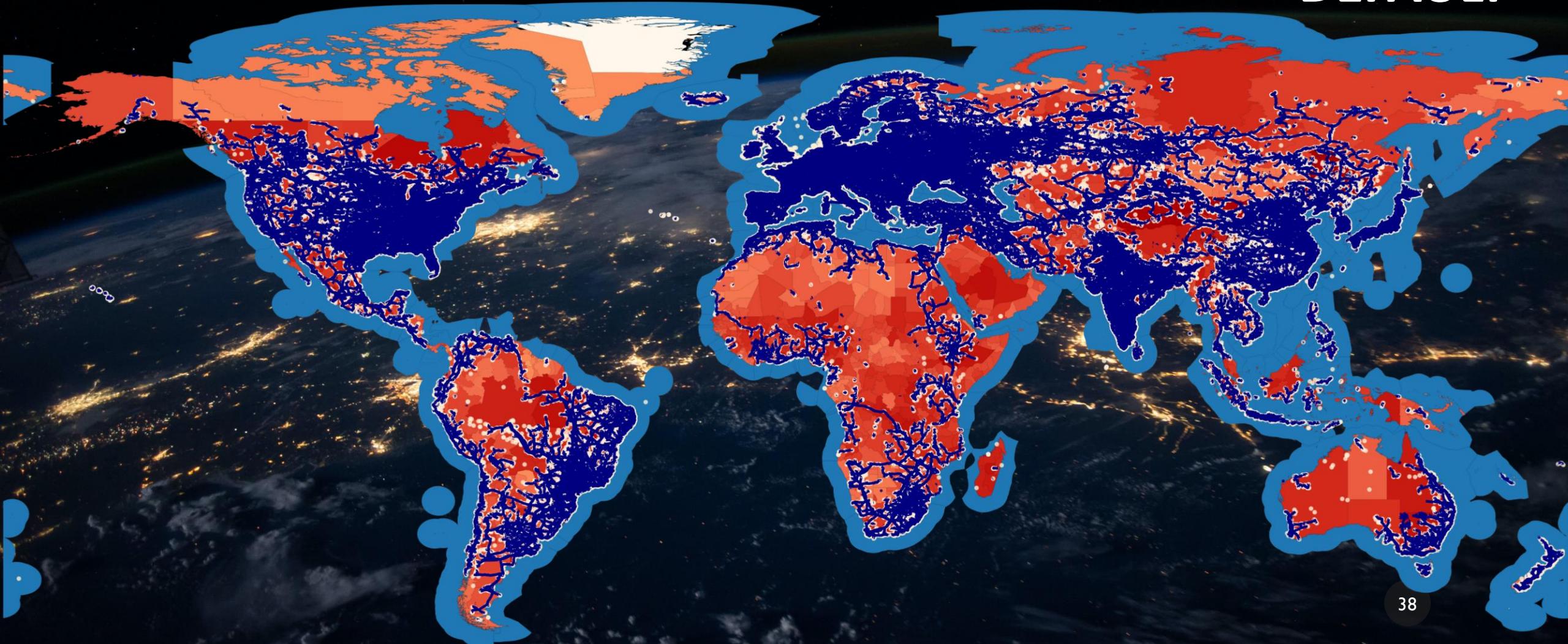




WIKIPEDIA
OF APPLIED
DATASTREAMS



GLOBAL
DATA BY
DEFAULT



WHAT IF YOU ARE MISSING DATA?

I.

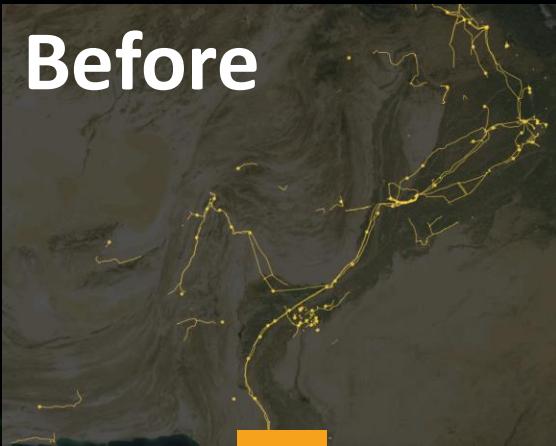
**INFRASTRUCTURE
DETECTION**



II.

**DEMAND
PREDICTION**

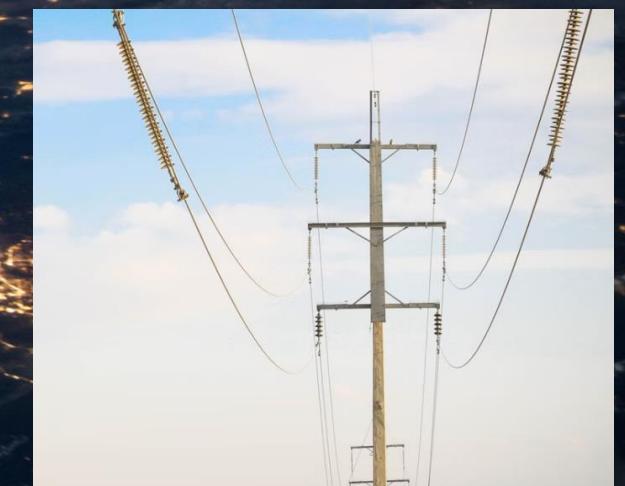
Before



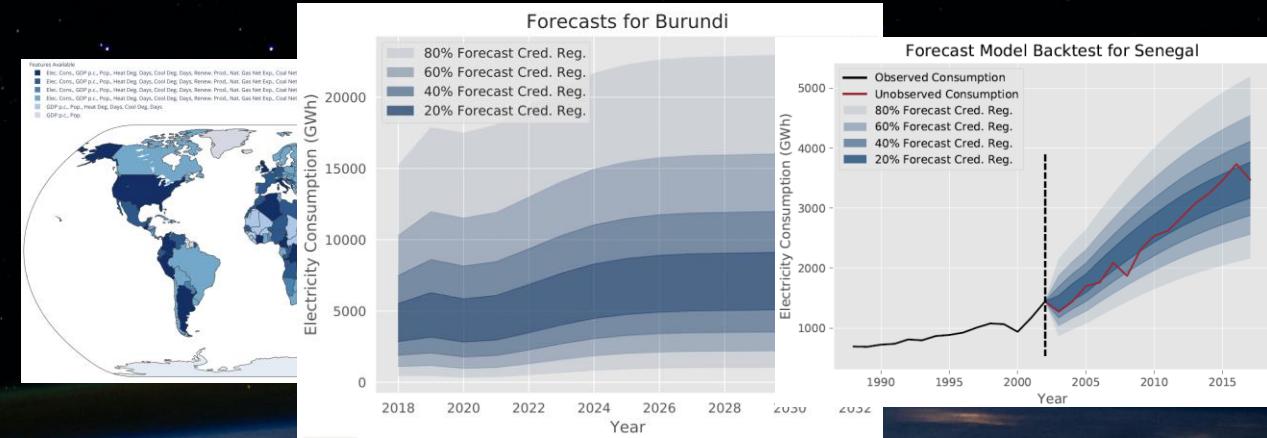
After



**Current F
ocus**



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



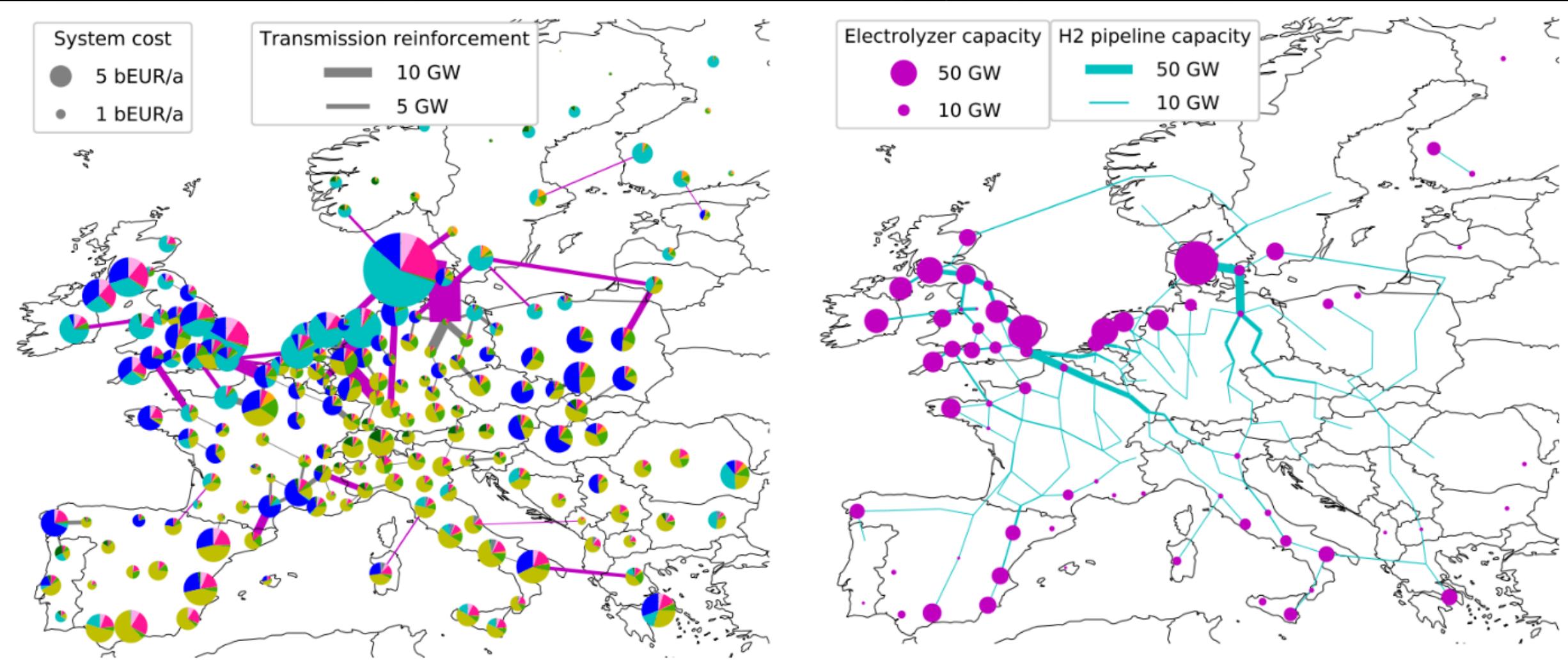
2. Downscaling via Economics-Informed Probabilistic Models and Others



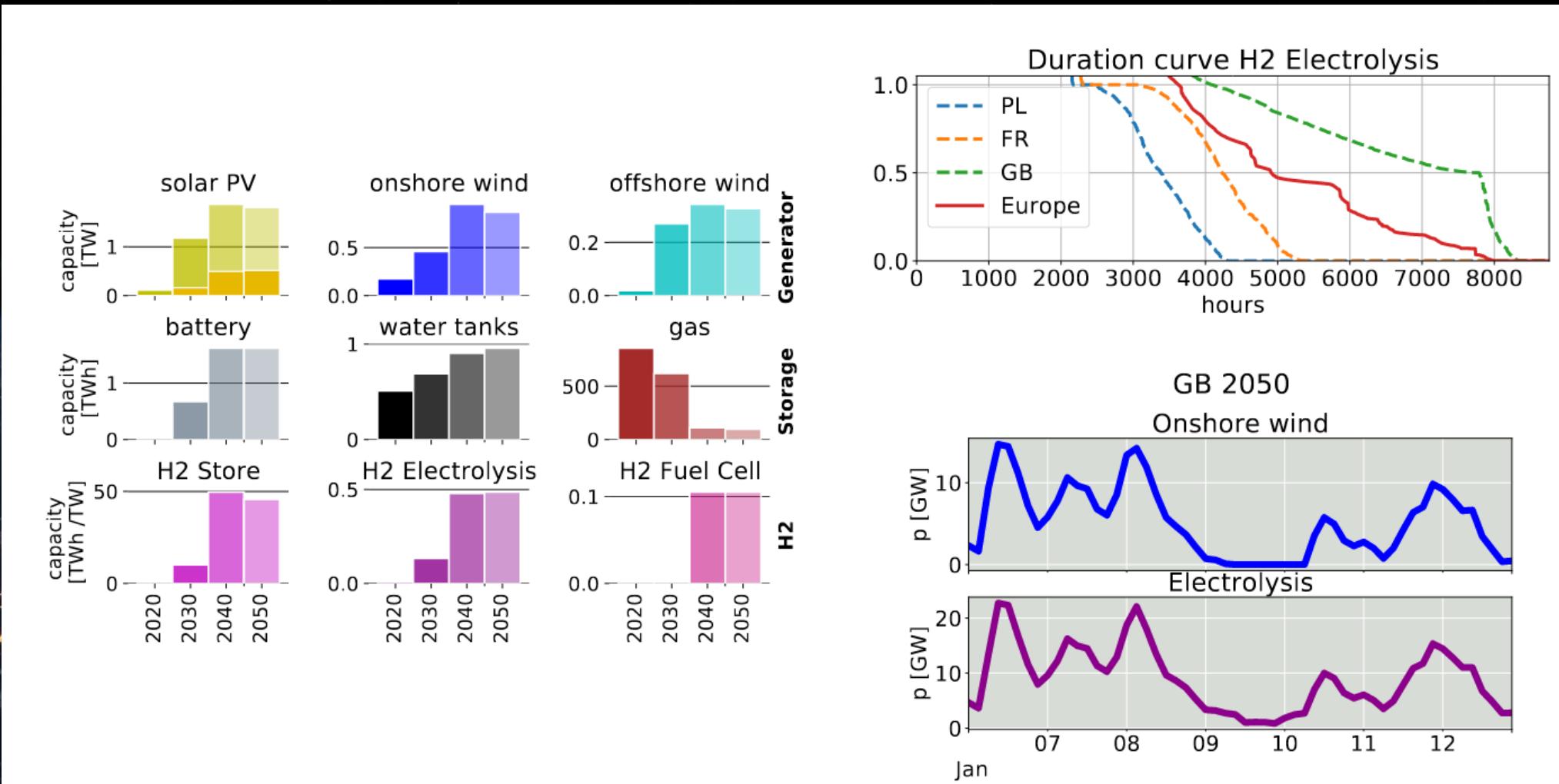
3. Building-Level Demand Forecasting via Bayesian Deep Learning and Others

HYDROGEN AND GIS

EXAMPLE OUTPUT: INVESTMENTS FOR 2050 NET ZERO SCENARIOS

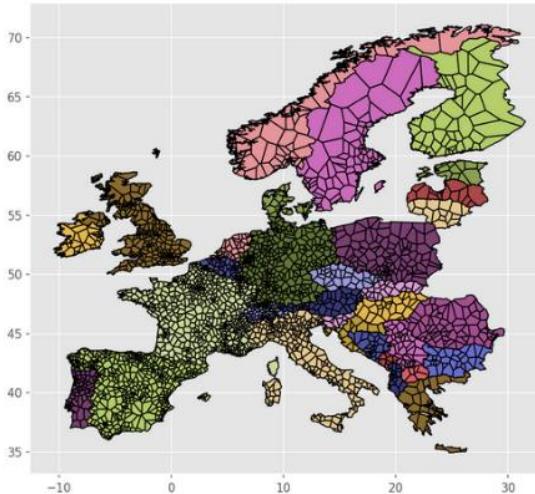


EXAMPLE OUTPUT: INVESTMENTS + OPERATION FOR 2050 NET ZERO SCENARIOS



EXAMPLE OUTPUT: INVESTMENTS + OPERATION FOR 2050 NET ZERO SCENARIOS

Installable Potential and Land Eligibility



example:
onshore wind
in one cell



Geospatial Land Availability for Energy Systems (GLAES)



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github.com/FZJ-IEK3-VSA/glaes

- **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