FROM AFRICA TO EARTH ENERGY SYSTEM MODELLING

THU, 27
JANUARY 2022
14:00 - 15:55
BST/UTC+0

Webinar on:

PyPSA meets Africa

PyPSA meets Earth

WEBINAR WITH PANEL DISCUSSION

Panellists associated to:

GLOBAL PST CONSORTIUM

CSIR
Touching lives through innovation

IRENA
International Renewable Energy Agency

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

"Limiting global warming to 1.5°C would require rapid, far-reaching and unprecedented changes in all aspects of society" **- IPCC**

PyPSA meets Earth

WE NEED TO PLAN NOT ONLY OPERATIONS BUT ALSO INVESTMENTS

AFFORDABLE RELIABLE SUSTAINABLE

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

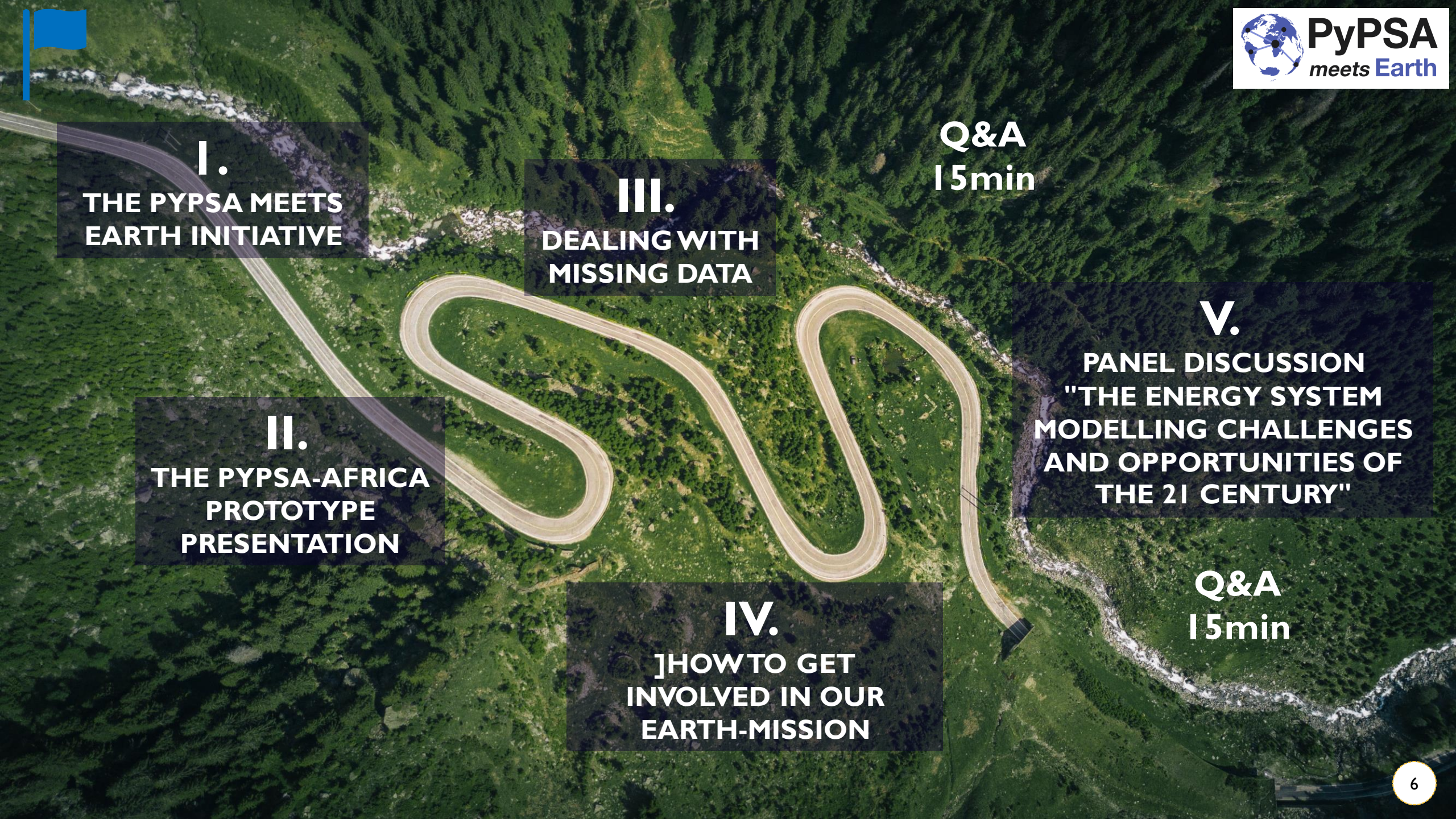
Dialogue

Training

Empower

VISION

Create TOGETHER useful alternatives to closed-source energy system models for industry and research


I.
THE PYPSA MEETS EARTH INITIATIVE
II.
THE PYPSA-AFRICA PROTOTYPE PRESENTATION
III.
DEALING WITH MISSING DATA
IV.
]HOW TO GET INVOLVED IN OUR EARTH-MISSION
Q&A
15min
V.
PANEL DISCUSSION "THE ENERGY SYSTEM MODELLING CHALLENGES AND OPPORTUNITIES OF THE 21 CENTURY"
Q&A
15min

I.
THE PYPSA MEETS EARTH INITIATIVE

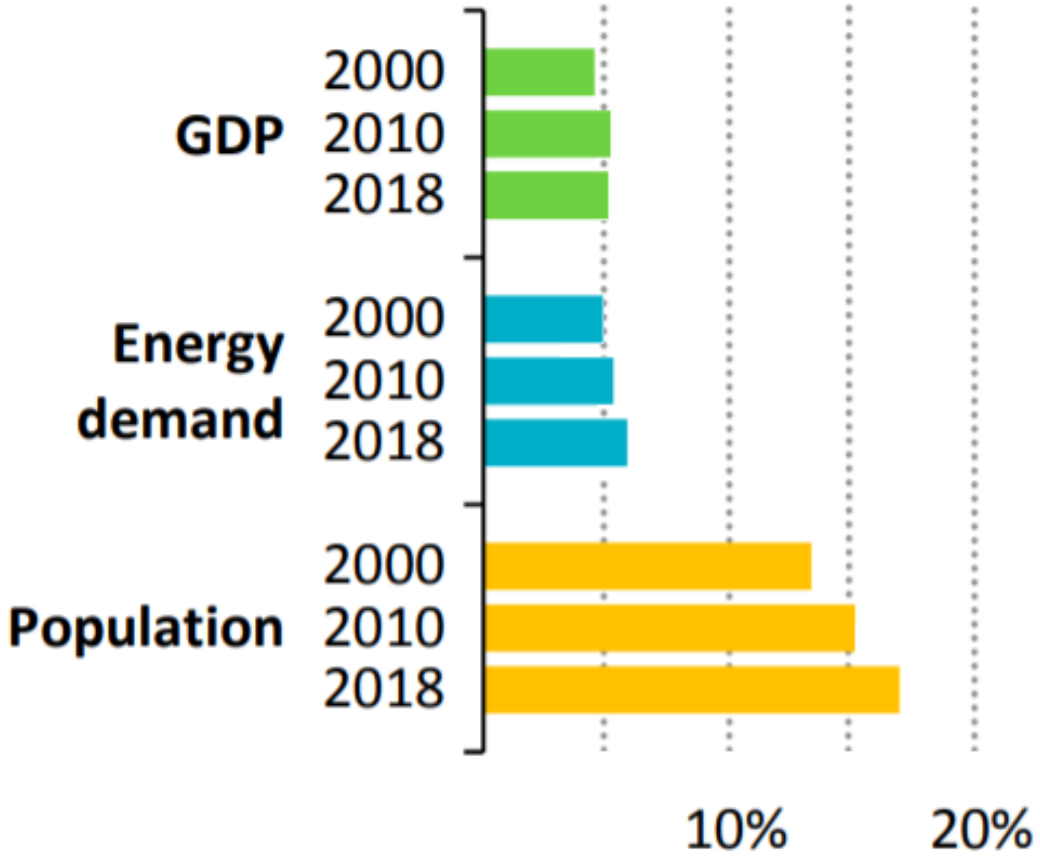
II.
THE PYPSA-AFRICA PROTOTYPE PRESENTATION

THE PROBLEM

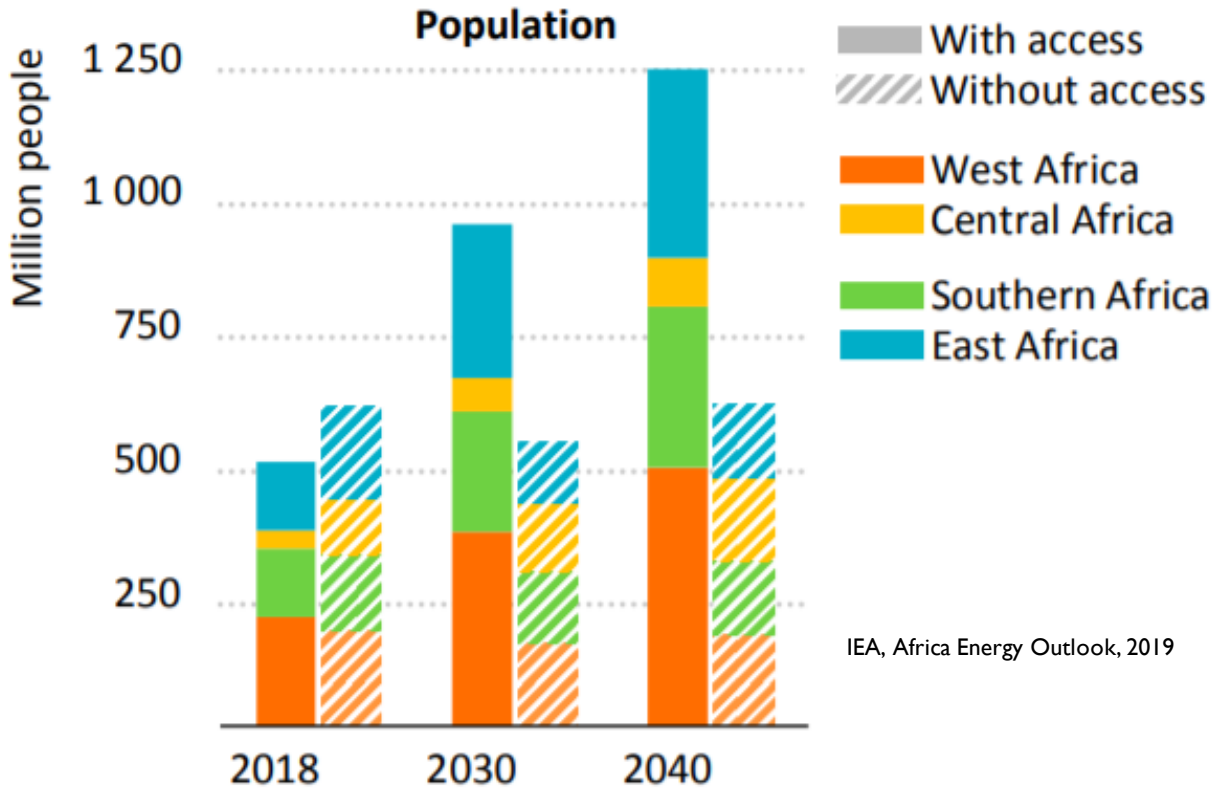
AFRICA IS DARK!

PROBLEM WILL GROW

Per capita indicators shall increase …



… and population is growing …



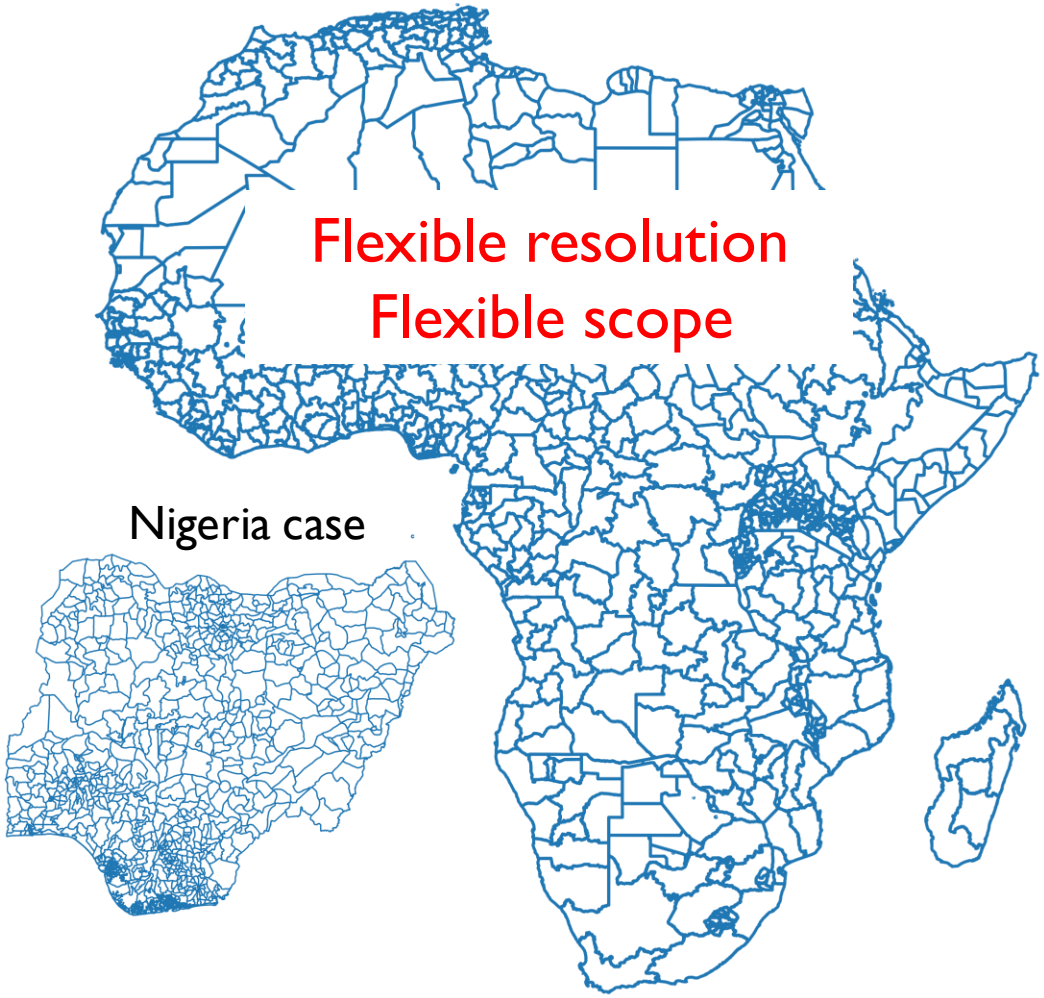
IEA, Africa Energy Outlook, 2019

PLANNING FOR A BRIGHT FUTURE

ROLE OF PYPSA

Standard models

PyPSA-Africa



PYPSA-AFRICA FEATURES

Policy makers and utilities need:

- **Robust**
- **Low cost**
- **Reliable**
- **Easy-to-use**
- **Planning & dispatch tools**

PYPSA-AFRICA FEATURES

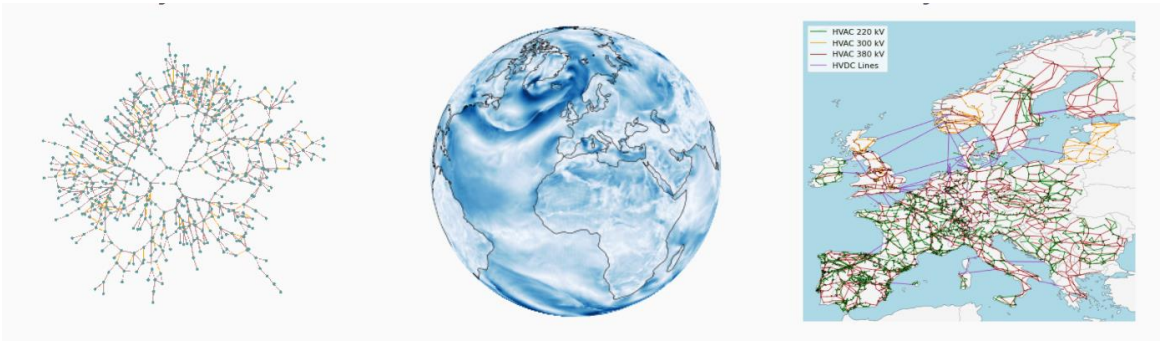
Policy makers and utilities need:

- **Robust** Built on top of PyPSA-Eur, …
- **Low cost** Open-source model
- **Reliable** Community support (>60pp)
- **Easy-to-use** python™
- **Planning & dispatch tools**

  Scenario analysis
  Adjustable resolution
  Sector-coupling (coming soon)

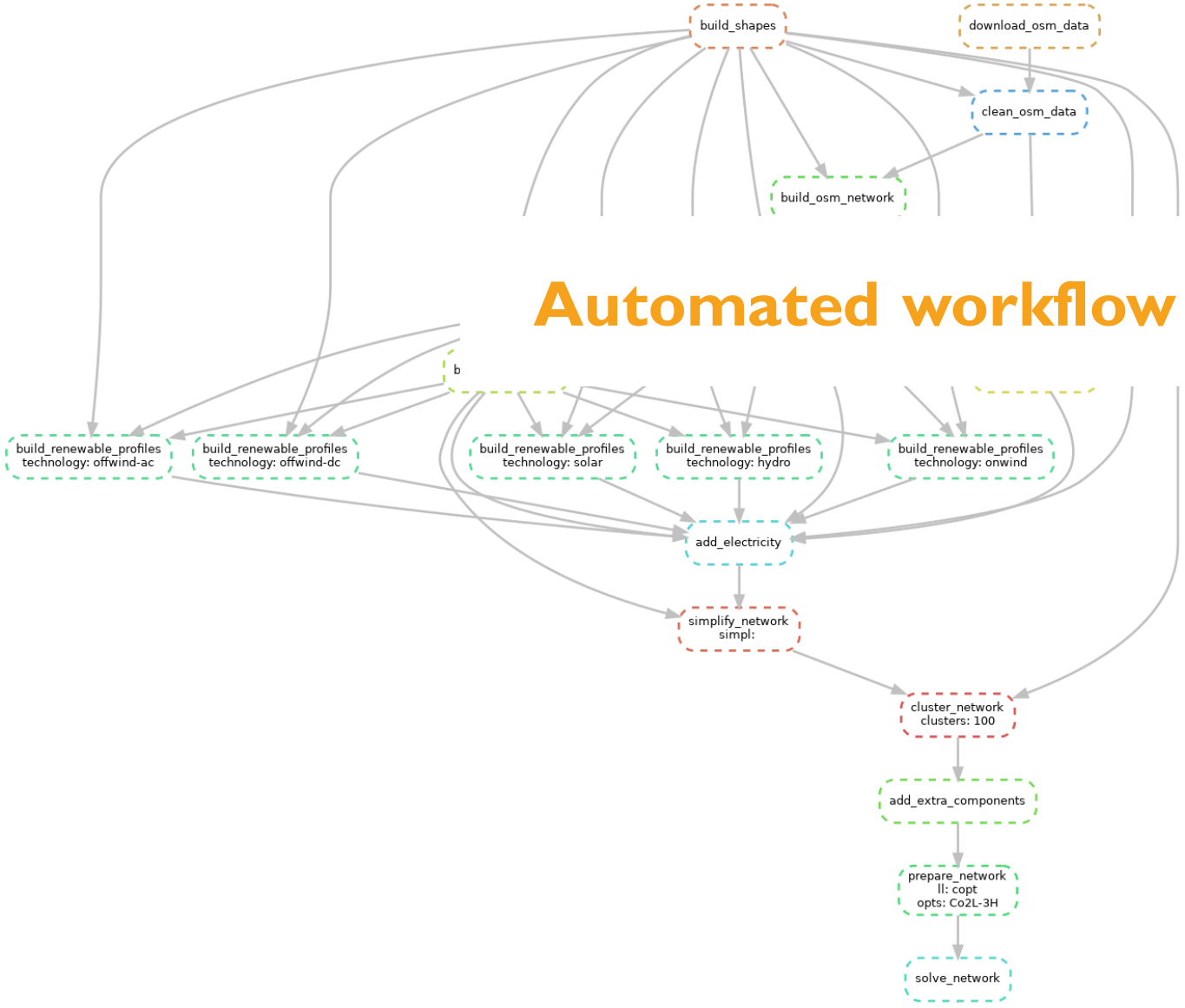
PyPSA meets Africa

Credits also to



PyPSA | Atlite | PyPSA-Eur

HOW IT WORKS



Config file

Data processing

Download data

Filter data

Combine data

Create model

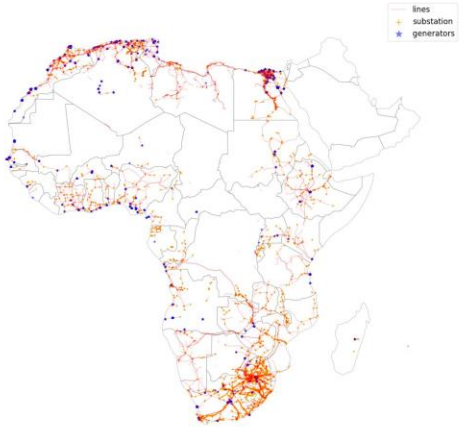
Solve

Results

DATA PROCESSING

Open-source datasets:

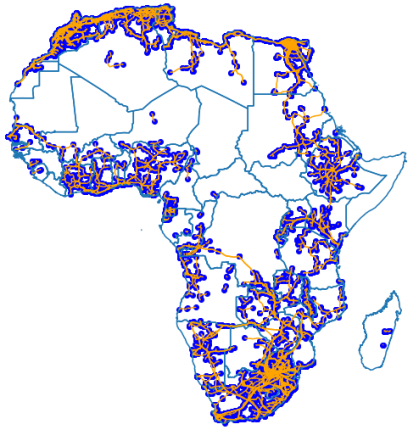
- OpenStreetMap (OSM)
- Database of Global Administrative Areas (GADM)
- ERA5 from Copernicus Climate Change Service
- ….



Download data
Filter data
Combine data

- **Accurate network description**
- **Demand and renewable by region**

GDP,
Population,
RES.
…



Network data

DEEP DIVE
THE PYPSA-AFRICA PROTOTYPE

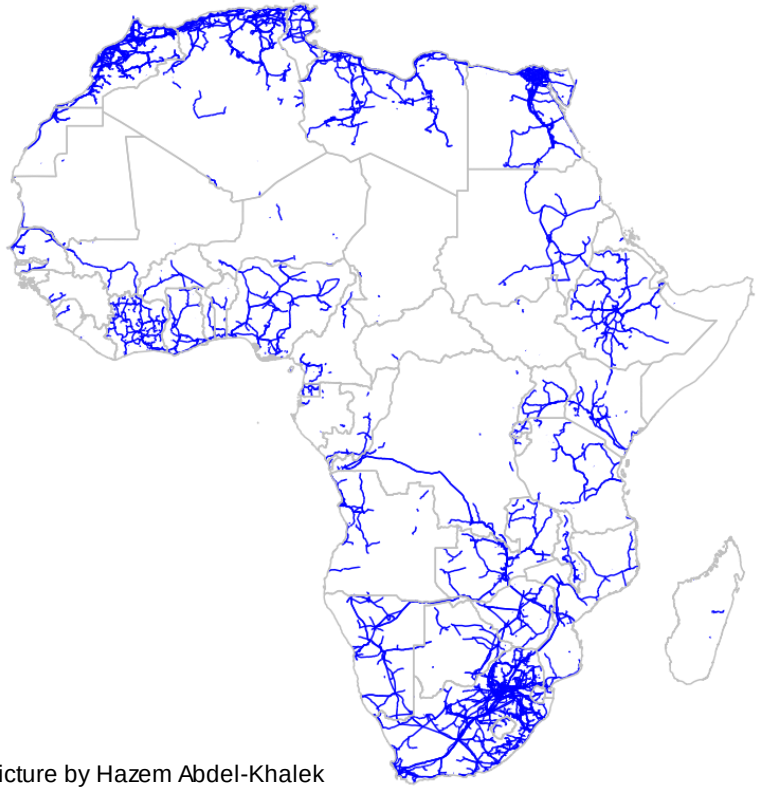
1. Network data by Open Street Map
2. Powerplant data
3. Renewables and demand assessment
4. Clustering to deal with complexity
5. Network augmentation
6. Some results

NETWORK DATA OPENSTREETMAP

PyPSA meets Africa

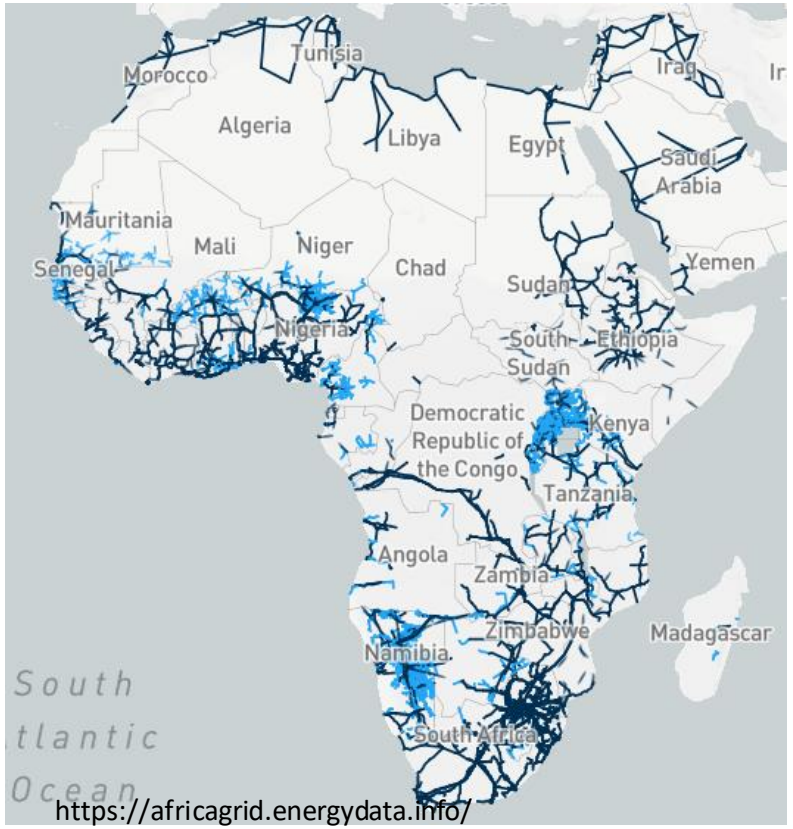
For the African continent …

```
countries: ["africa"]
```

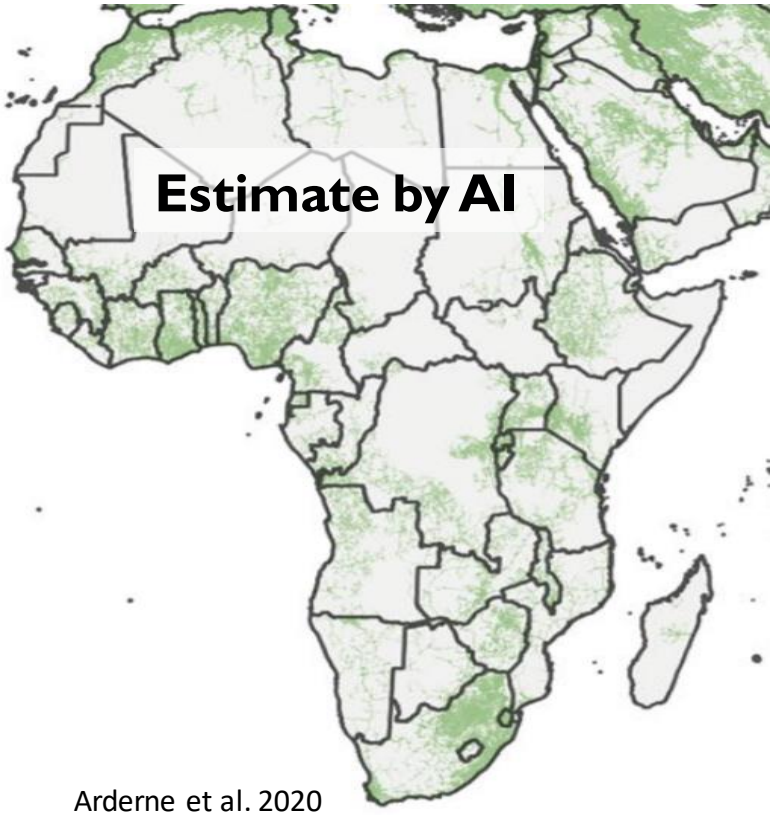


Picture by Hazem Abdel-Khalek

Good but improvements needed



https://africagrid.energydata.info/



Arderne et al. 2020

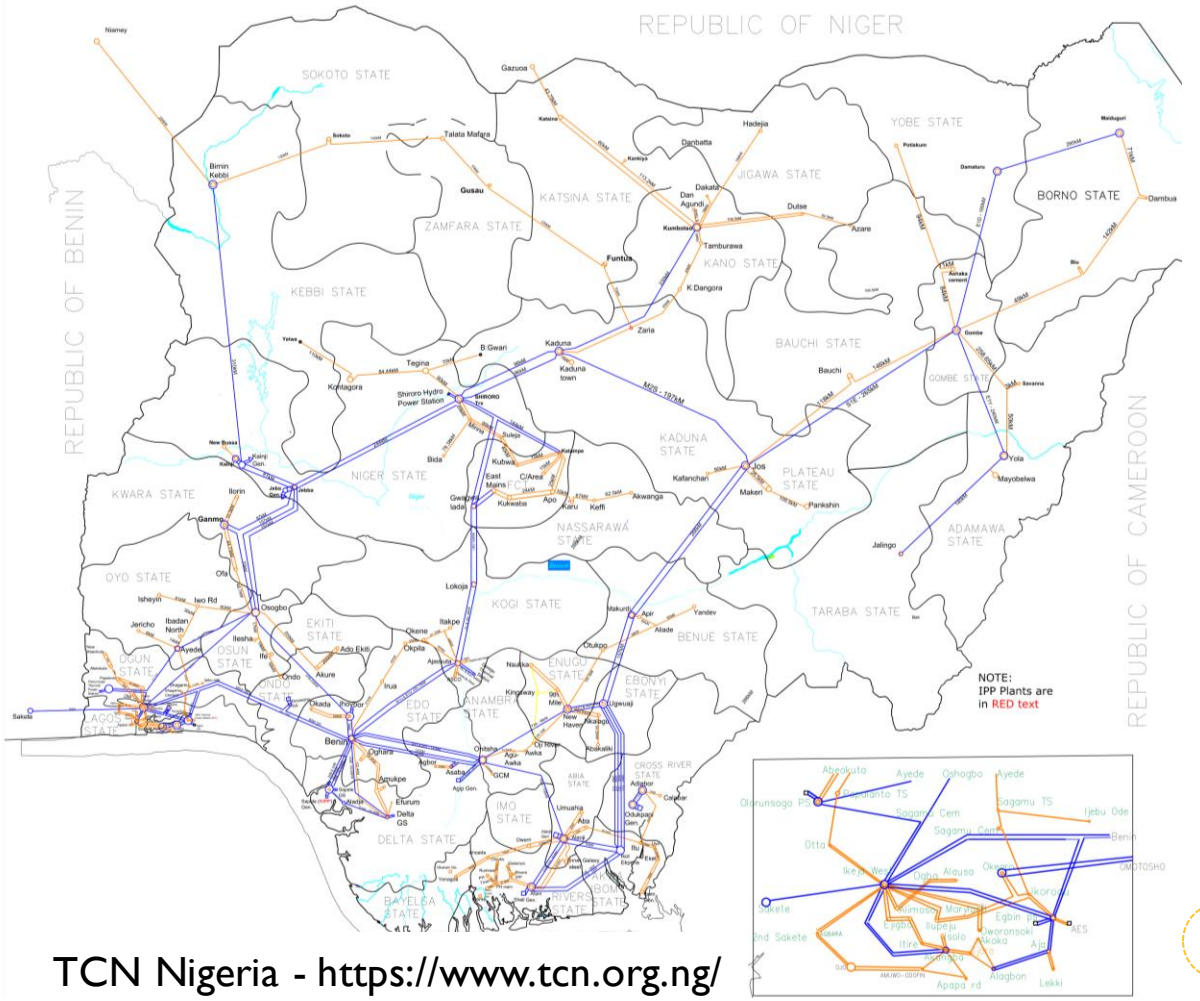
NETWORK DATA OPENSTREETMAP

PyPSA meets Africa

… and (group of) countries

```
countries: ["NG"]
```

100% validation of topology, data TSO



TCN Nigeria - https://www.tcn.org.ng/

POWERPLANTS

WHAT DATASET?

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

POWERPLANTS

WHAT DATASET?

- Carbon Monitoring for Action (**CARMA**)
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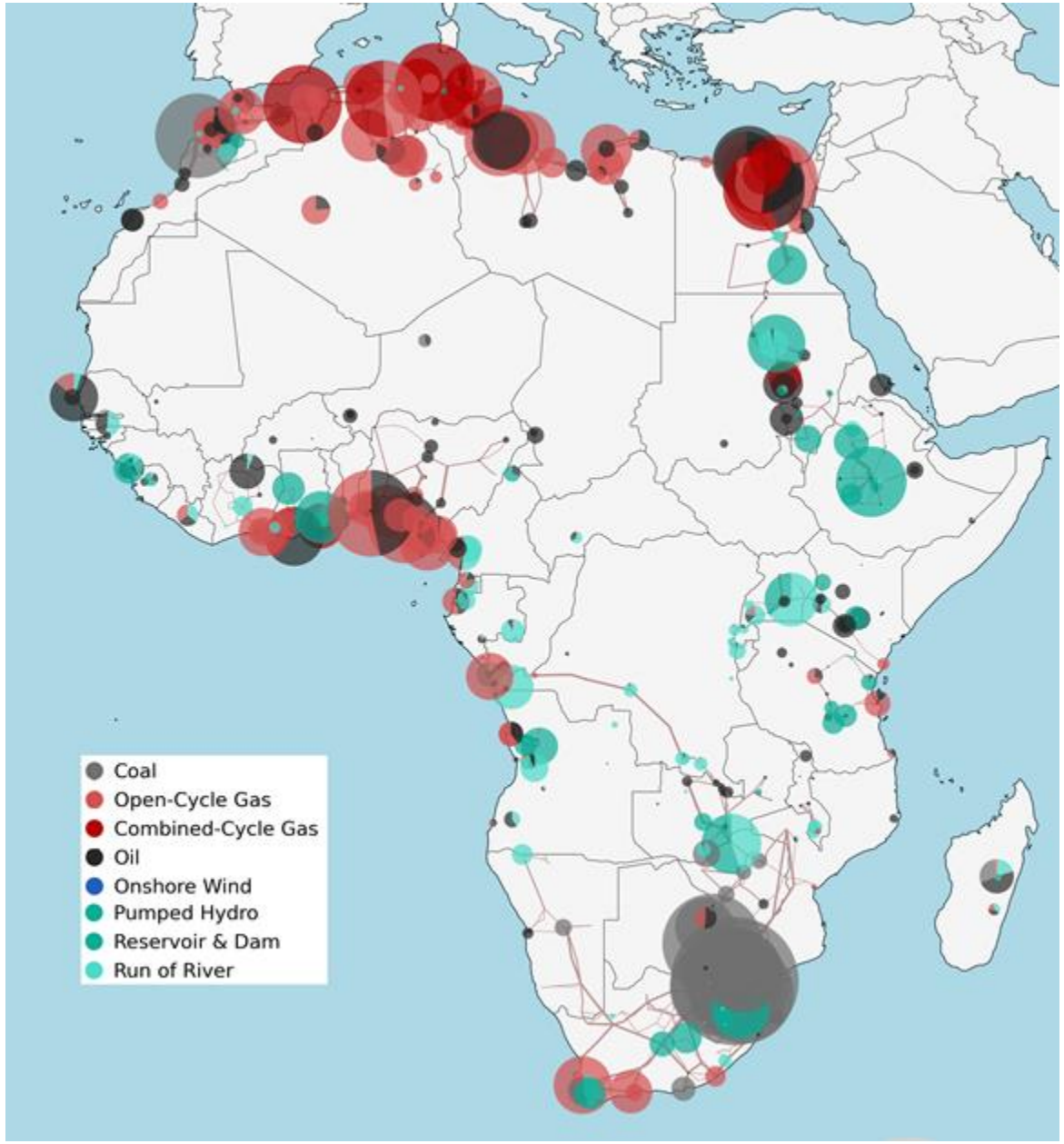
ALL! Powerplantmatching!

POWERPLANTS

Datasets to merge:

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

Merge datasets by 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

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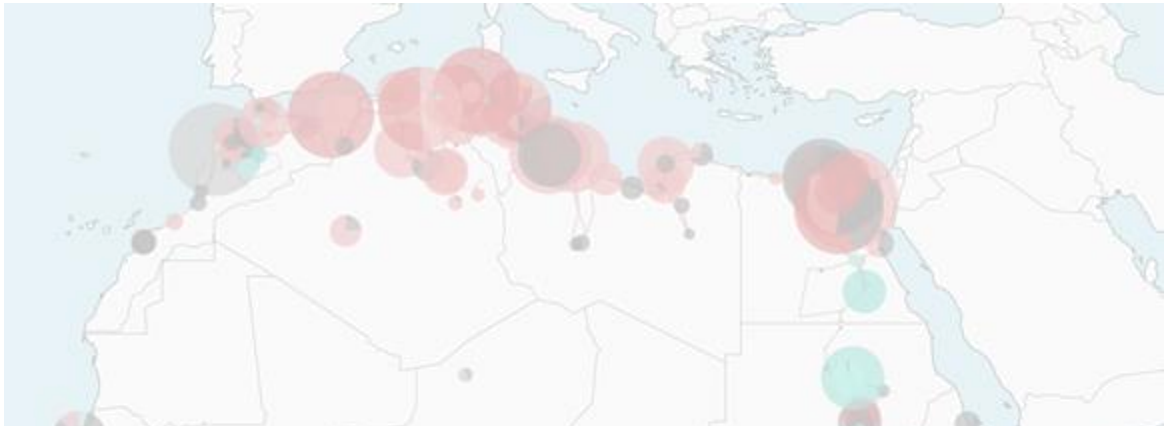
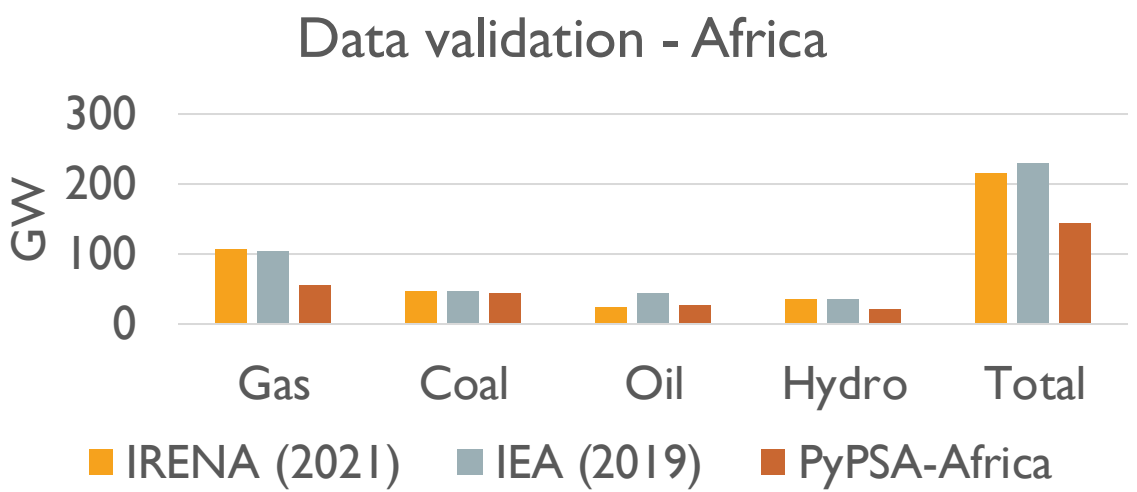
- …yours?

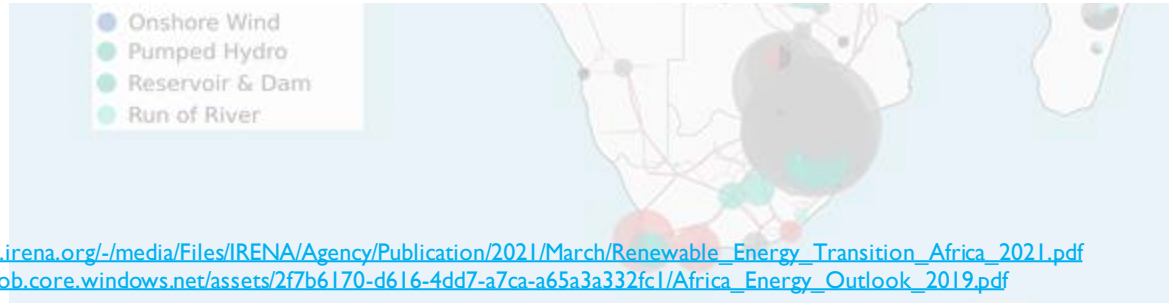
Merge datasets by Powerplantmatching

Help welcome on

- Country-level validation
- Merge different datasources (powerplantmatching)
- Look for accurate data







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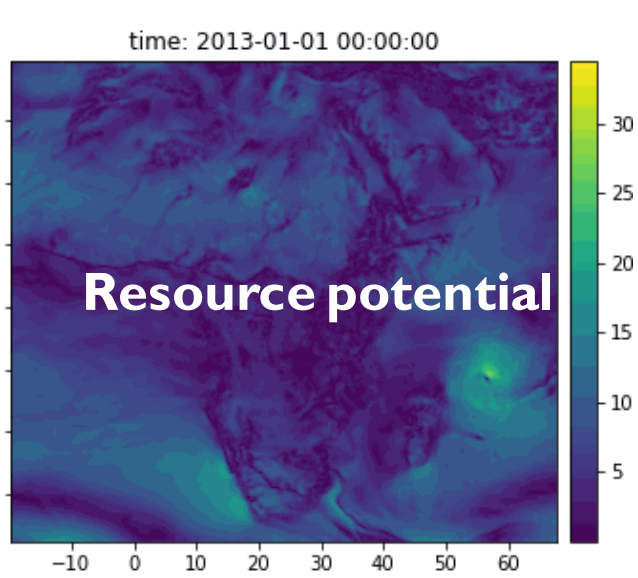
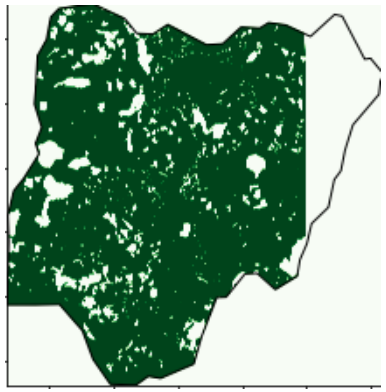
https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2021/March/Renewable_Energy_Transition_Africa_2021.pdf
https://iea.blob.core.windows.net/assets/2f7b6170-d616-4dd7-a7ca-a65a3a332fc1/Africa_Energy_Outlook_2019.pdf

RENEWABLE PRODUCTION

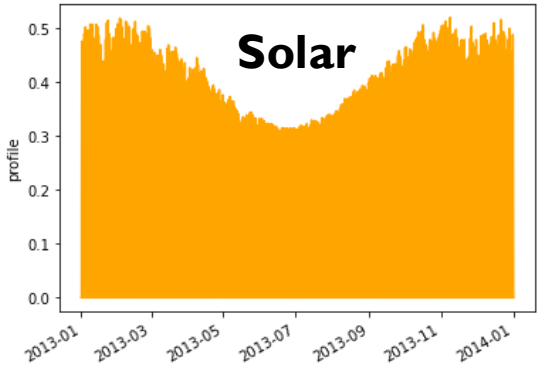


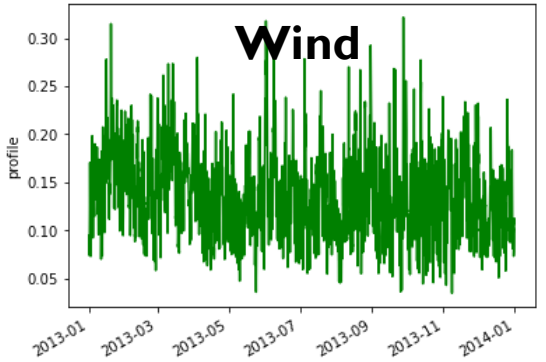
Land constraints

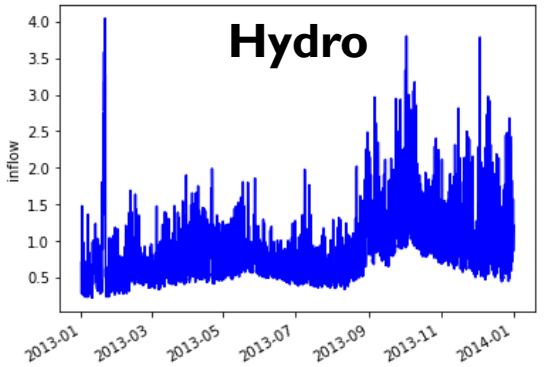


Pictures by Johannes Hampp

Atlite



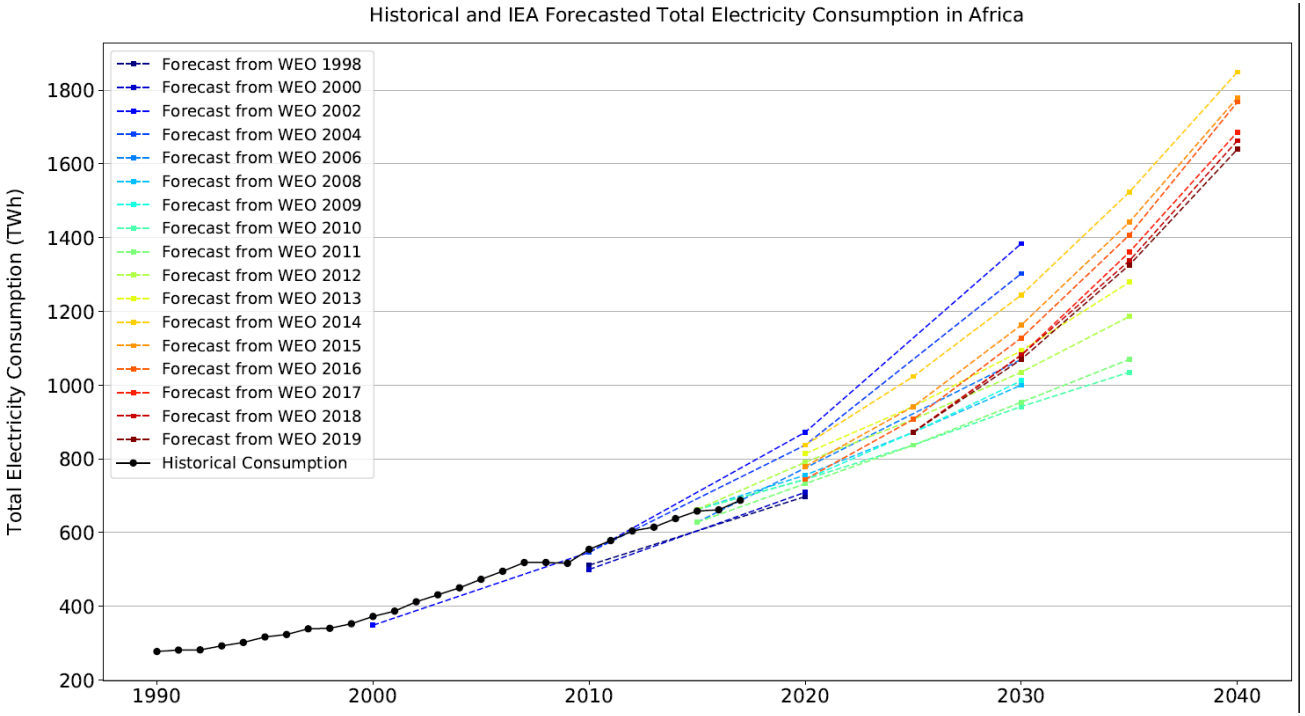




CSP (coming),…

DEMAND DATA

Forecasting is not easy!



Lee, S.J. et al., How probabilistic electricity demand forecasts can expedite universal access to clean and reliable electricity. 2021. Energy for Economic Growth

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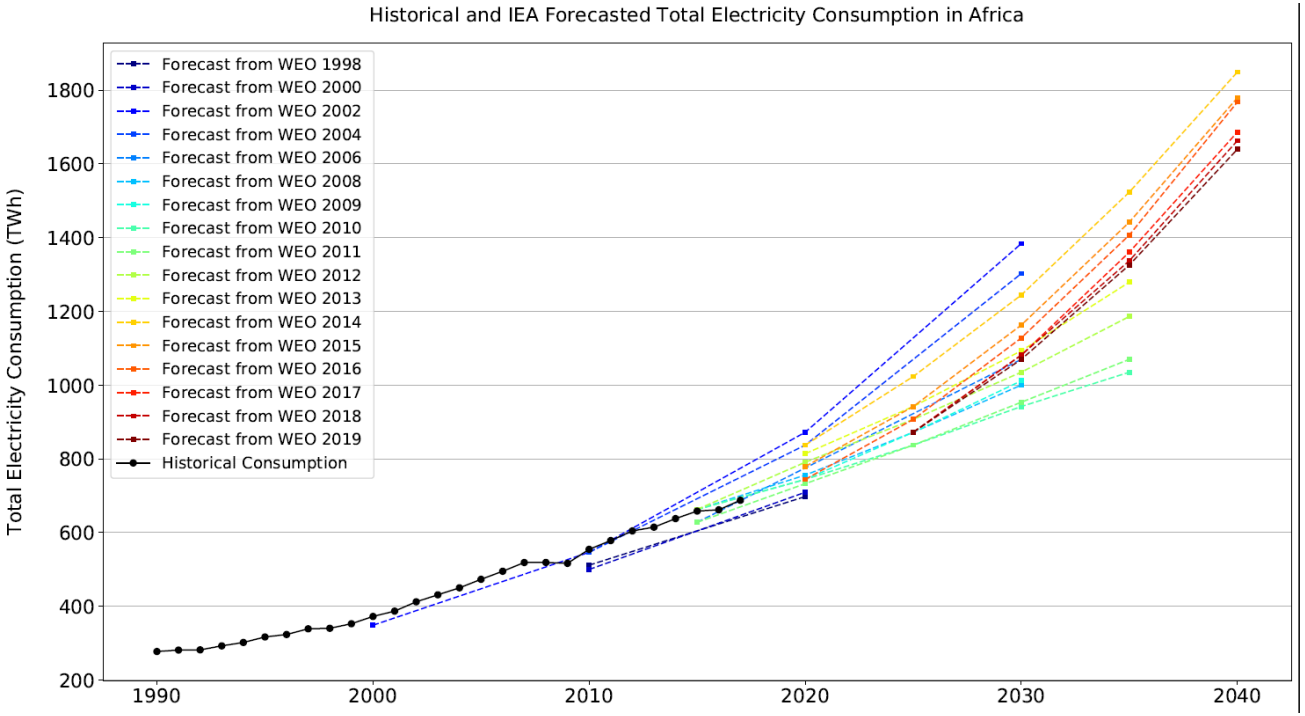
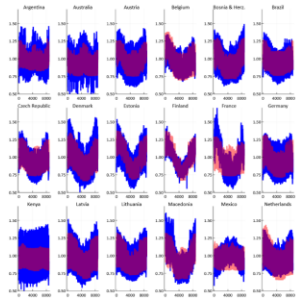
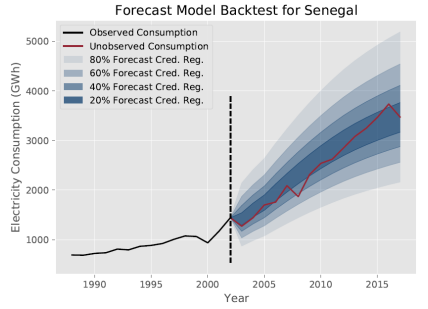


Use different models!

1) GlobalEnergyGIS* (currently used)



2) Demand-Creator (coming)



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DEMAND DATA

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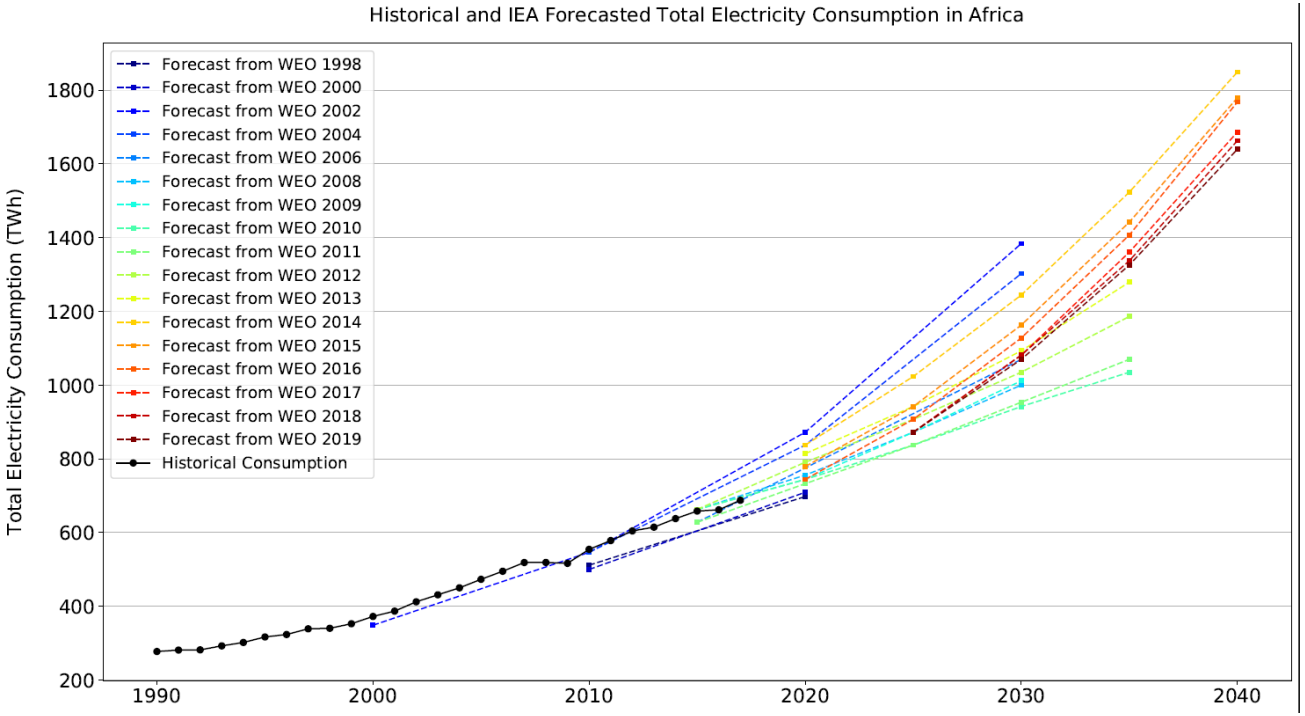

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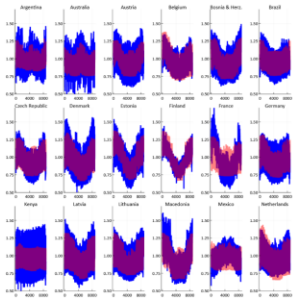

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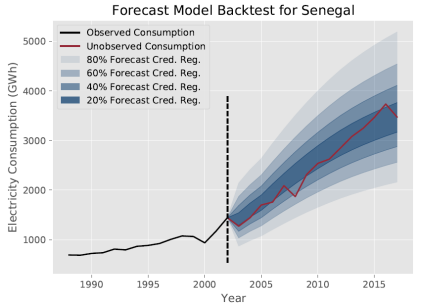


3) Your model!

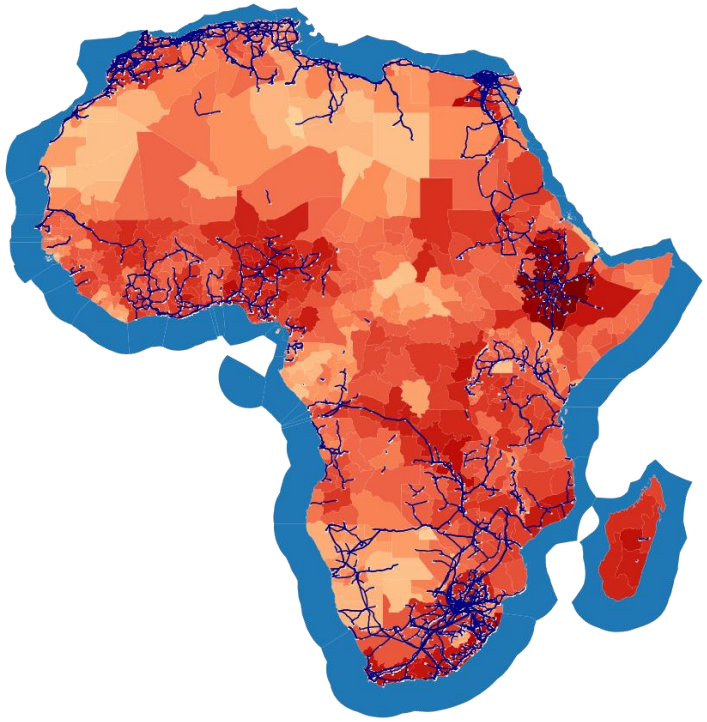
Lee, S.J. et al., How probabilistic electricity demand forecasts can expedite universal access to clean and reliable electricity. 2021. Energy for Economic Growth

CLUSTERING FOR TRACTABILITY

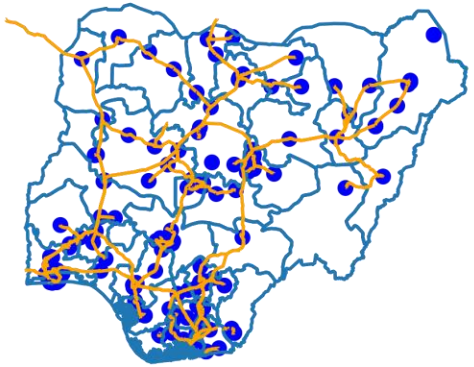
PyPSA meets Africa

Cleaned Network

["Africa"]



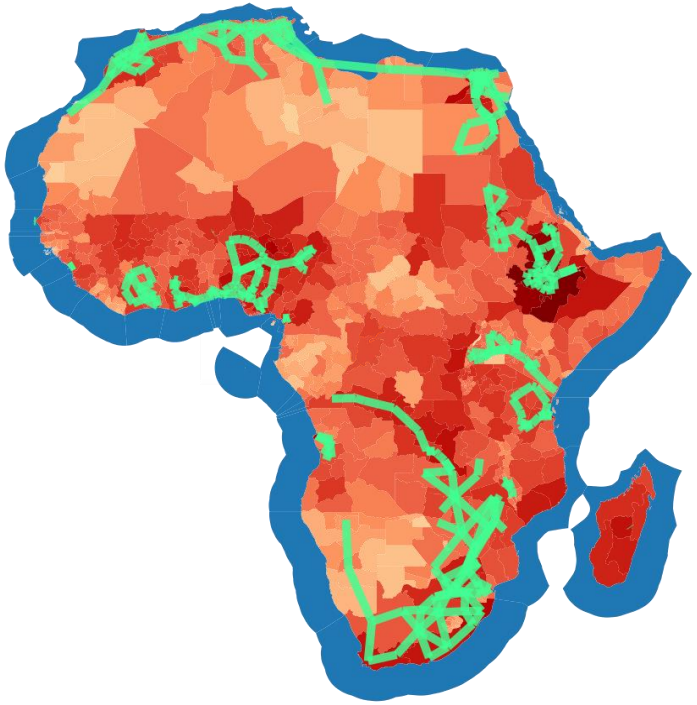
["Nigeria"]



After clustering

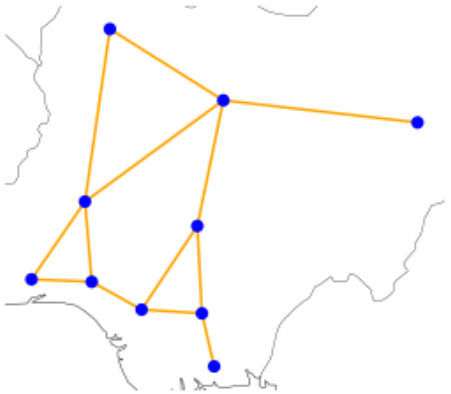
["Africa"]

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



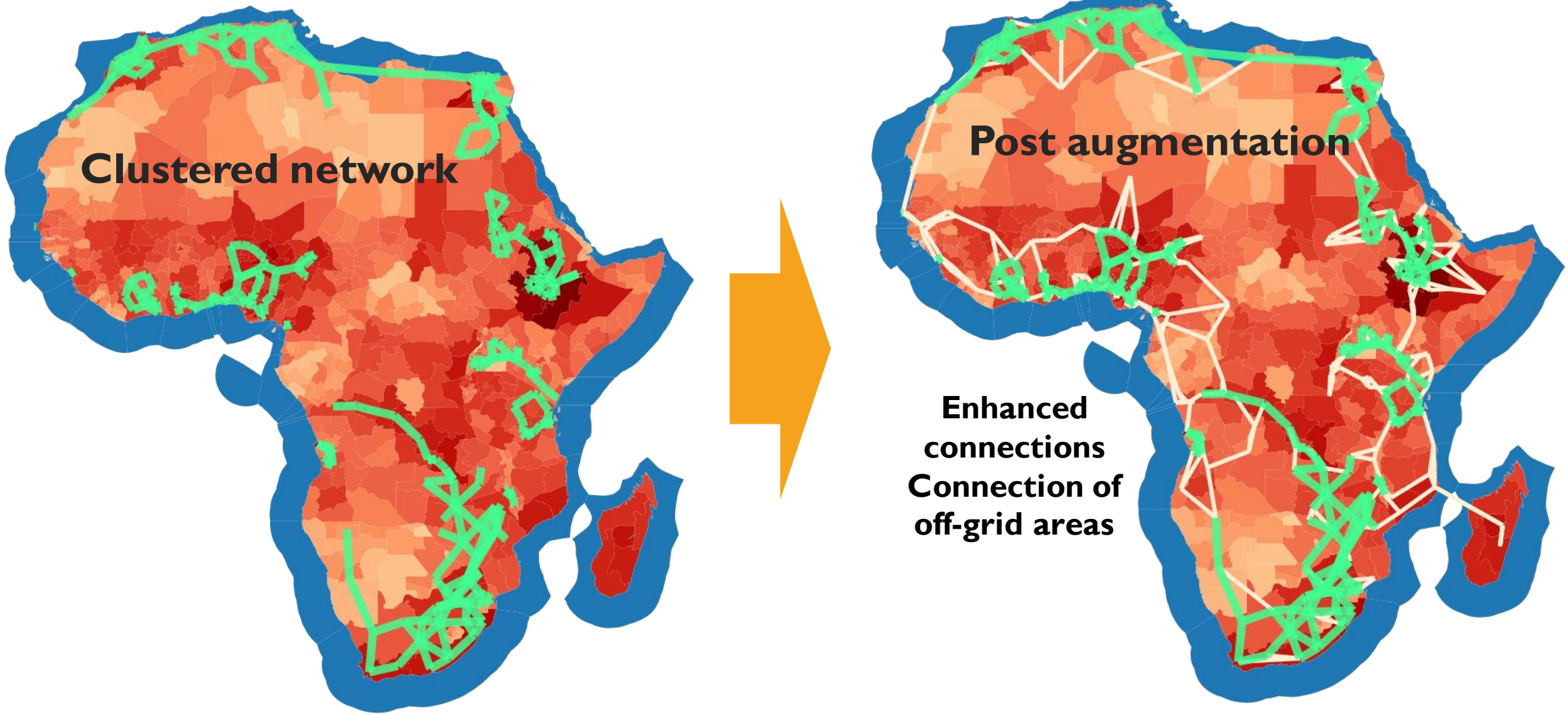
["Nigeria"]

10-node grid



Reduction of complexity
Preserve representation of the system

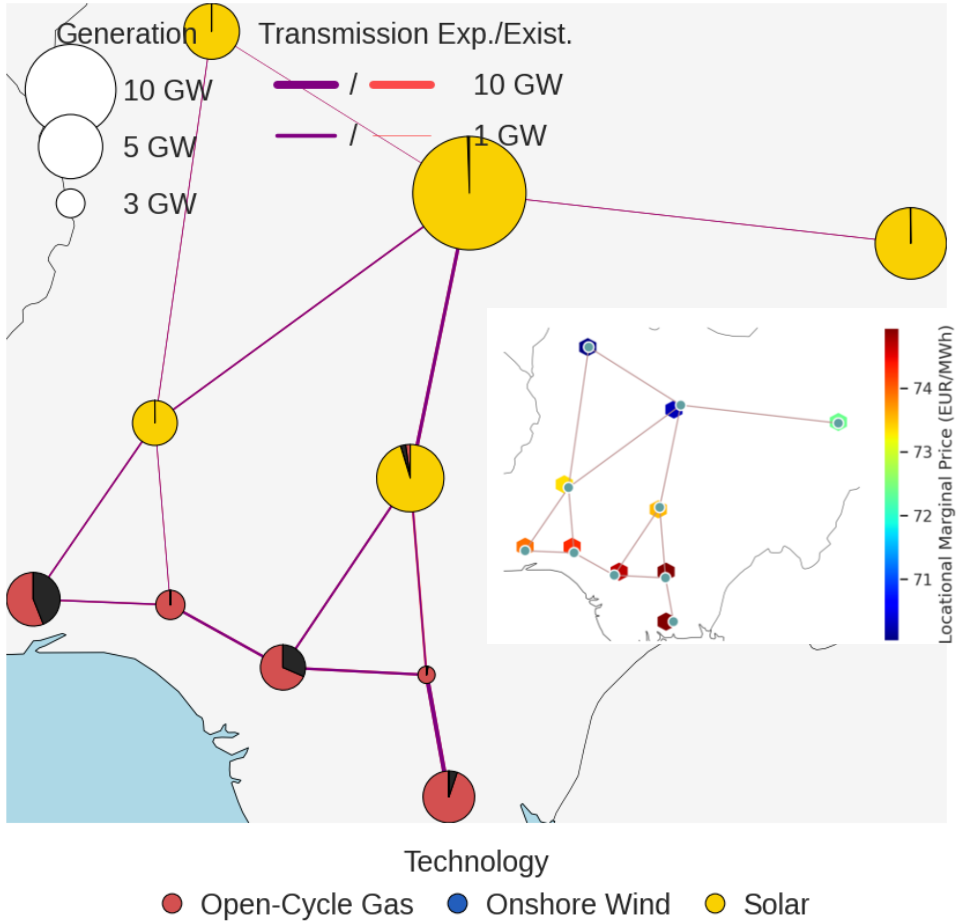
NETWORK AUGMENTATION



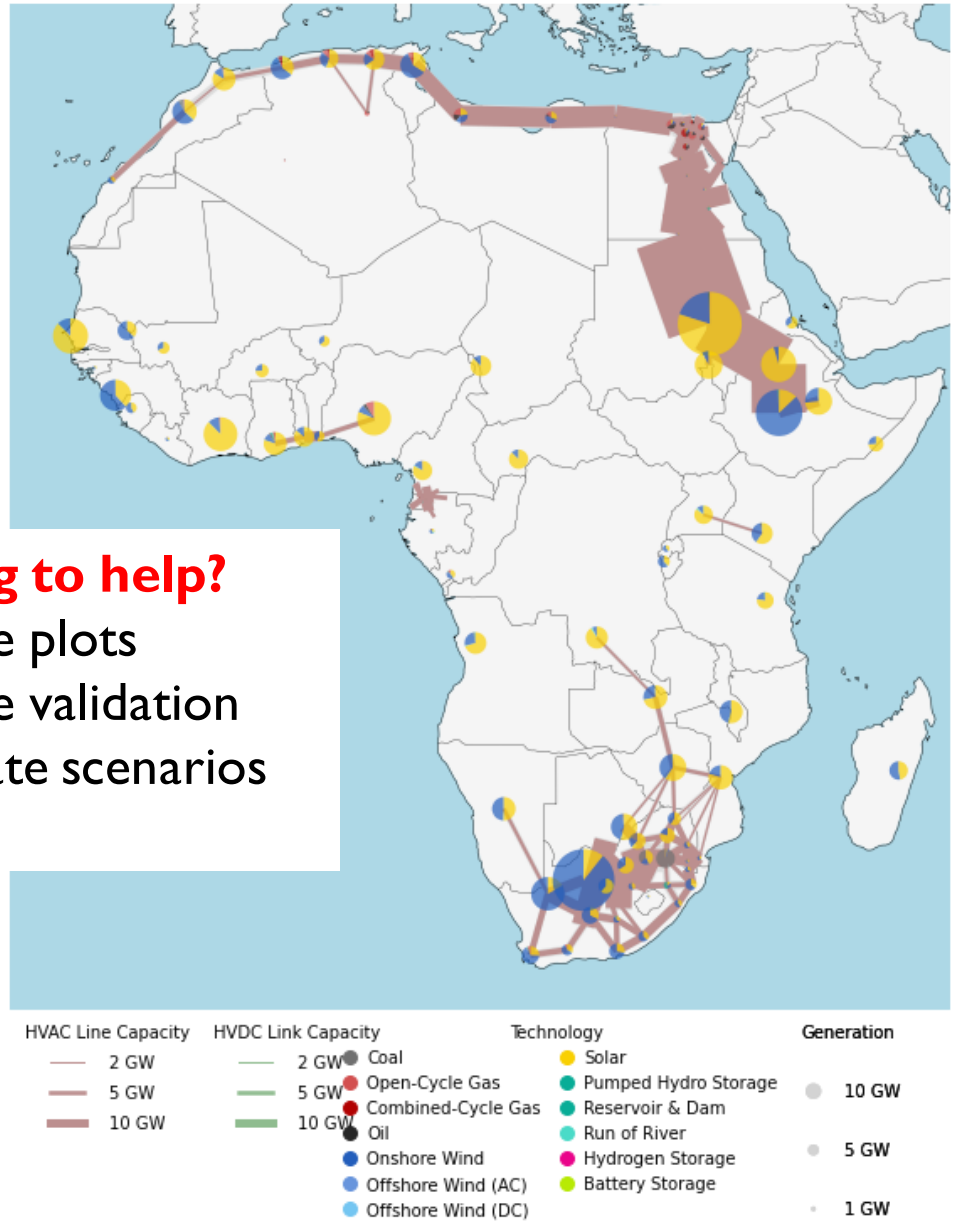
DESIGN&DISPATCH OPTIMIZATION

PyPSA meets Africa

Nigeria



Africa



Willing to help?

- More plots
- More validation
- Create scenarios
- …

WHAT NEXT

Low data accuracy?

Only electricity?

Single-year?

WHAT NEXT

Low data accuracy?

Ongoing validation!
«Linkers» to use most reliable source

Only electricity?

Single-year?

WHAT NEXT

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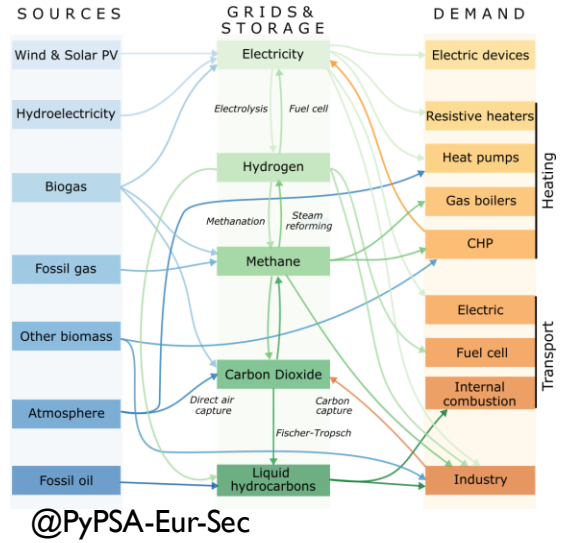
PyPSA Africa Sector coupled!



Single-year?

WHAT NEXT

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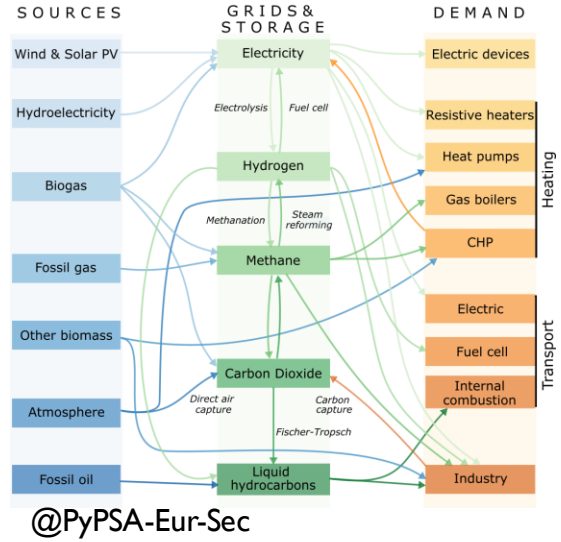
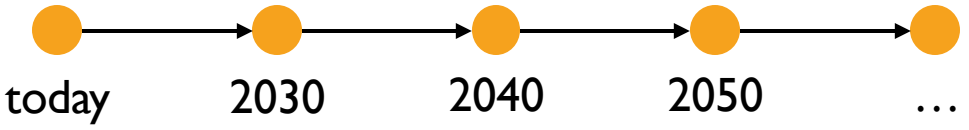
PyPSA Africa Sector coupled!



Single-year?

Pathway optimization!

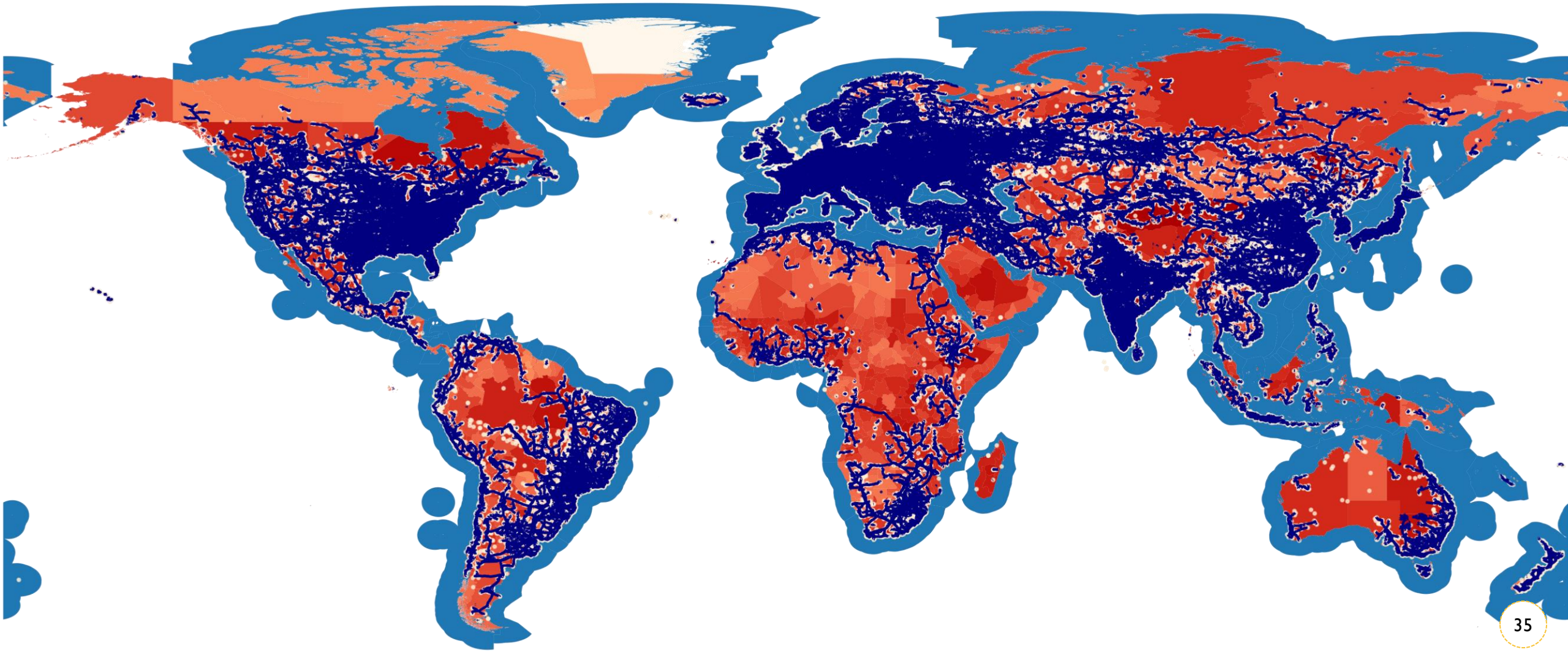


PYPSA MEETS EARTH

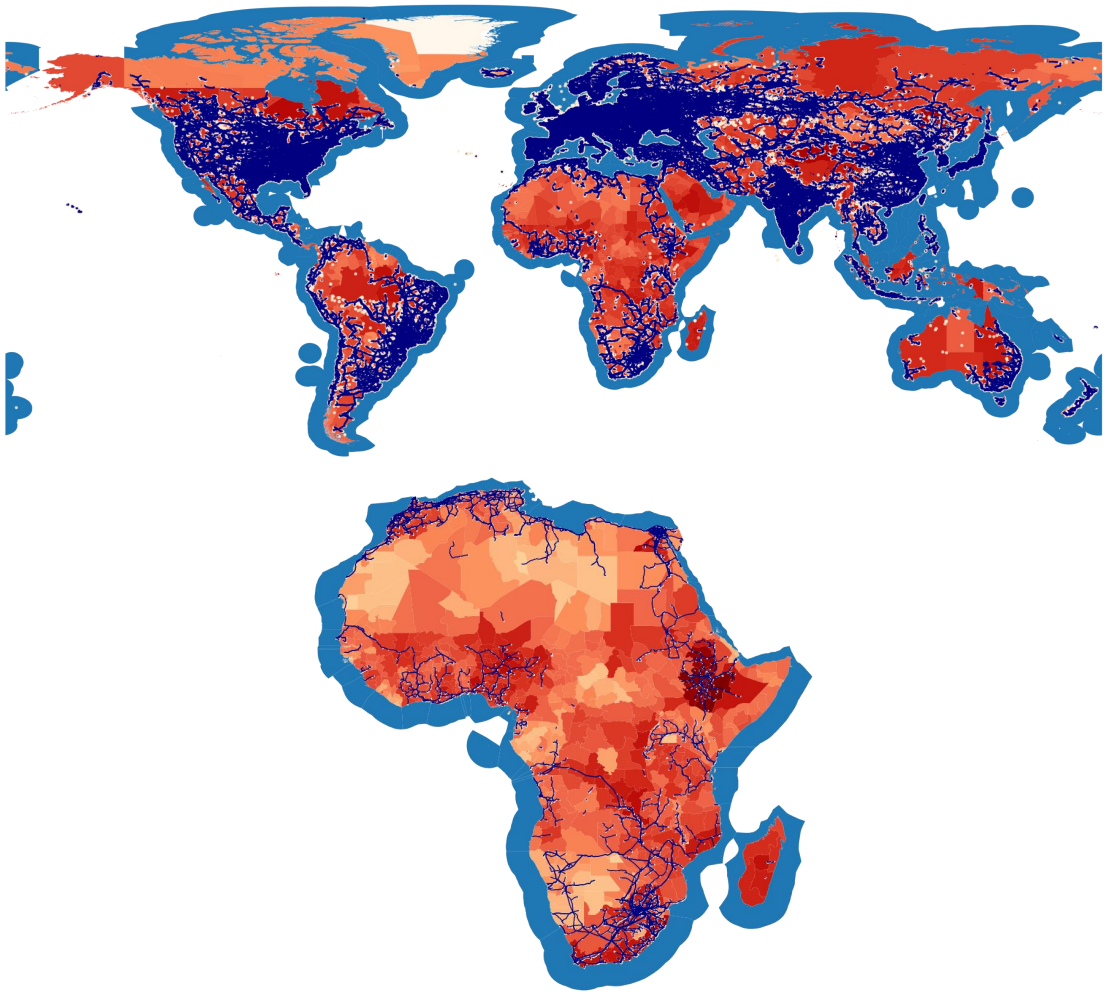
2022 GETTING READY TO CHANGE THE WORLD

PyPSA meets Africa

PyPSA meets Earth



PyPSA meets Africa → PyPSA meets Earth



PyPSA-Africa and PyPSA-Earth welcome support for:

- Electrical and energy engineers, computer science, data scientists, GIS experts and Python developers.
- High-level insights from NGOs, governmental entities and project developers.
- Contributors to validate country data
- Institutions and companies for data access and resources to speed up the development.
- Providers of cloud and remote computing resources.


PyPSA
meets Earth
I.
THE PYPSA MEETS EARTH INITIATIVE
II.
THE PYPSA-AFRICA PROTOTYPE PRESENTATION
III.
DEALING WITH MISSING DATA

PyPSA meets Earth

I. INFRASTRUCTURE DETECTION

II. DEMAND PREDICTION

Previous Work

PyPSA meets Earth

World Bank & Development Seed

http://devseed.com/ml-griddocs/introduction/strategy/

Previous Work

PyPSA meets Earth

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Previous Work

PyPSA meets Earth

World Bank & Development Seed

World Bank & Facebook

http://devseed.com/ml-griddocs/introduction/strategy/
nara.getarchive.net

Previous Work

PyPSA meets Earth

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World Bank & Facebook

http://devseed.com/ml-griddocs/introduction/strategy/
gridfinder.org

Re-Tackle Detection of Individual Towers

PyPSA meets Earth

Three Developments

https://figshare.com/articles/dataset/Electric_Transmission_and_Distribution_Infrastructure_magery_Dataset

Re-Tackle Detection of Individual Towers

PyPSA meets Earth

Three Developments

- Grid Infrastructure Dataset by Duke University
-
-

https://figshare.com/articles/dataset/Electric_Transmission_and_Distribution_Infrastructure_Imagery_Dataset

Re-Tackle Detection of Individual Towers

PyPSA meets Earth

Three Developments

- Grid Infrastructure Dataset by Duke University
- Satellite Imagery released by maxar for humanitarian purposes
-

maxar.com/open-data
https://figshare.com/articles/dataset/Electric_Transmission_and_Distribution_Infrastructure_Imagery_Dataset

Re-Tackle Detection of Individual Towers

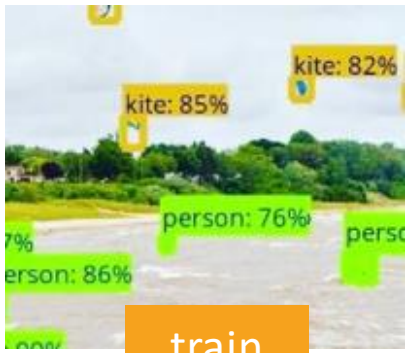
PyPSA meets Earth

Three Developments

- Grid Infrastructure Dataset by Duke University

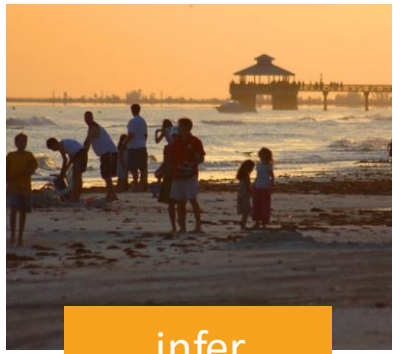
- Satellite Imagery released by maxar for humanitarian purposes

- Research advances in machine learning



train

transfer



infer

maxar.com/open-data
https://figshare.com/articles/dataset/Electric_Transmission_and_Distribution_Infrastructure_Imagery_Dataset
https://pxhere.com/en/photo/560374

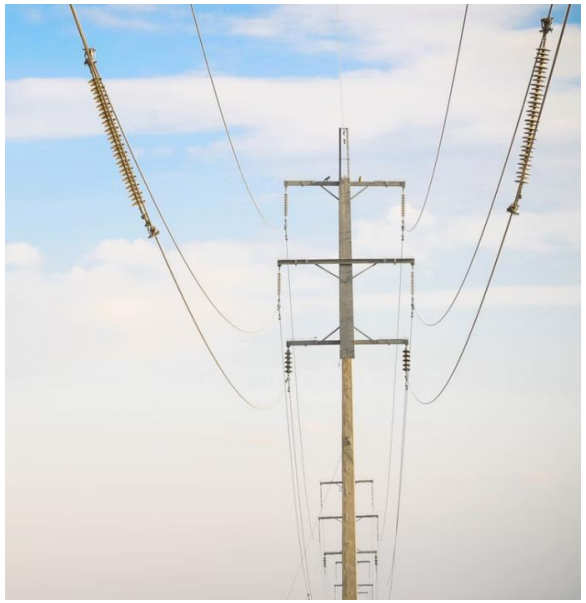
Re-Tackle Detection of Individual Towers

PyPSA meets Earth

Three Developments

- Grid Infrastructure Dataset by Duke University
- Satellite Imagery released by maxar for humanitarian purposes
- Research advances in machine learning

Re-Tackle Detection of Individual Towers



The **PyPSA meets Africa detect-energy team** welcomes support:

- Machine learning engineers, data scientists and Python developers.
- Cloud credits for computation and data storage.
- High-level insights from NGOs, governmental entities and project developers.

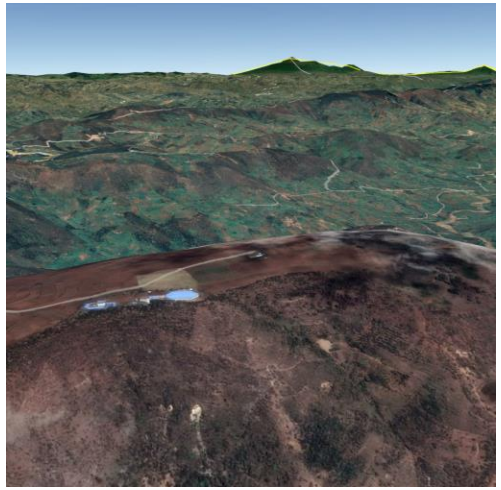
unsplash.com

PyPSA meets Earth

I. INFRASTRUCTURE DETECTION

II. DEMAND PREDICTION

Machine Learning-Based Demand Forecasting Across Africa



1. Country-Level Demand Forecasting

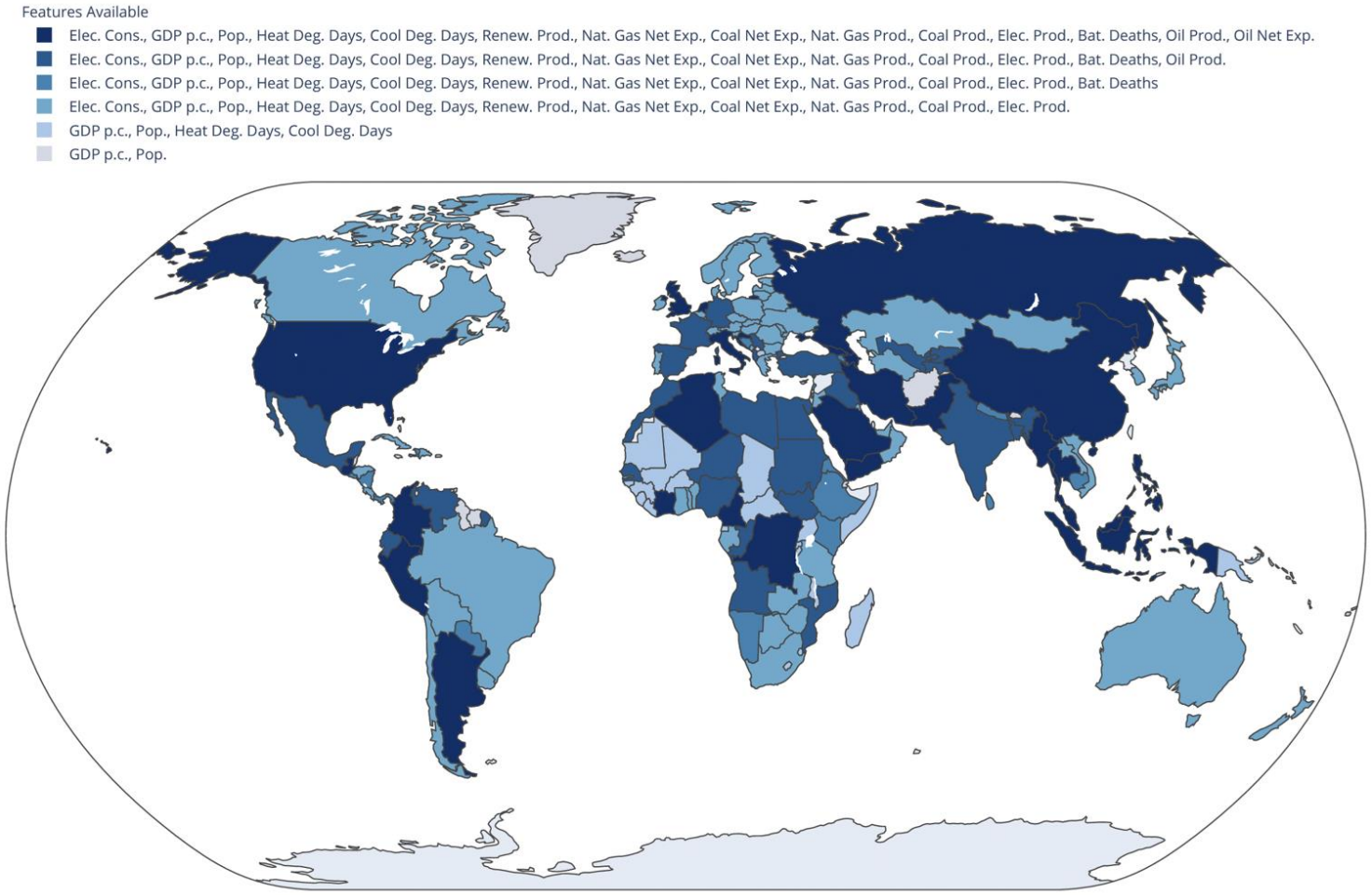
2. Data-driven Downscaling

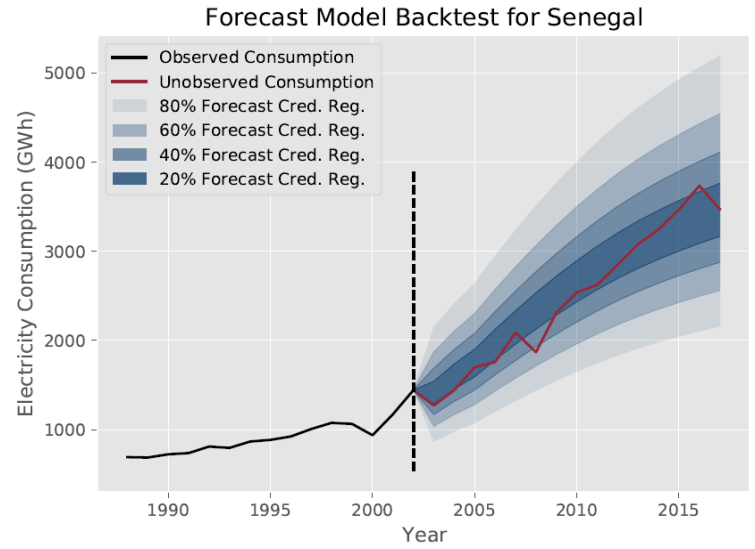
3. Building-Level Demand Forecasting

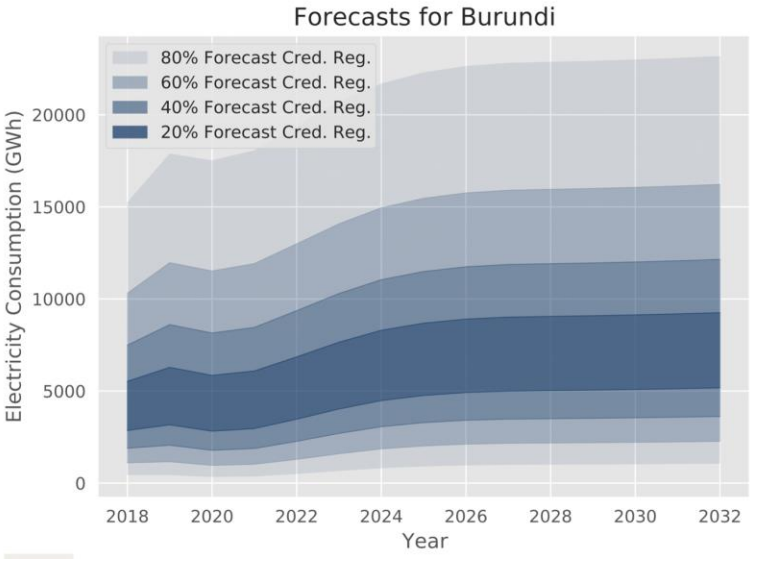
Aggregation (optional)

PyPSA meets Africa

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

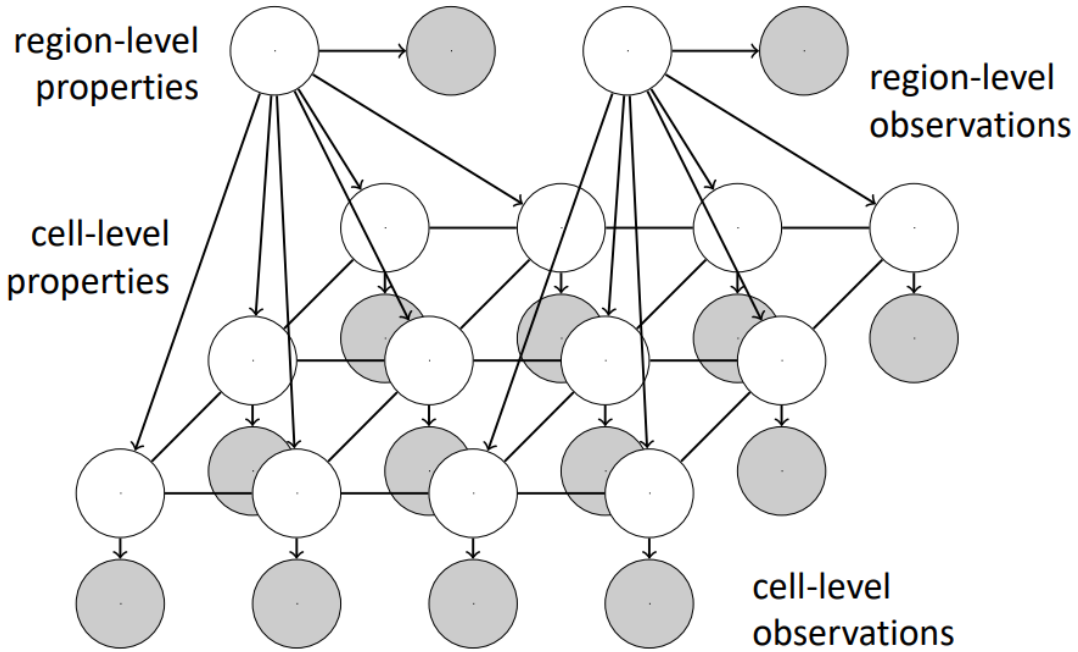






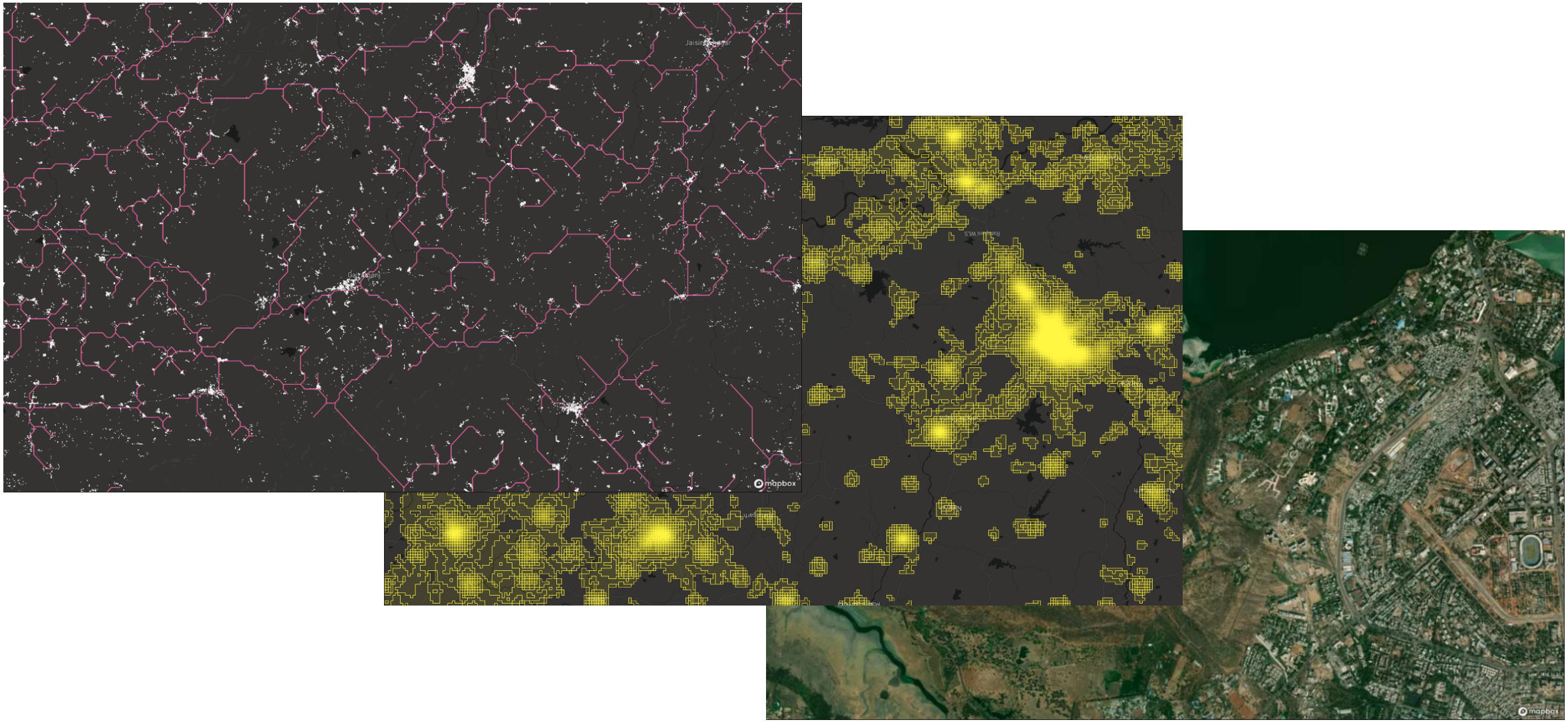
Sources: S. J. Lee, D. Suri, P. Somani, C. L. Dean, J. Pacheco, R. Stoner, I. Perez-Arriaga, J. W. Fisher III, and J. Taneja, "How probabilistic electricity demand forecasts can expedite universal access to clean and reliable electricity," *Energy for Economic Growth*, 2021.; S. J. Lee, C. L. Dean, D. 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

2. Downscaling via Economics-Informed Probabilistic Models and Others

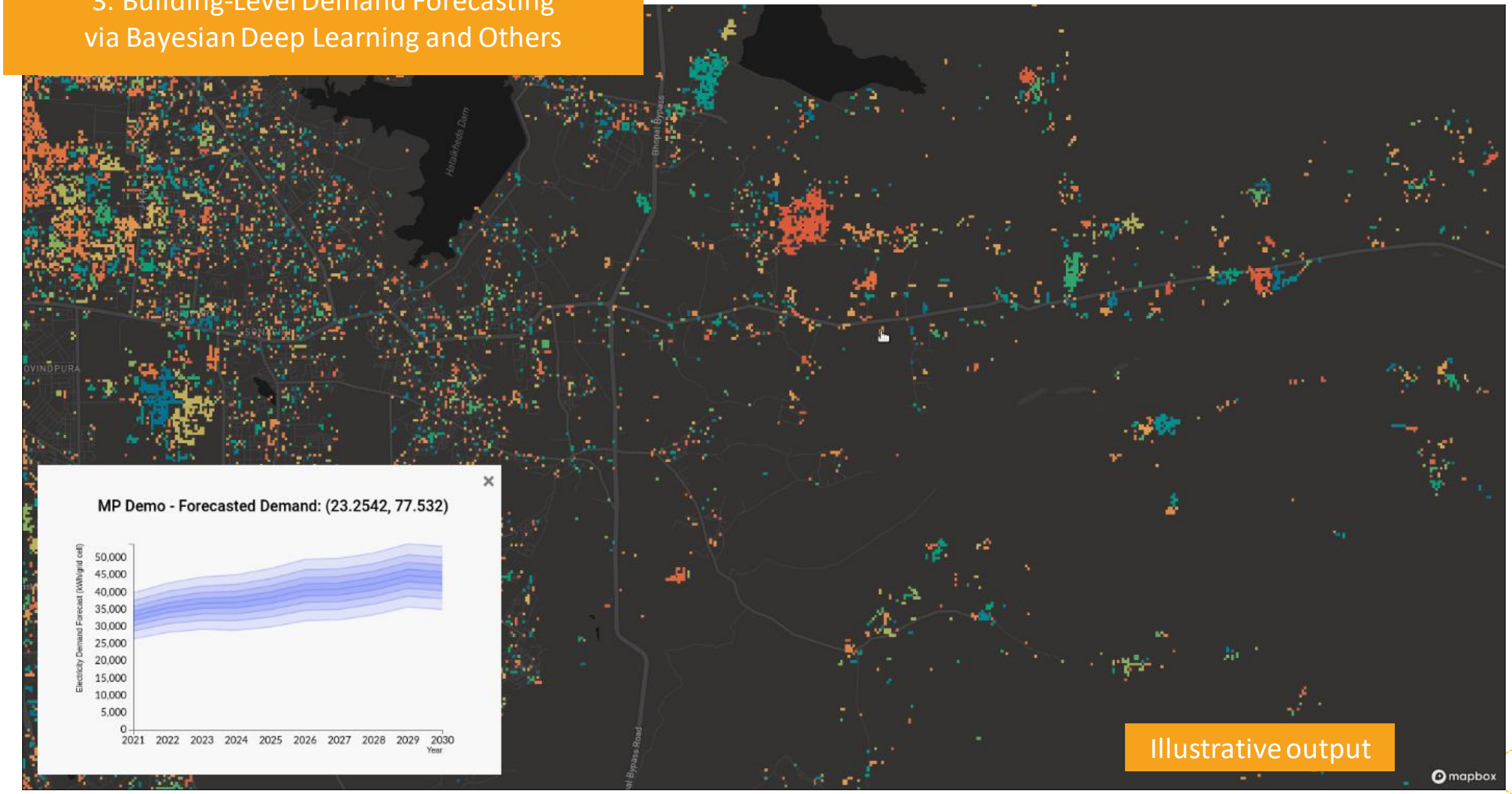


W. Sirko, S. Kashubin, M. Ritter, A. Annkah, Y.S.E. Bouchareb, Y. Dauphin, D. Keysers, M. Neumann, M. Cisse, J.A. Quinn. Continental-scale building detection from high resolution satellite imagery. arXiv:2107.12283, 2021.; Haklay, M. and Weber, P., 2008. Openstreetmap: User-generated street maps. IEEE Pervasive computing, 7(4), pp.12-18.

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

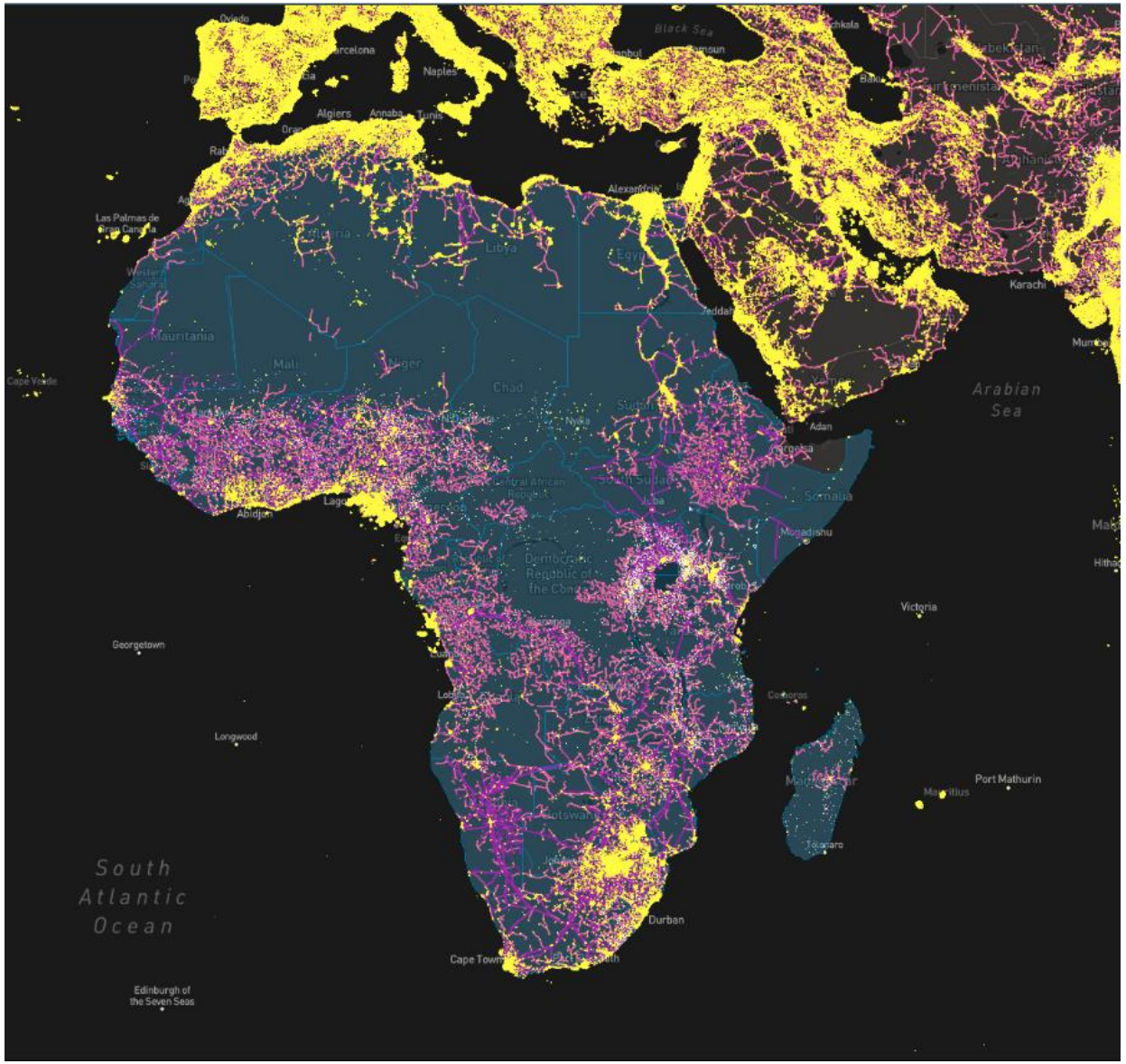


3. Building-Level Demand Forecasting via Bayesian Deep Learning and Others



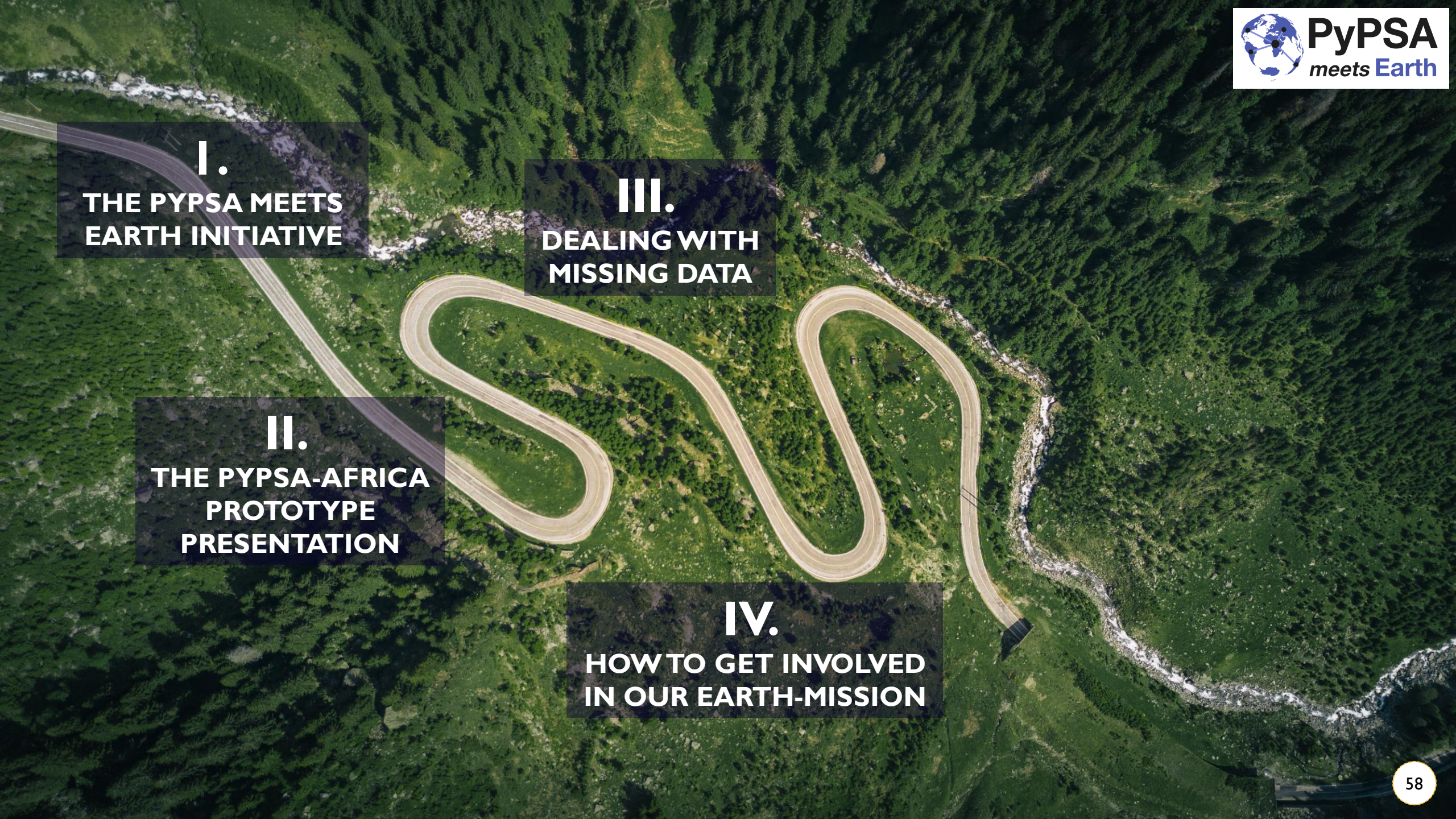
Machine Learning-Based Demand Forecasting Across Africa

PyPSA meets Earth



What the **PyPSA meets Africa demand team** is looking for:

- GIS analysts, data scientists, machine learning engineers and researchers, frontend developers, backend developers.
- African agricultural experts, energy policy analysts, climate change analysts.
- Cloud credits for hosting tile servers.
- Collaborations with African governments, utilities, NGOs, and project developers for:
  - Ground-truth validation of results
  - Open-sourcing anonymized consumption data
  - Other beneficial uses of electricity demand forecasts.


PyPSA
meets Earth
I.
THE PYPSA MEETS EARTH INITIATIVE
II.
THE PYPSA-AFRICA PROTOTYPE PRESENTATION
III.
DEALING WITH MISSING DATA
IV.
HOW TO GET INVOLVED IN OUR EARTH-MISSION

JOIN OUR TEAM!

Our intiative has 61 members...

- 26 coders
- 27 advisors
- 9 communicators
- 14 PhD students
- 9 professors
- 13 energy professionals
- ...students, postdocs, scientists...

...associated to:

WHY PEOPLE JOIN US?

- Creating impact
- Solve your energy problem
- Learn and apply methods
- Work together
- What is your motivation?

HOW PEOPLE JOIN US

- As a hobby
- Use PyPSA meets Earth for your work
- Fund dedicated positions (coming)

OUR WISHLIST

OR: WHAT WE NEED TO CONTINUE

PyPSA meets Earth

- Contribute new open data and methods
- Expand and validate model in your region
- Participate and share your ideas
- Join or lead an open data campaign
- Join or lead a code team

Open Source Ladder

"up and down the ladder" by Robert Couse-Baker is licensed under CC BY 2.0

PyPSA meets Africa

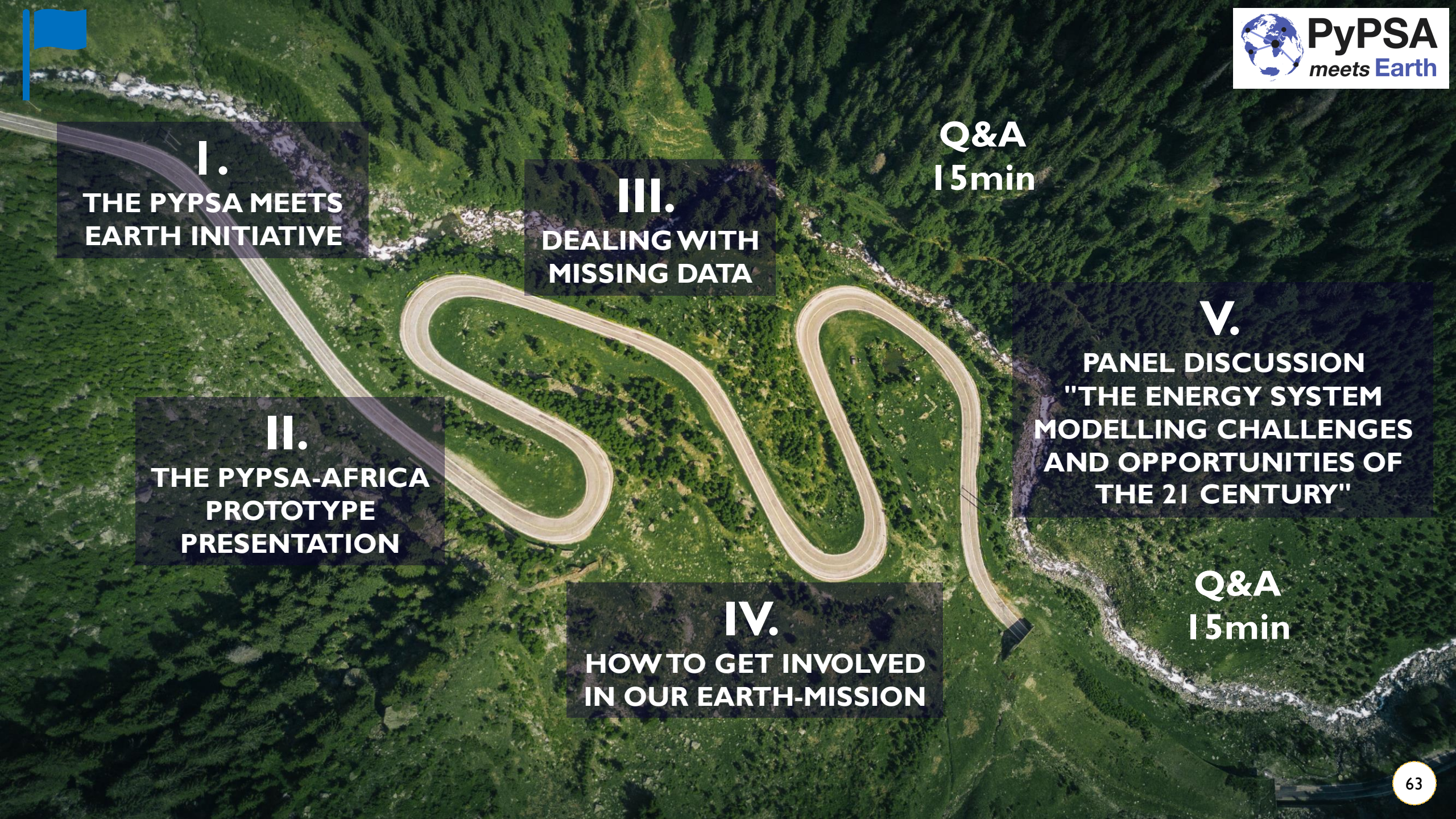
LEAD

IMPROVE

PARTICIPATE

USE

UNDERSTAND


PyPSA
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HOW TO GET INVOLVED IN OUR EARTH-MISSION
Q&A
15min
V.
PANEL DISCUSSION "THE ENERGY SYSTEM MODELLING CHALLENGES AND OPPORTUNITIES OF THE 21 CENTURY"
Q&A
15min

"Energy system modelling challenges and opportunities of the 21 century"

PyPSA meets Africa

PyPSA meets Earth

CLAYTON BARROWS

SENIOR RESEARCH ENGINEER AT NREL, AND TECHNICAL CO-LEAD ON THE OPEN DATA AND TOOLS PILLAR OF THE GLOBAL POWER SYSTEMS TRANSFORMATION CONSORTIUM (G-PST)

ASAMI MIKETA

SENIOR PROGRAMME OFFICER, POWER SECTOR INVESTMENT PLANNING AT INTERNATIONAL RENEWABLE ENERGY AGENCY (IRENA)

JARRAD WRIGHT

PREVIOUSLY, PRINCIPAL GRID PLANNING ENGINEER AT CSIR IN SOUTH AFRICA AND SOON TO JOIN NREL AS SENIOR RESEARCHER

MAXIMILIAN PARZEN

DIRECTOR OF PYPSA MEETS EARTH INITIATIVE AND PHD STUDENT AT UNIVERSITY OF EDINBURGH

GLOBAL PST CONSORTIUM

NREL

IRENA International Renewable Energy Agency

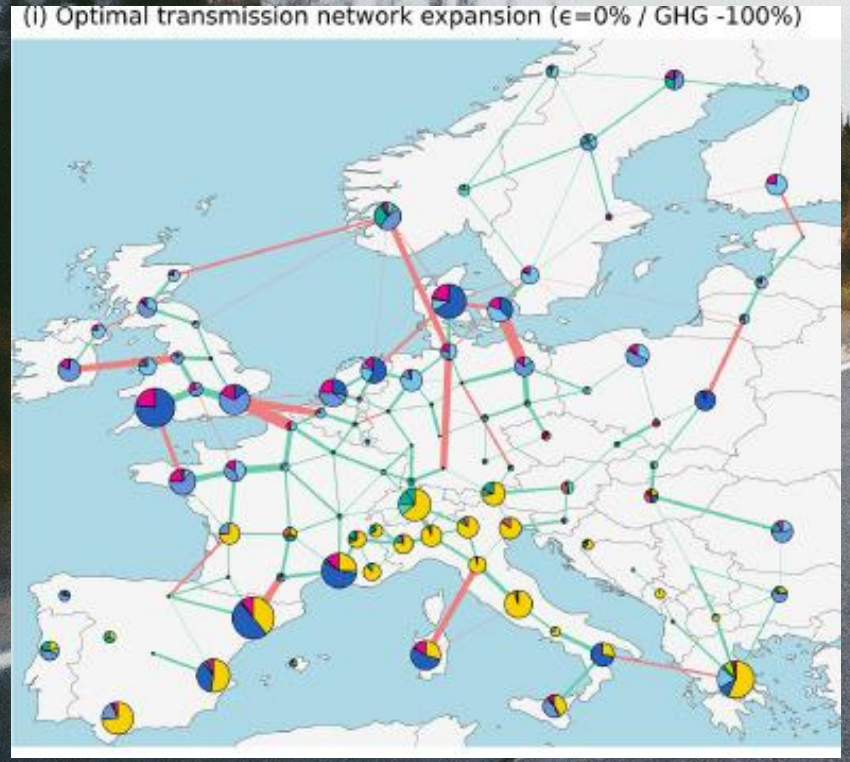
CSIR Touching lives through innovation

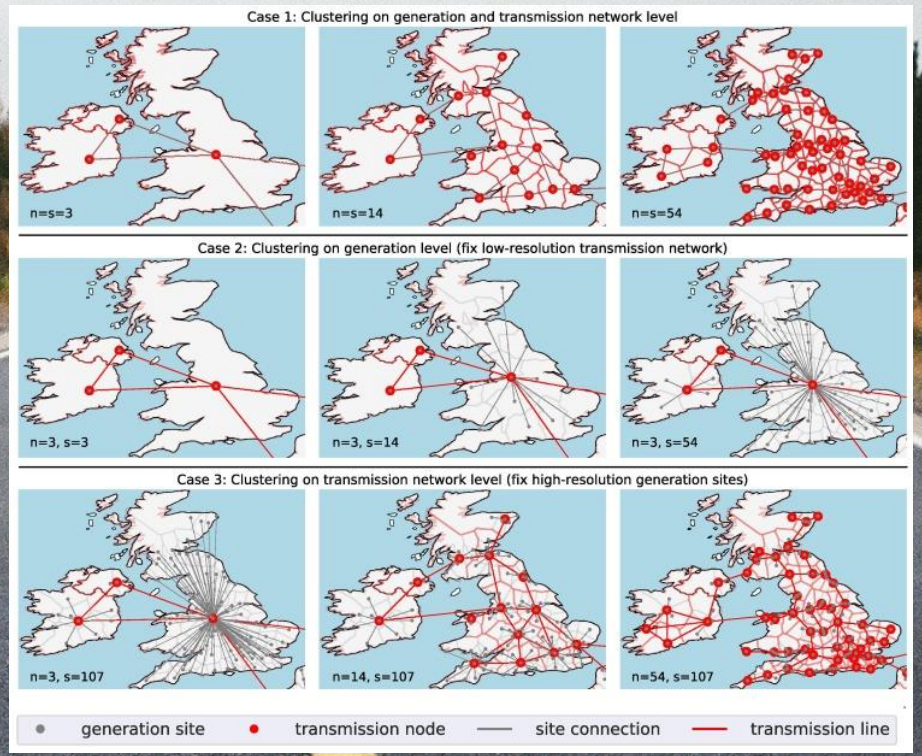

PyPSA
meets Africa
PyPSA
meets Earth
PYPSA MEETS EARTH
2022
GETTING READY TO
CHANGE THE WORLD

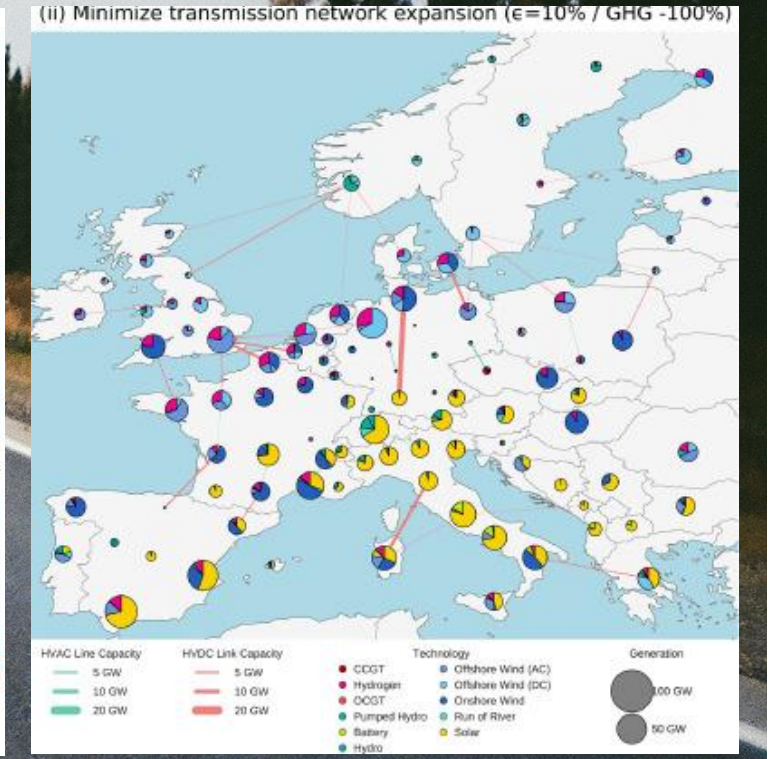
DRAFTS/BACK-UP

WHAT IS POSSIBLE?

- **POLICY RECOMMENDATIONS**
- ENERGY TRANSITION PLANS
- GRID EXPANSION STUDIES
- **GENERATION EXPANSION STUDIES**
- TECHNOLOGY EVALUATIONS
- …





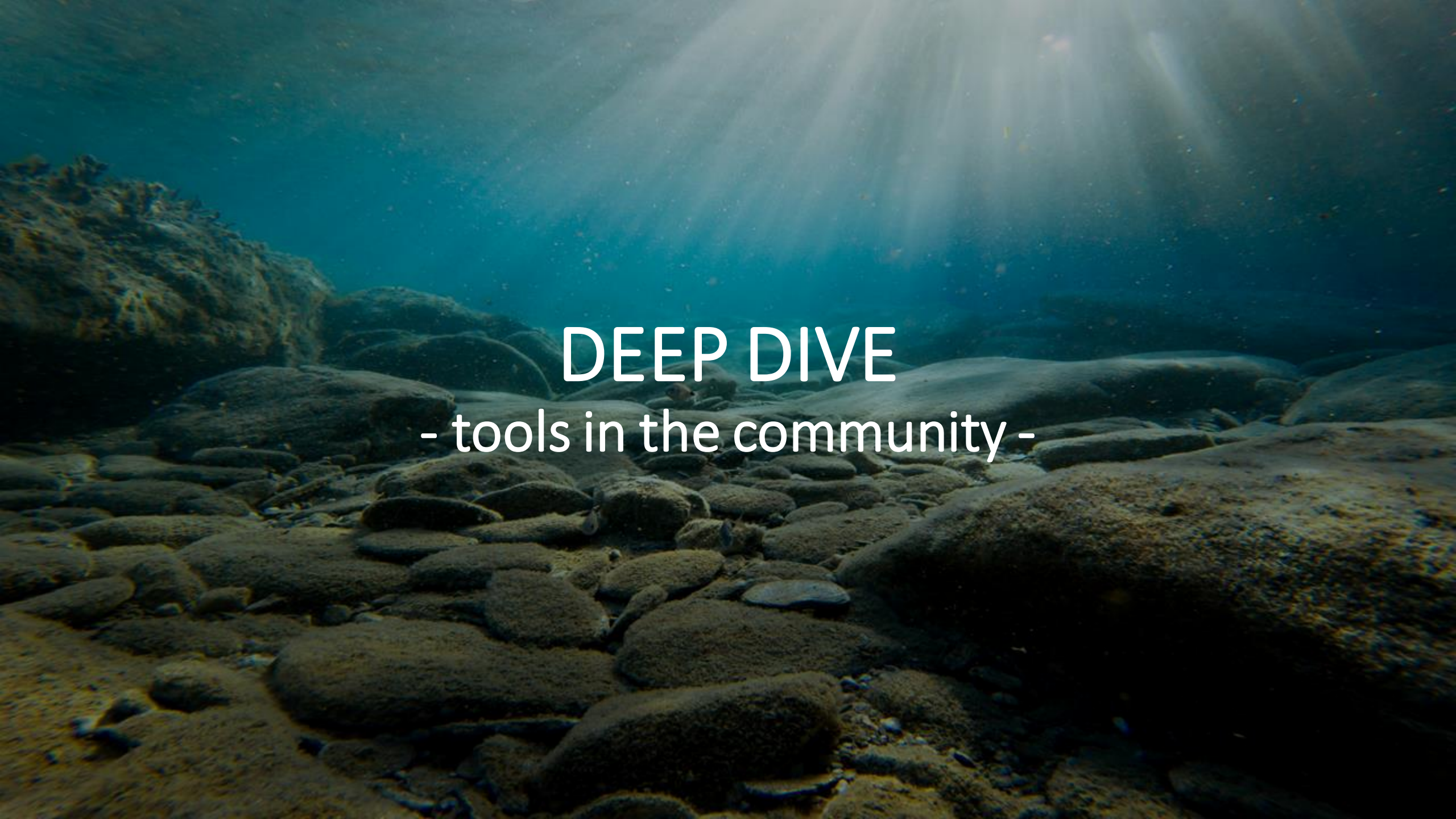


INFLUENCE DECISION MAKING - CASA INDIA

VISION

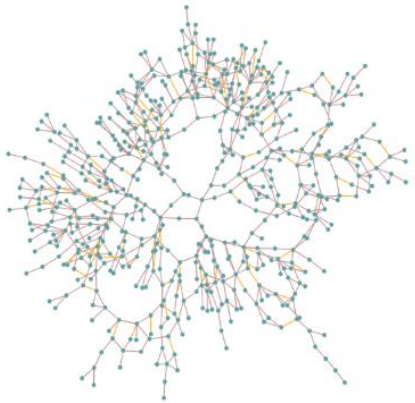
Create TOGETHER useful alternatives to closed-source energy system models for industry and research


PyPSA
meets Earth
MISSION
#PyPSA-AFRICA2021
#PyPSA-EARTH2022
#...?


DEEP DIVE
- tools in the community -

PyPSA meets Africa

SOLVER	PROBLEM FORMULATOR	DATA WORKFLOW	DATA CREATION	UX/UI
@LINOPY @SMS++ @PIPS-IPM++	@PYPSA	@PYPSA-AFRICA @PYPSA-EUR @PYPSA-EUR-SEC @ATLITE	@PYPSA-AFRICA	@ALL @PYAM

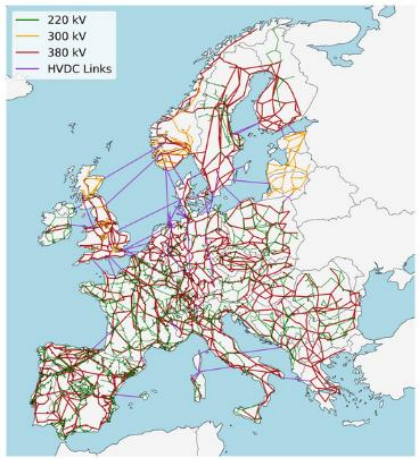


PyPSA

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

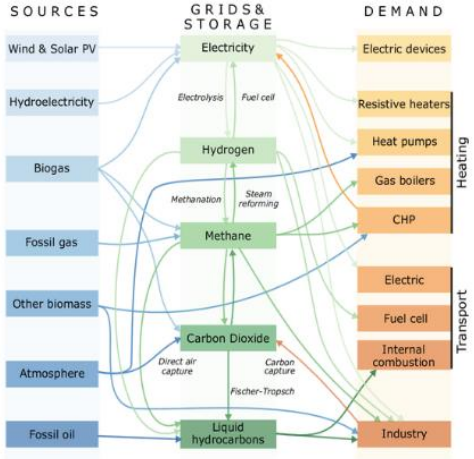
Atlite

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



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.

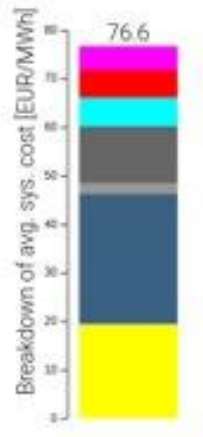
Linopy

Linear optimization interface for N-D labeled variables.

Documentation →

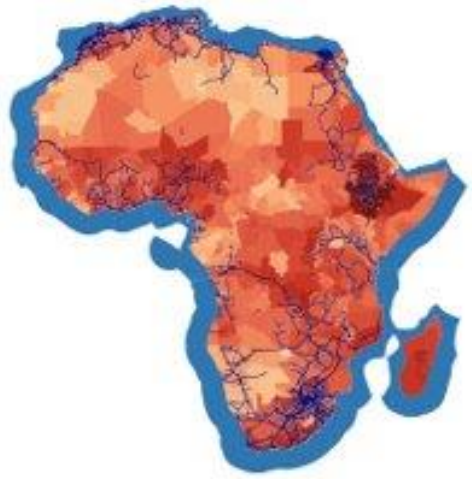
Powerplantmatching

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



Model Energy

An online toolkit for calculating renewable electricity supplies.

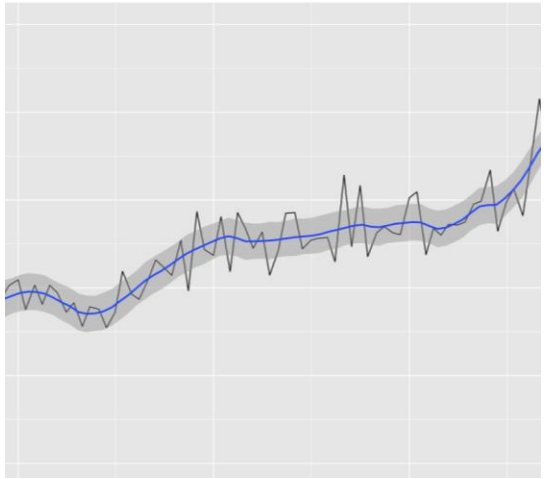


PyPSA-Earth

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

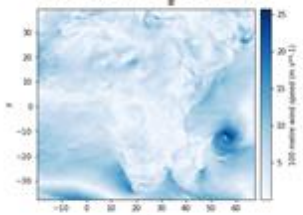
Detect-Energy

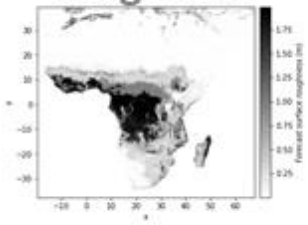
A machine learning framework to detect energy assets from satellite images

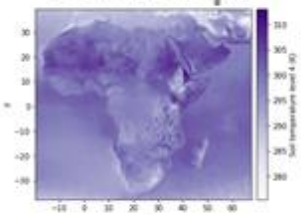


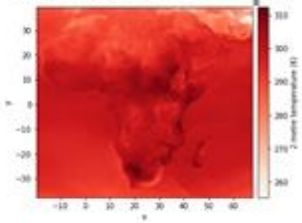
Demand-Creator

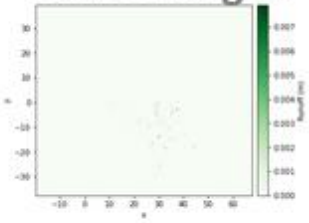
A general framework to create demand timeseries in subnational resolution

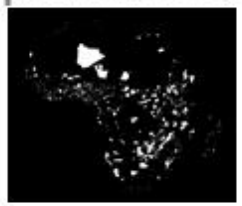


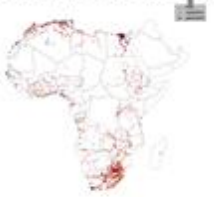


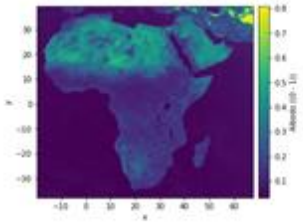






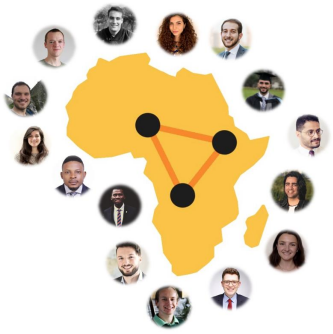




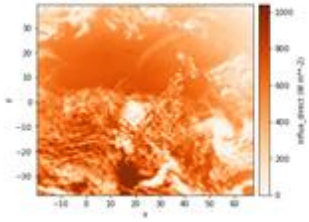


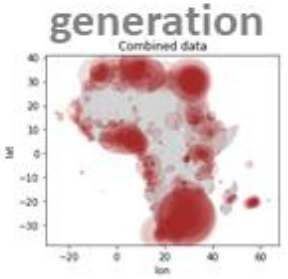
An open digital twin of energy systems

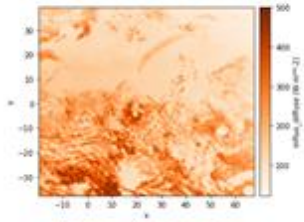
***that can optimize**

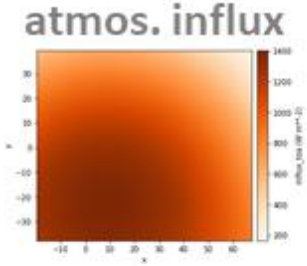


PyPSA meets Africa



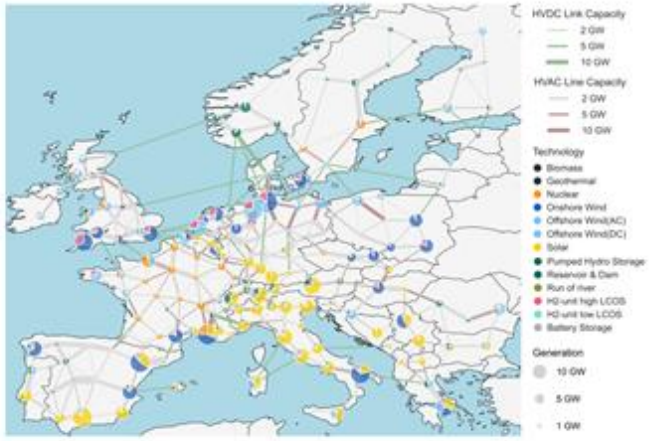






Digital Twin

Foundation
@PyPSA
@PyPSA-Eur
@PyPSA-Eur-Sec
@Atlite



...

GDP raster

Popul. raster

...

AI detection

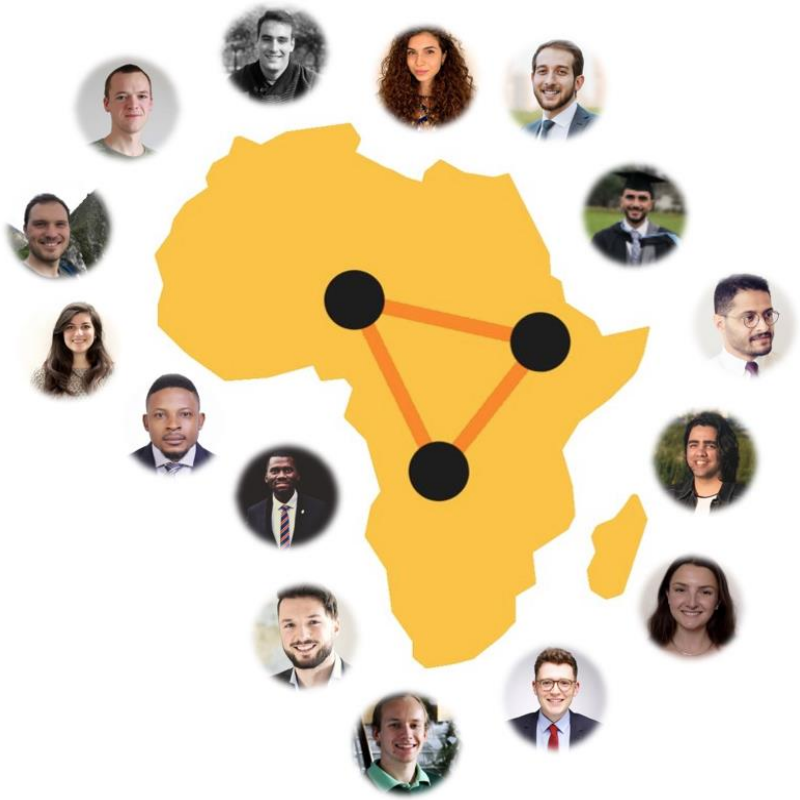
Maximilian Parzen max.parzen@ed.ac.uk | Find out how to join the mission: | https://pypsa-meets-africa.github.io/


EMPOWERING
PEOPLE

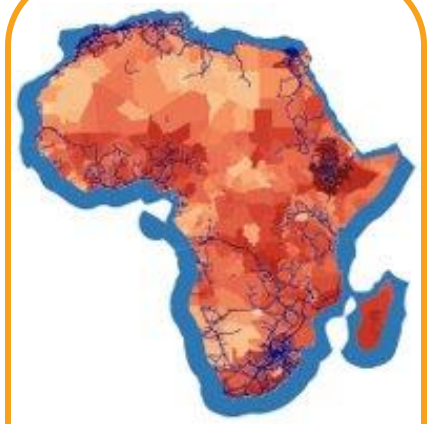

PyPSA
meets Africa
PyPSA
meets Earth
PYPSA MEETS EARTH
2022
GETTING READY TO
CHANGE THE WORLD

DUPLICATION – REMOVAL?

1) Empowering people: growing community (>60pp)

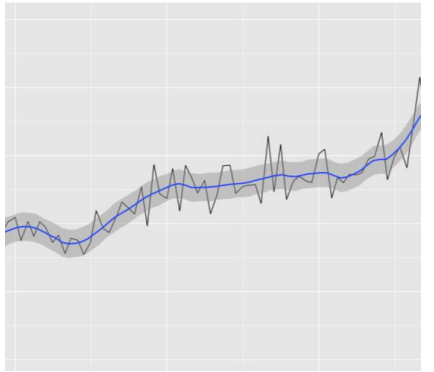


2) Collaborative environment for answering energy questions through open tools, solvers and data



PyPSA-Africa

Detect-Energy

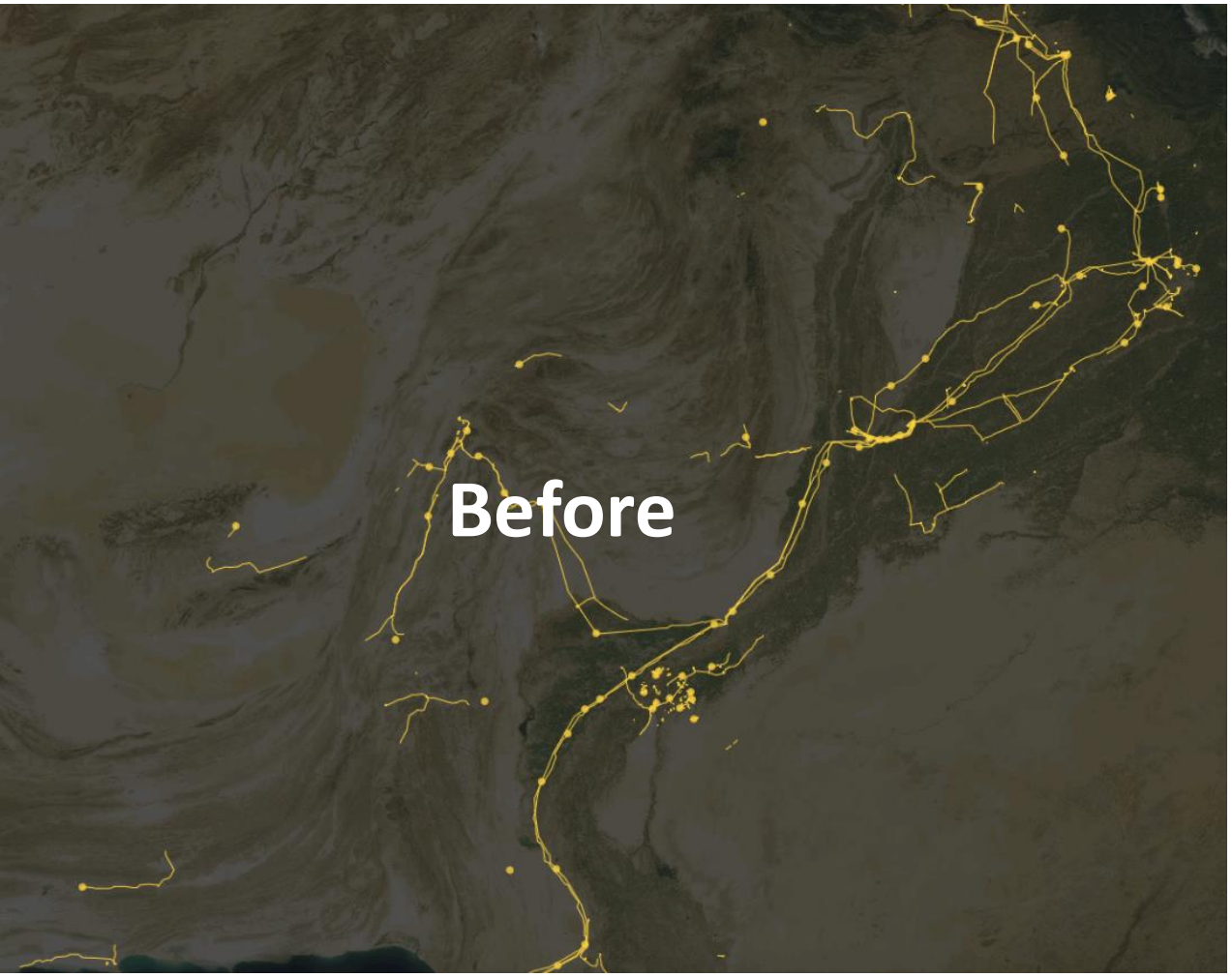


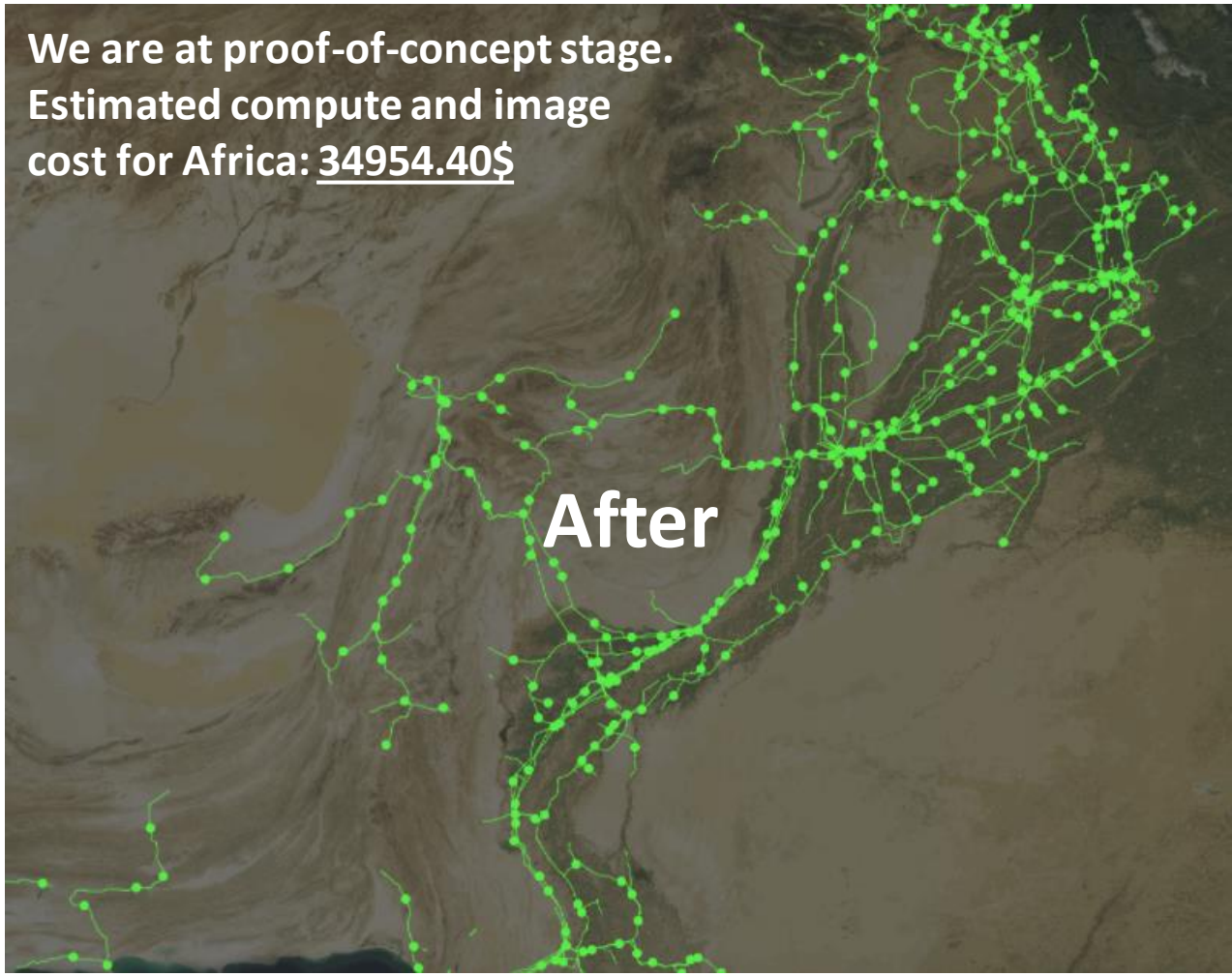
Demand-Creator

Recent Work

2017: Cooperation between *World Bank* and *Development Seed*

PyPSA meets Earth

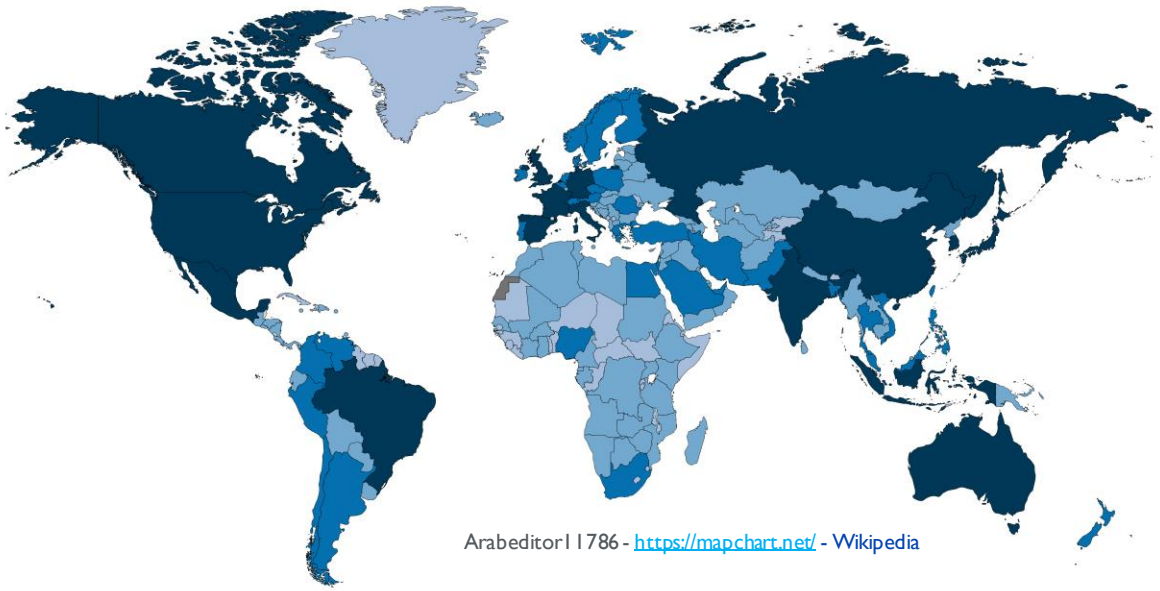




https://devseed.com/ml-grid-docs/results/mapping-output-and-speed/

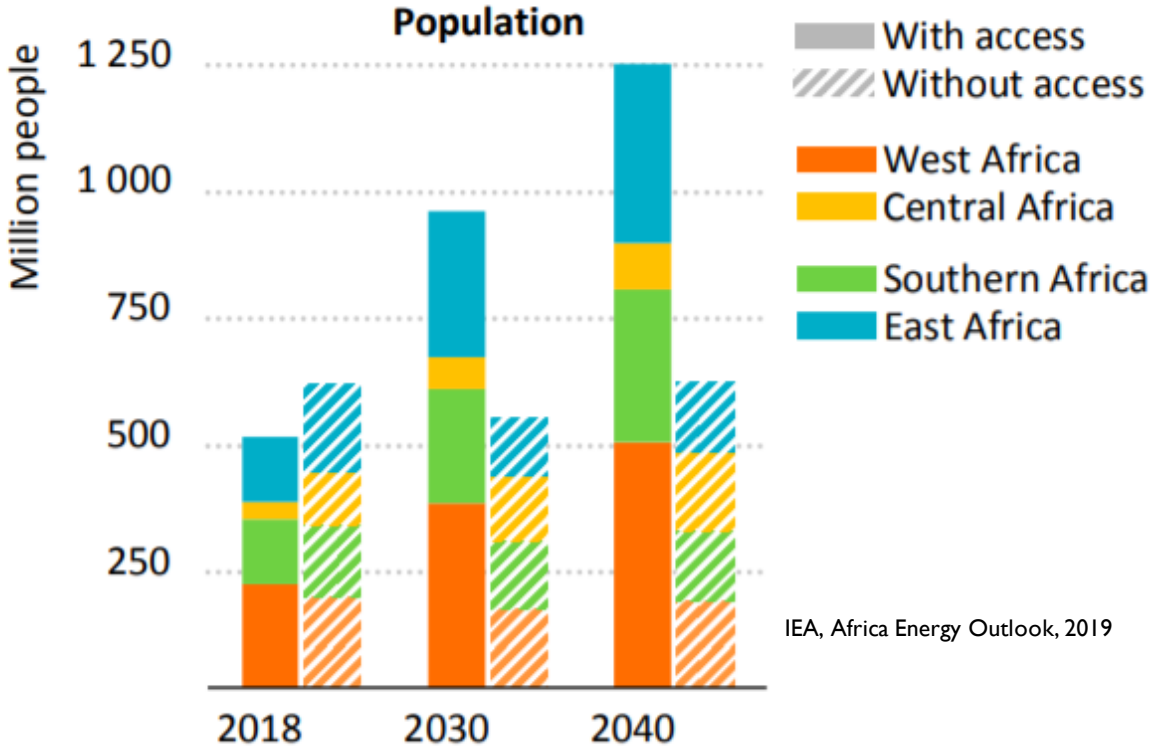
PROBLEM WILL GROW

GDP per capita must increase …



Arabeditor1786 - https://mapchart.net/ - Wikipedia

… and population is growing …



IEA, Africa Energy Outlook, 2019

POWERPLANTS

Datasets to merge:

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

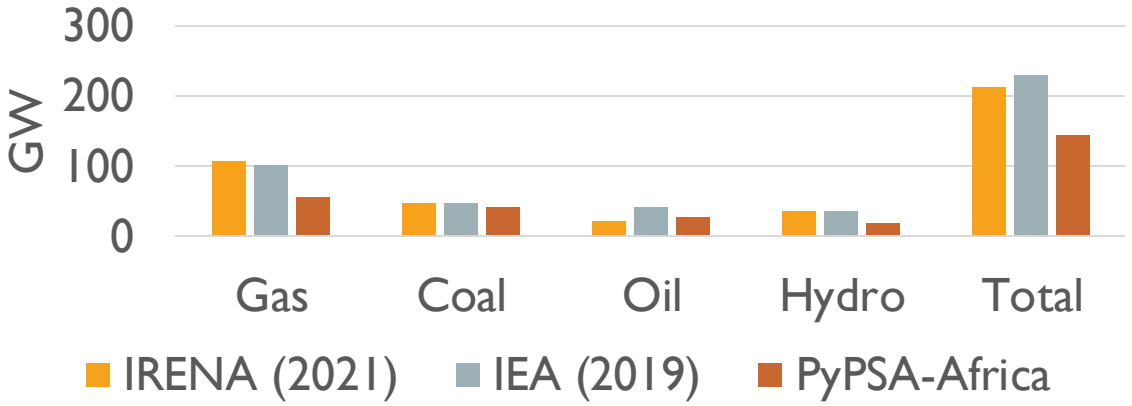
Merge datasets by Powerplantmatching

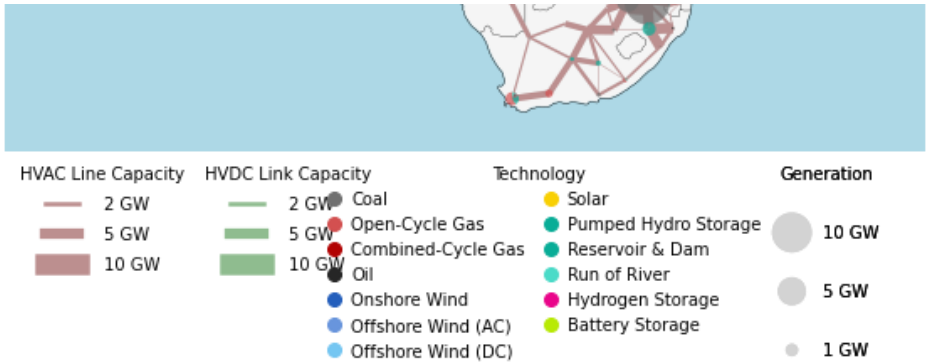
Help welcome on

- Country-level validation
- Merge different datasources (powerplantmatching)
- Look for accurate data

PyPSA Africa

Data validation - Africa





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

https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2021/March/Renewable_Energy_Transition_Africa_2021.pdf
https://iea.blob.core.windows.net/assets/2f7b6170-d616-4dd7-a7ca-a65a3a332fc1/Africa_Energy_Outlook_2019.pdf

COMPLEXITY AND DATA PROBLEM

WHAT DATA?

Merge and populate data

1. Network data by Open Street Map
2. Powerplant data
3. Resource and demand assessment

DIFFICULT PROBLEM?

Tools to handle complexity

4. Clustering to deal with complexity
5. Network augmentation
6. Some results

PYPSA-AFRICA FEATURES

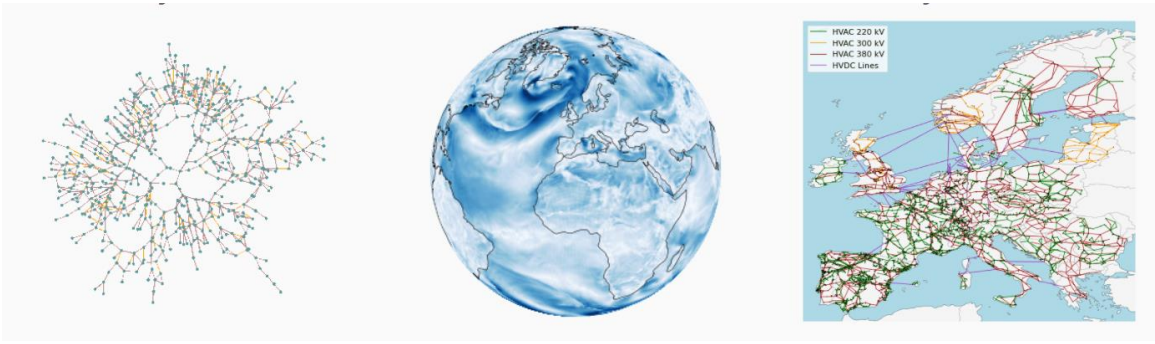
Policy makers and utilities need:

- **Robust** Built on top of PyPSA-Eur, …
- **Low cost** Open-source model
- **Reliable** Community support (>60pp)
- **Easy-to-use** python™
- **Planning & dispatch tools**

  Scenario analysis
  Adjustable resolution
  Sector-coupling (coming soon)

PyPSA meets Africa

Credits also to



PyPSA | Atlite | PyPSA-Eur

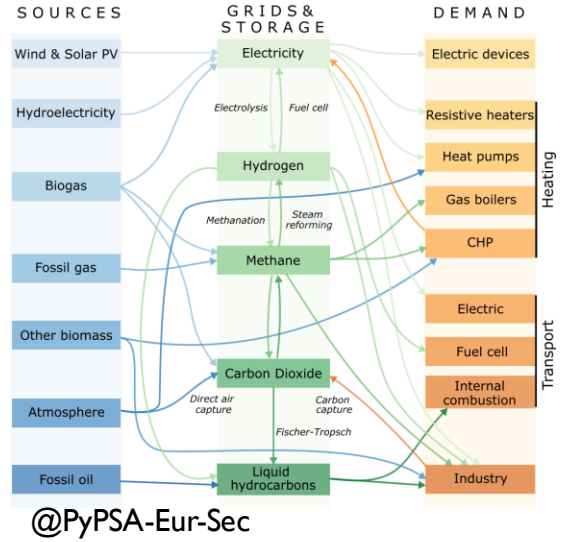
WHAT NEXT

Low data accuracy?

Ongoing validation!
«Linkers» to use most reliable source

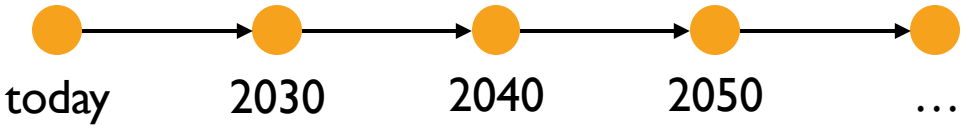
Only electricity?

PyPSA Africa Sector coupled!



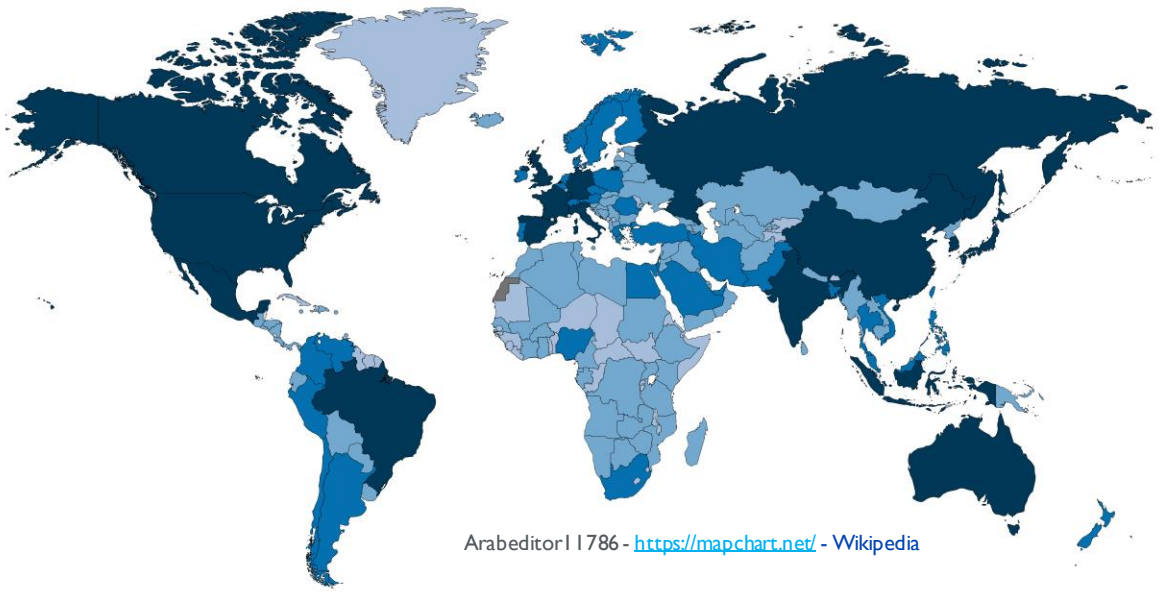
Single-year?

Pathway optimization!



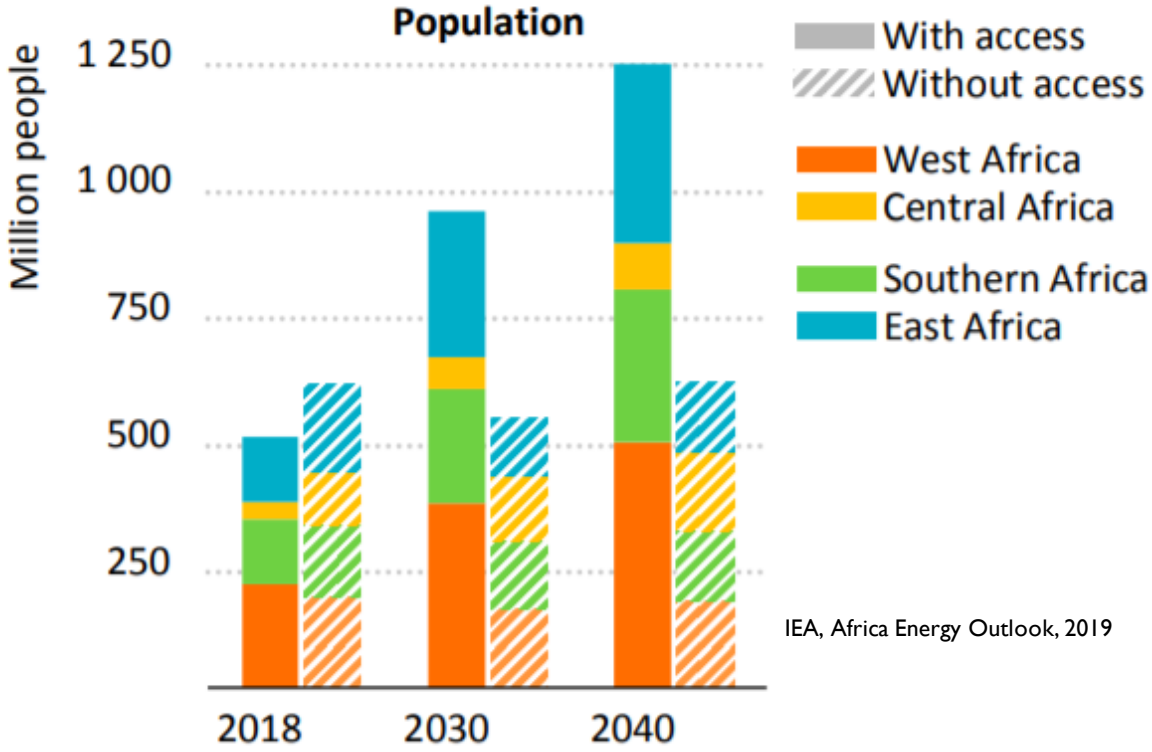
PROBLEM WILL GROW

GDP per capita must increase …



Arabeditor1786 - https://mapchart.net/ - Wikipedia

… and population is growing …



IEA, Africa Energy Outlook, 2019

Per capita energy (2019) 4 21 MWh/pp

https://ourworldindata.org/grapher/per-capita-energy-stacked

WHAT ARE WE BUILDING?

AFRICAN ENERGY SYSTEM MODEL

Special features:

- Investment and dispatch optimisation
- Adjustable resolution and grid modelling
- Multi-horizon opt. (PyPSA-EUR-SEC)
- Sector-coupled (PyPSA-EUR-SEC)

- **Written in Python**
- Modular design with open-source libraries
- Automated, reproducible workflow
- Easy to incorporate new data
- Easy to tailor to different needs
- **Open source down to the source code**