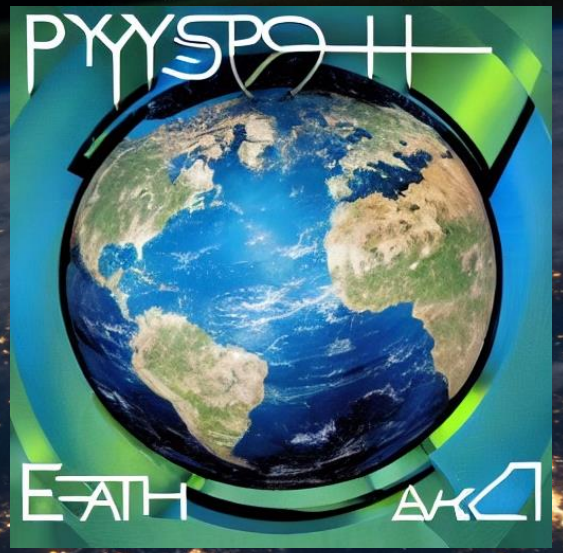
PyPSA meets Earth

Intro-slides



19.01.2023

Davide Fioriti
Maximilian Parzen

PyPSA meets Earth

OPEN Global Independent Research Initiative

SOLVER

Help sustaining

Support developers

Reveal bottlenecks

Initiate new paths

ENERGY SYSTEM MODELS

High resolution

Features

Performant

Problem formulator

Modular

DATA

Creating open data

Predicting data

Data workflow

High resolution

USER AND DEVELOPER COMMUNITY

Open

Collaborative

Dialogue

Training

Empower

PyPSA meets Earth

Grassroots initiative that aims to accelerate and cost-optimize the world's transition to sustainable, accessible and reliable energy with open-source planning tools and open data.

FRAMEWORK AND MODELS FOR ENERGY SYSTEM MODELLING

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

Documentation | Source Code | Category: Framework | Maintained: pypsa.org

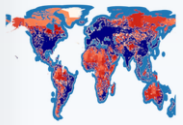
PyPSA-Eur
An open optimisation model of the European transmission system.

Documentation | Source Code | Category: Model | Maintained: pypsa.org

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

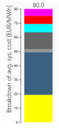
Documentation | Source Code | Category: Model | Maintained: pypsa.org

PyPSA-Earth
A flexible open sector-coupled optimization model of the global energy system.



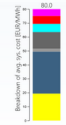
Documentation | Source Code | Category: Model | Maintained: pypsa-meets-earth

Model.Scenarios
An online toolkit for running and exploring PyPSA-Eur-Sec senarios.



Documentation | Source Code | Category: Model+Front-End | Maintained: pypsa.org

Model.Energy
An online toolkit for calculating renewable electricity supplies around the world.



Documentation | Source Code | Category: Model+Front-End | Maintained: pypsa.org

OPEN COMMUNITY

Check out our Discord server
The heart of the community life is happening on Discord (which we describe as better Slack alternative). We hold there all our meetings, coffee breaks and exchanges. Discord provides voice channels, text channels, and event stages. This also allows you to meet up or host your own events if desired.

Maintained: pypsa-meets-earth

Check out our Github Repository
You can find our developments in the GitHub repository, where you can join our community, create issues, share ideas and discuss with us. All of our developments are open source and GPL3 or MIT licensed, meaning they must stay open. Even the website you are looking at is open source. Feel free to use it and suggest improvements.

Maintained: pypsa-meets-earth

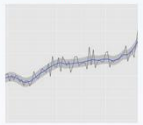
Check out our Documentation
The documentation describes in more detail how you can contribute, how our project is structured and further provides the code documentation. Additionally, we share learning materials and some relevant talks and papers in the roam of PyPSA and Earth modelling. The documentation is also open, feel free to make it better.

DATA FOR ENERGY SYSTEM MODELLING

Atlite
Convert weather data to energy systems data.

Documentation | Source Code | Category: Data | Maintained: pypsa.org

pydemand
A machine learning toolbox to create demand-timeseries in subnational resolution.



Source Code | Category: Data | Maintained: pypsa-meets-earth

Detect-Infra
A machine learning pipeline to detect infrastructure from satellite images.

Source Code | Category: Data | Maintained: pypsa-meets-earth

Powerplantmatching
A toolbox to combine multiple powerplant databases.

Documentation | Source Code | Category: Data | Maintained: pypsa.org

Technology Data
A tool that compiles assumptions on energy system technologies.

Documentation | Source Code | Category: Data | Maintained: pypsa.org

OPEN SOURCE SOLVER INTERFACES AND SUPPORT

Linopy
Linear optimization interface for Python.

Documentation | Source Code | Category: Solver interface | Maintained: pypsa.org

HiGHS-campaign
We organised a campaign, collecting +500k$, to make the worlds-fastest open-source solver HiGHS ready for large energy planning problems.

Public Proposal | Source Code | Category: Campaign | Lead by: pypsa-meets-earth

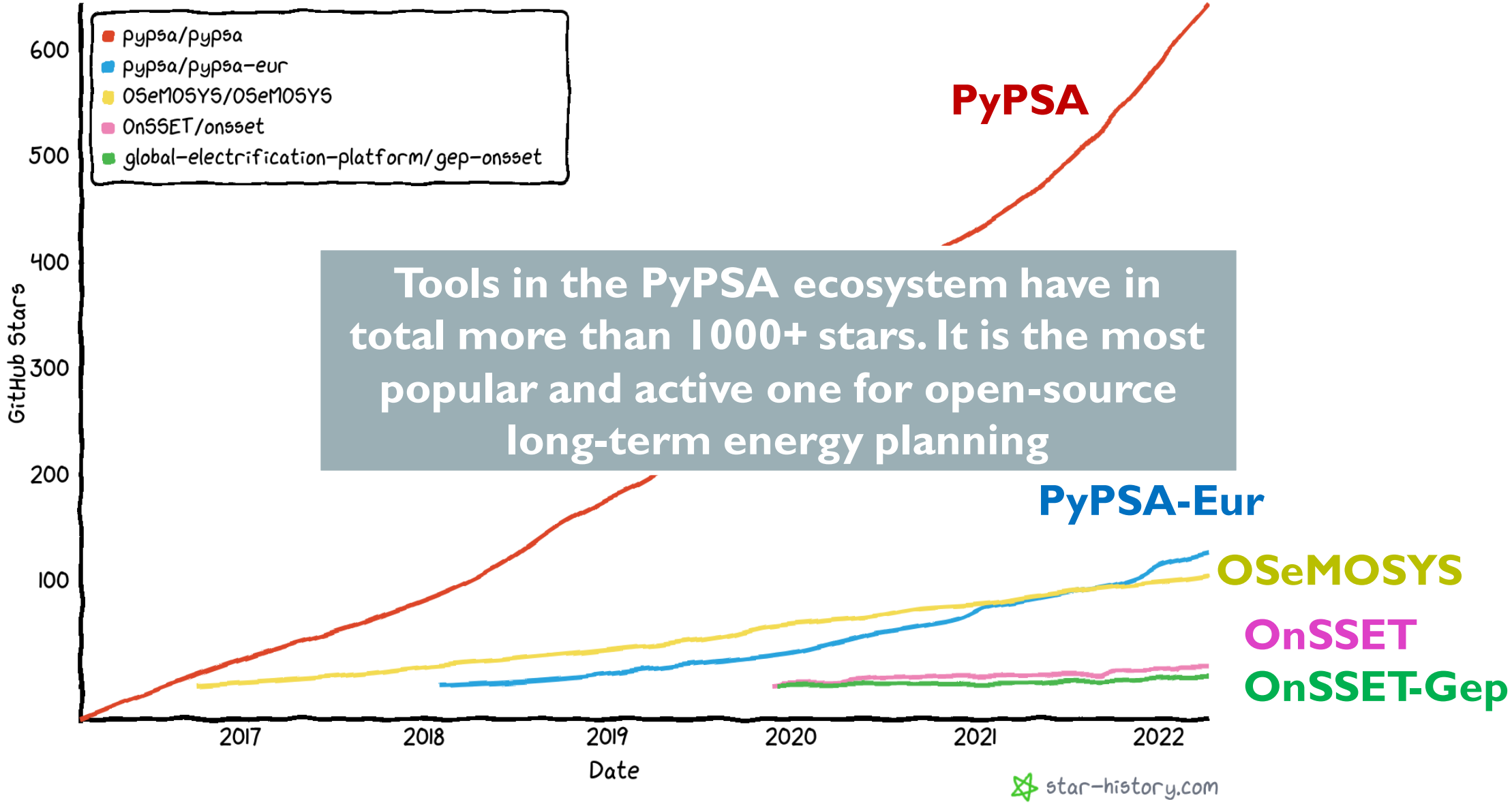
Table 1: Comparison of selected features for energy system modelling frameworks that are applied in Africa.

Software	Version	Citation	Language	Free and Open	Power Flow	Transport Model	LOPF	SCOPF	Unit Commitment	Sector-Coupling	Pathway Optimiza
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			✓	✓		✓	✓	✓

[a] Is available in GNU Mathprog, Python and GAMS.

[b] NA = no information available.

GitHub stars – indicating the user popularity and adoption



Tools in the PyPSA ecosystem have in total more than 1000+ stars. It is the most popular and active one for open-source long-term energy planning

PYPSA-EARTH
A GLOBAL MODAL SOLUTION.

PYPSA-EARTH OUTPUT EXAMPLE

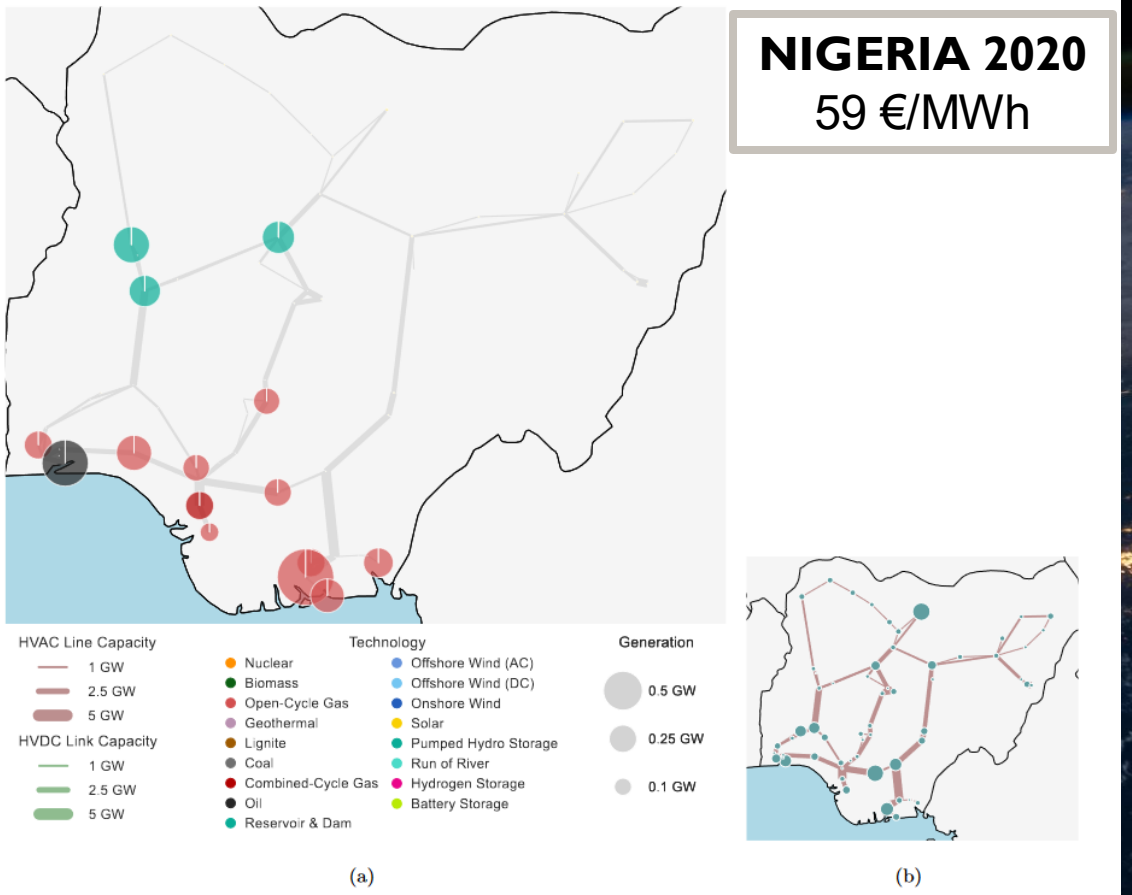


Figure 13: Optimization results of Nigeria's (a) 2020 power system. The coloured points represent installed capacities. (b) Shows all network options on a different scale as (a) with the total electricity consumption per node.

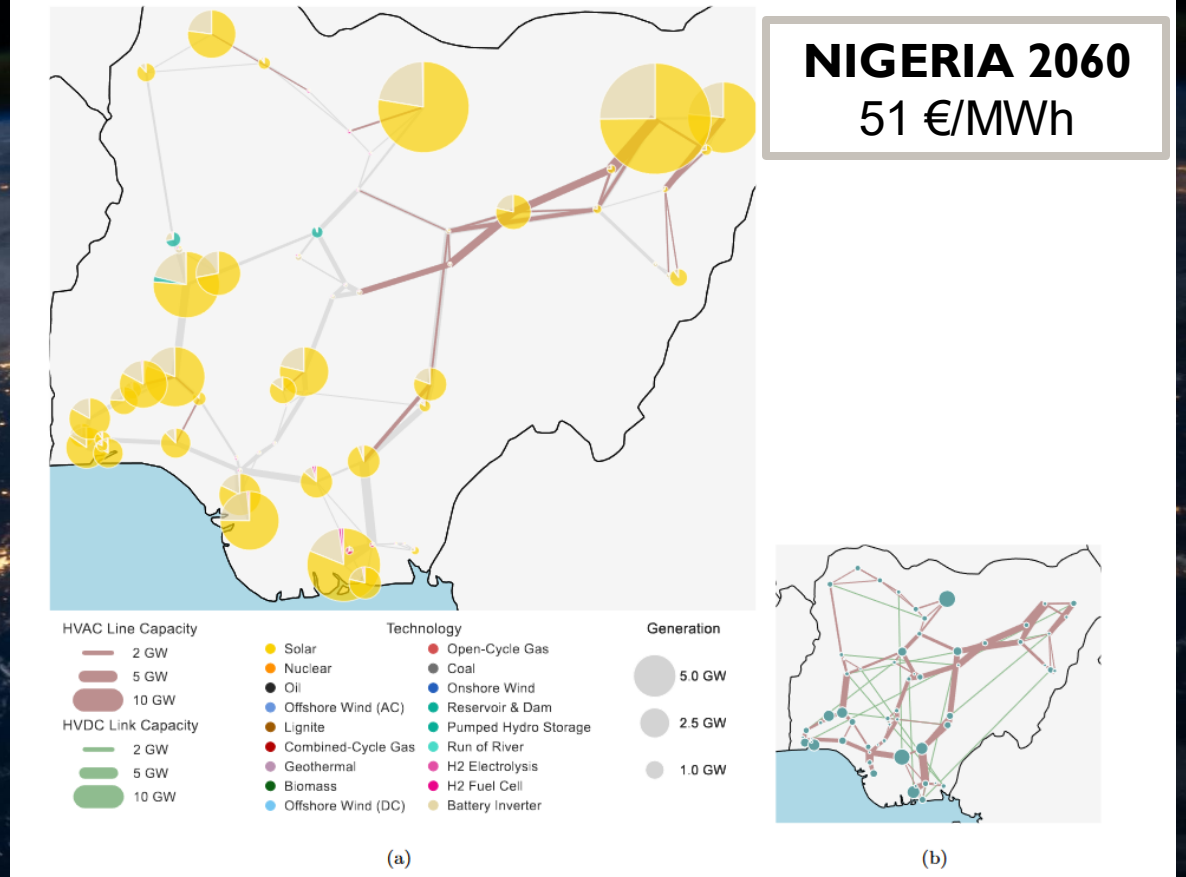
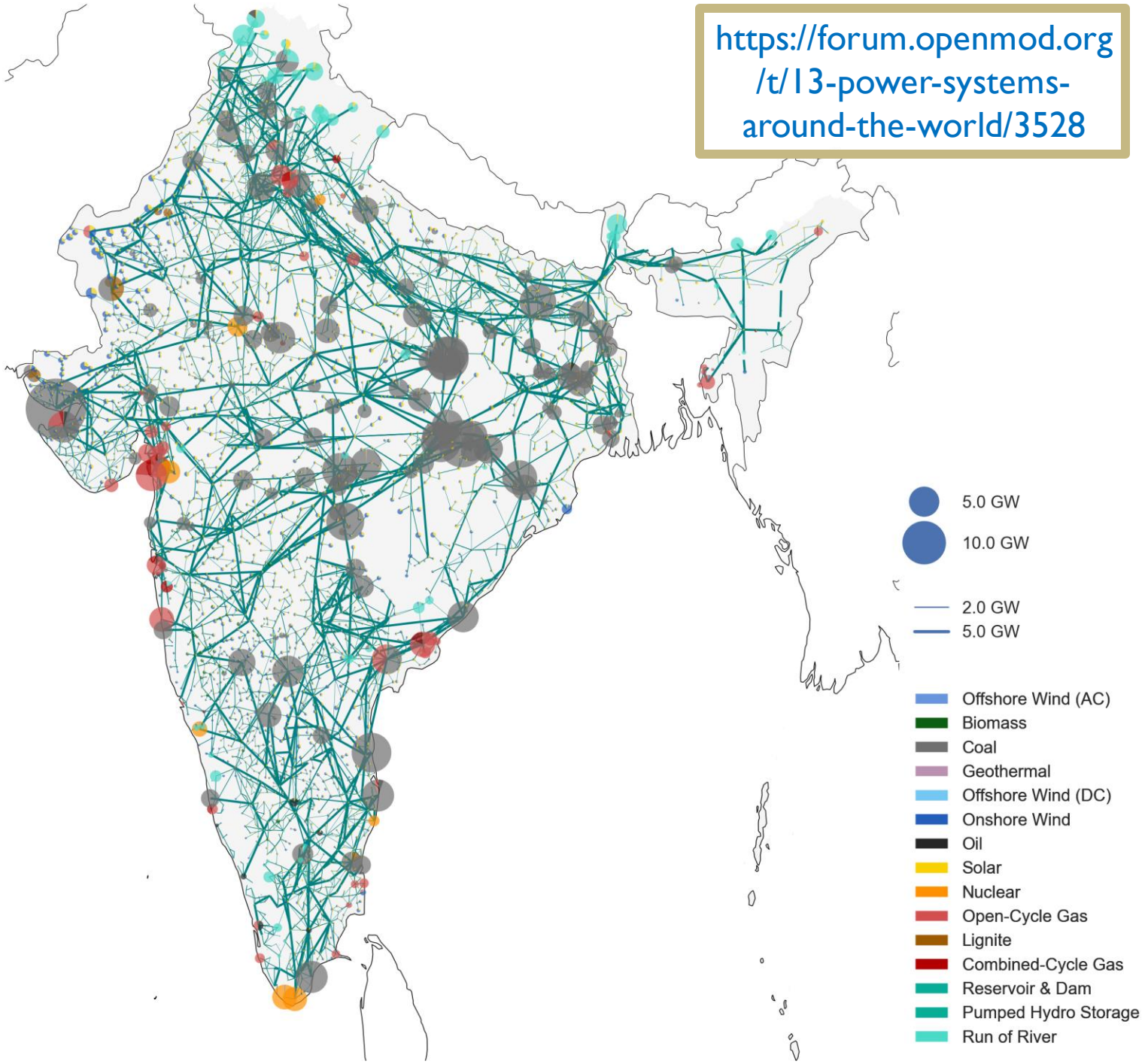


Figure 14: Optimization result represent Nigeria's (a) 2060 power system. The coloured points represent installed capacities. Light grey and dark grey lines are existing and newly optimized transmission lines, respectively. (b) Shows all network options on a different scale as (a) with the total electricity consumption per node.

https://forum.openmod.org/t/13-power-systems-around-the-world/3528



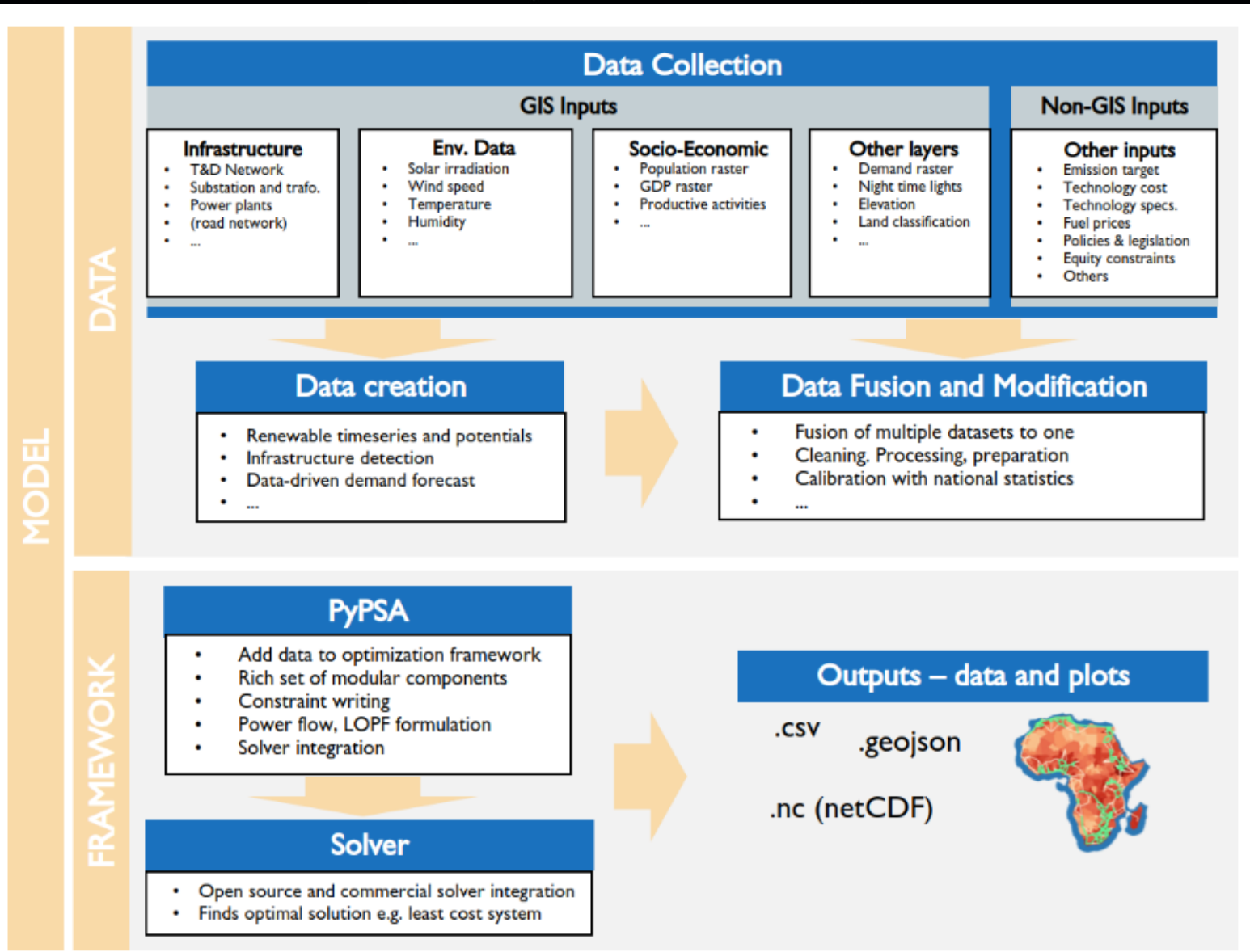
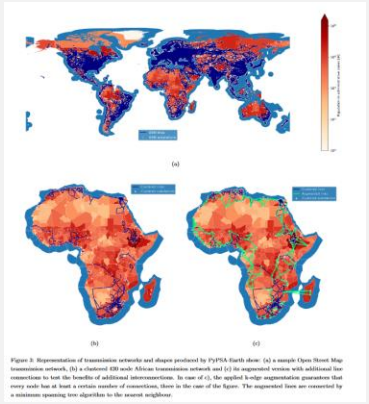


Figure 1: PyPSA-Earth model design. After providing the configuration parameters and countries of interest, data is collected and processed to be then fed into the PyPSA model framework which enables to perform the desired optimization studies such as least-cost system transition scenarios.

DIFFERENCE TO EU-MODEL

1. NEW DATA INTEGRATIONS
   - OpenStreetMap grid,
   - OpenStreetMap generators,
   - Global protected areas
   - Global landcover
   - New load data integrations (h)
   - Parameter updates
2. NEW FUNCTIONALITIES
   - Functions are generalized to work on Earth
   - Clustering along administrative zones
   - Augmented lines e.g. k-edge augmentation
   - New testing, validation and illustration soft. design
3. NEW VALIDATIONS
   - Africa validation
   - Nigeria close-look



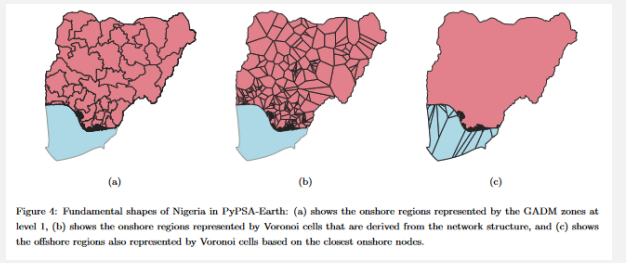


Figure 4: Fundamental shapes of Nigeria in PyPSA-Earth: (a) shows the onshore regions represented by the GADM zones at level 1, (b) shows the onshore regions represented by Voronoi cells that are derived from the network structure, and (c) shows the offshore regions also represented by Voronoi cells based on the closest onshore nodes.

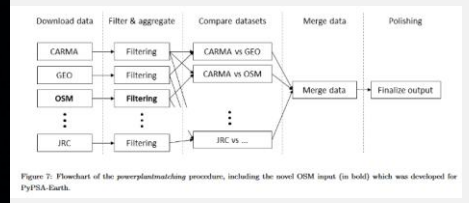
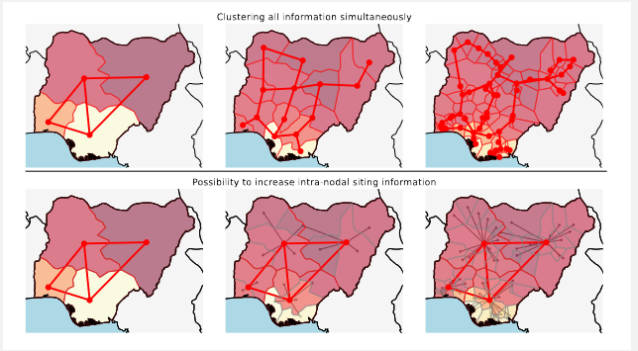
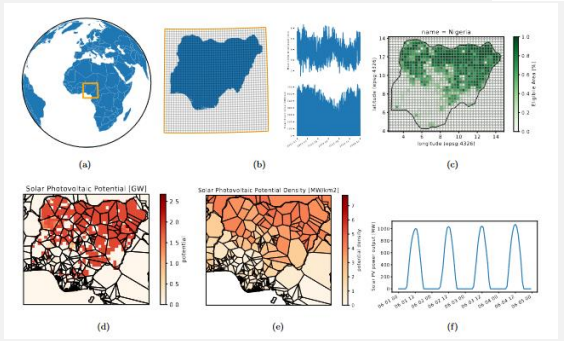


Figure 7: Flowchart of the *powerplantmatching* procedure, including the novel OSM input (in bold) which was developed for PyPSA-Earth.





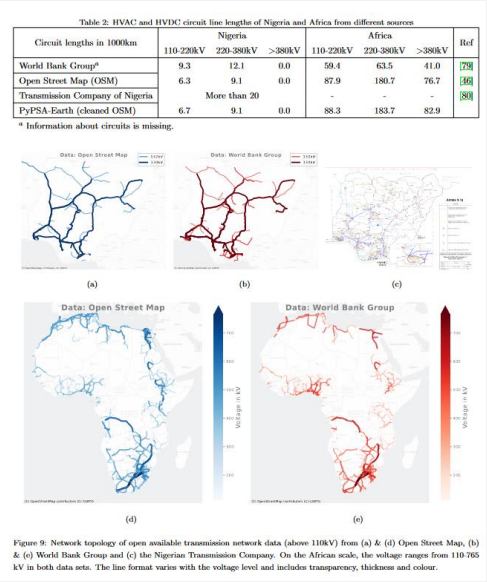
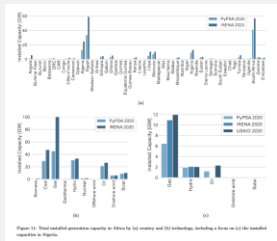


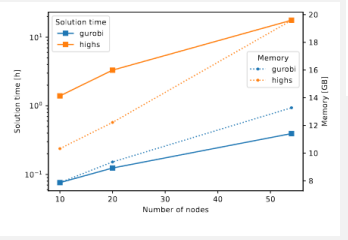
Table 2: HVAC and HVDC circuit line lengths of Nigeria and Africa from different sources

Circuit lengths in 1000km	Nigeria			Africa			Ref
	110-220kV	220-380kV	>380kV	110-220kV	220-380kV	>380kV	
World Bank Group[a]	9.3	12.1	0.0	59.4	63.5	41.0	[79]
Open Street Map (OSM)	6.3	9.1	0.0	87.9	180.7	76.7	[46]
Transmission Company of Nigeria	More than 20			-	-	-	[80]
PyPSA-Earth (cleaned OSM)	6.7	9.1	0.0	88.3	183.7	82.9	

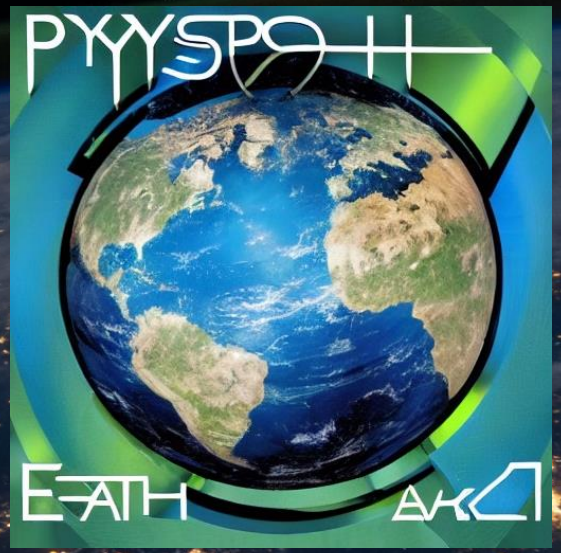
[a] Information about circuits is missing.

Figure 9: Network topology of open available transmission network data (above 110kV) from (a) & (d) Open Street Map, (b) & (e) World Bank Group and (c) the Nigerian Transmission Company. On the African scale, the voltage ranges from 110-765 kV in both data sets. The line format varies with the voltage level and includes transparency, thickness and colour.





YOU CAN CHANGE THE WORLD!



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