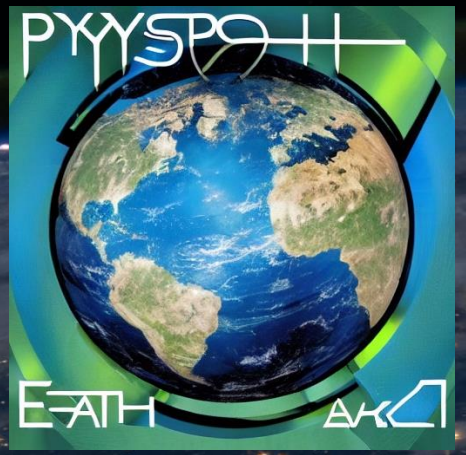
Open energy planning 'n' PyPSA meets Earth



06.04.2023
Maximilian Parzen,
Dr. Martha Frysztacki,
Prof. Dr. Davide Fioriti

PyPSA meets Earth

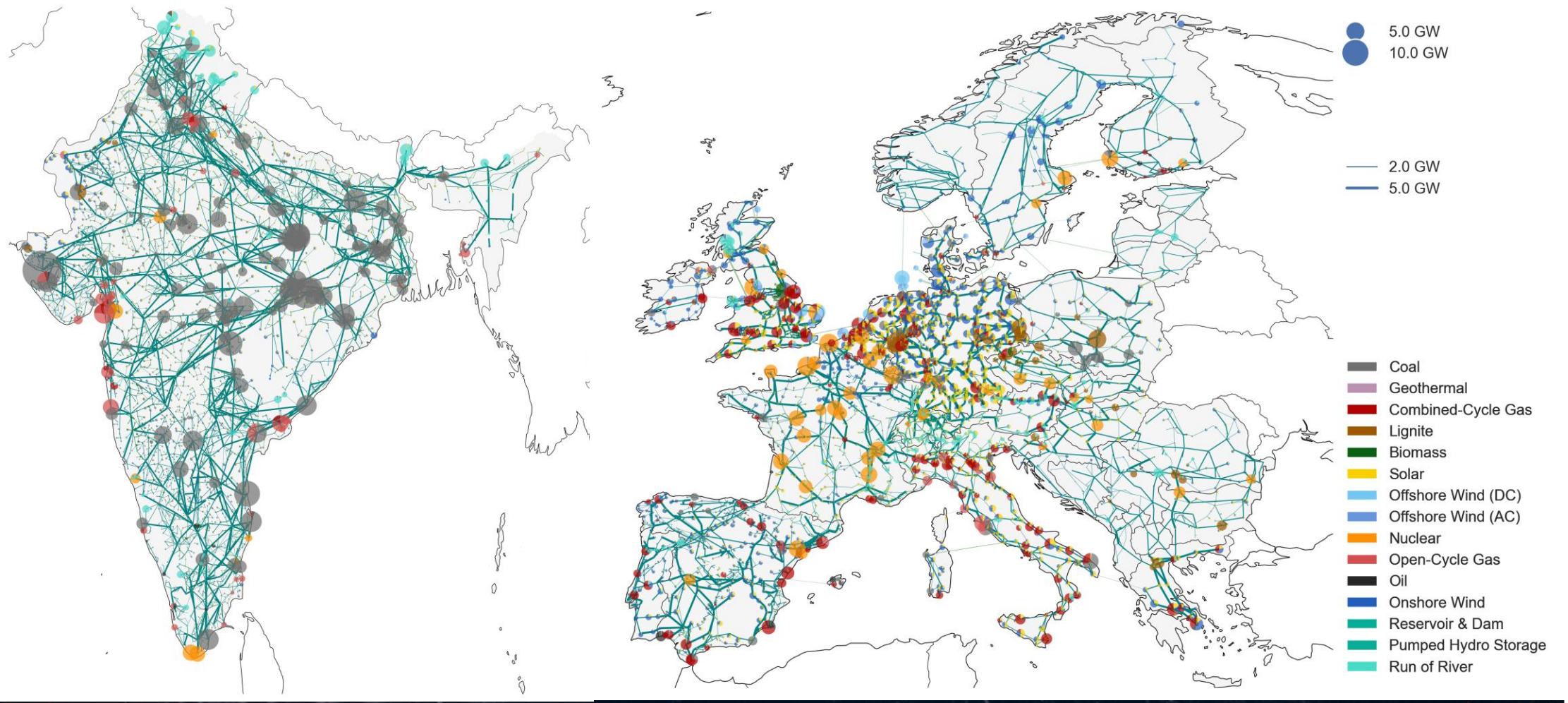
CC

PART I. Open Energy Planning

PyPSA meets Earth

Digital Twins as Planning Foundations

PyPSA meets Earth



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

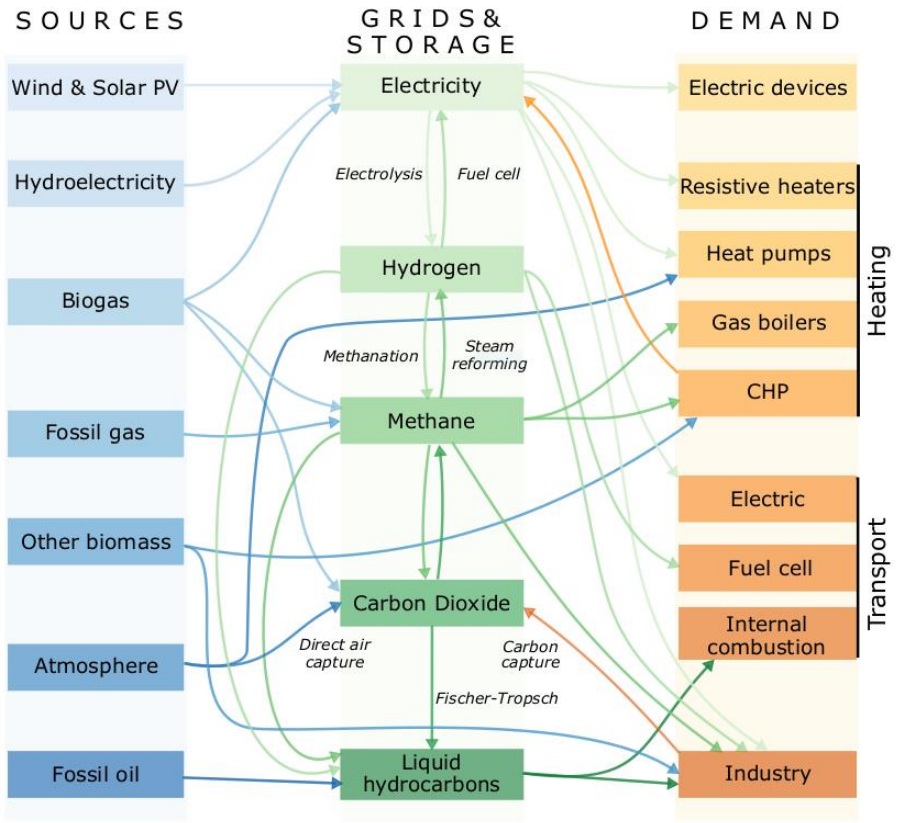
What does these models include?

PyPSA meets Earth

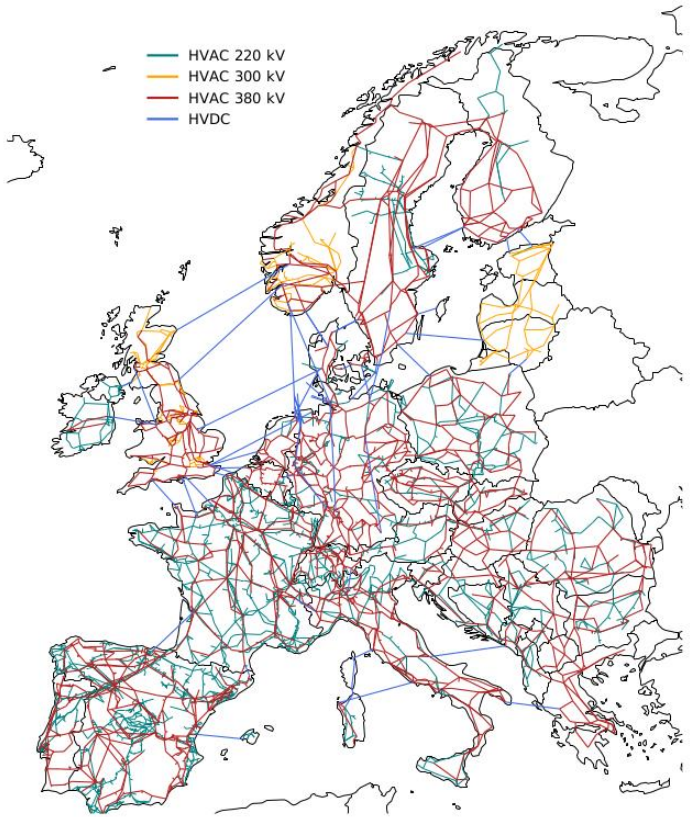
What is PyPSA-Eur-Sec?

Technische Universität Berlin

Model for Europe with all energy flows...



and bottlenecks in energy networks.



Why Energy Modelling in Particular Need to be Open

Technische Universität Berlin

What makes energy modelling special?

- Energy has **high social, political and economic relevance** (large positive role in economy, but also negative role in climate change, air pollution, resource conflicts)
- Large role of **business interests** in energy (hundreds of billions of euros spent each year in Europe on energy, much of it imported)
- Large **uncertainties about future** (technology cost & availability, acceptance, politics, geopolitics)
- Many **trade-offs beyond cost** (environmental impact, acceptance, political/social support, land use, industry relocation versus security, e-fuel imports)
- Need for **computer modelling** to avoid bad investment decisions (and save the planet)
- But results are **strongly driven by inputs and assumptions** (cost, demand, constraints)

What is open modelling?

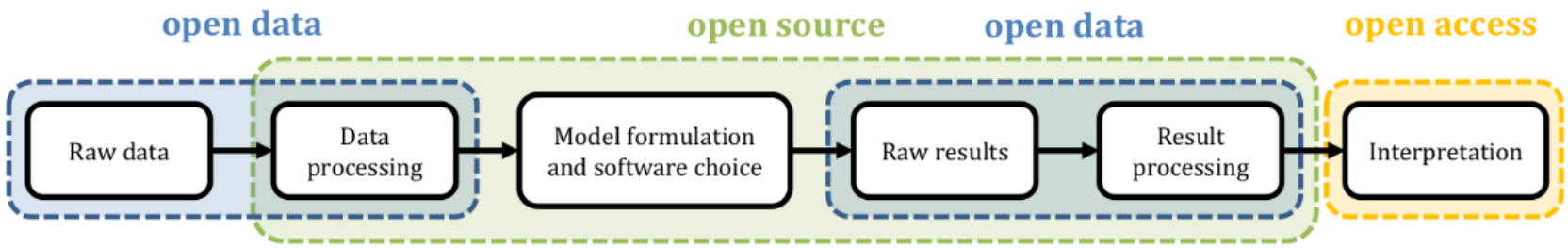
Technische Universität Berlin

Open energy modelling means modelling with open software, open data and open publishing.

Open means that anybody is free to download the software/data/publications, inspect it, machine process it, share it with others, modify it, and redistribute the changes.

This is typically done by uploading the model to an online platform with an **open licence** telling users what their reuse rights are.

The **whole pipeline** should be open:



How does openness and transparency help?

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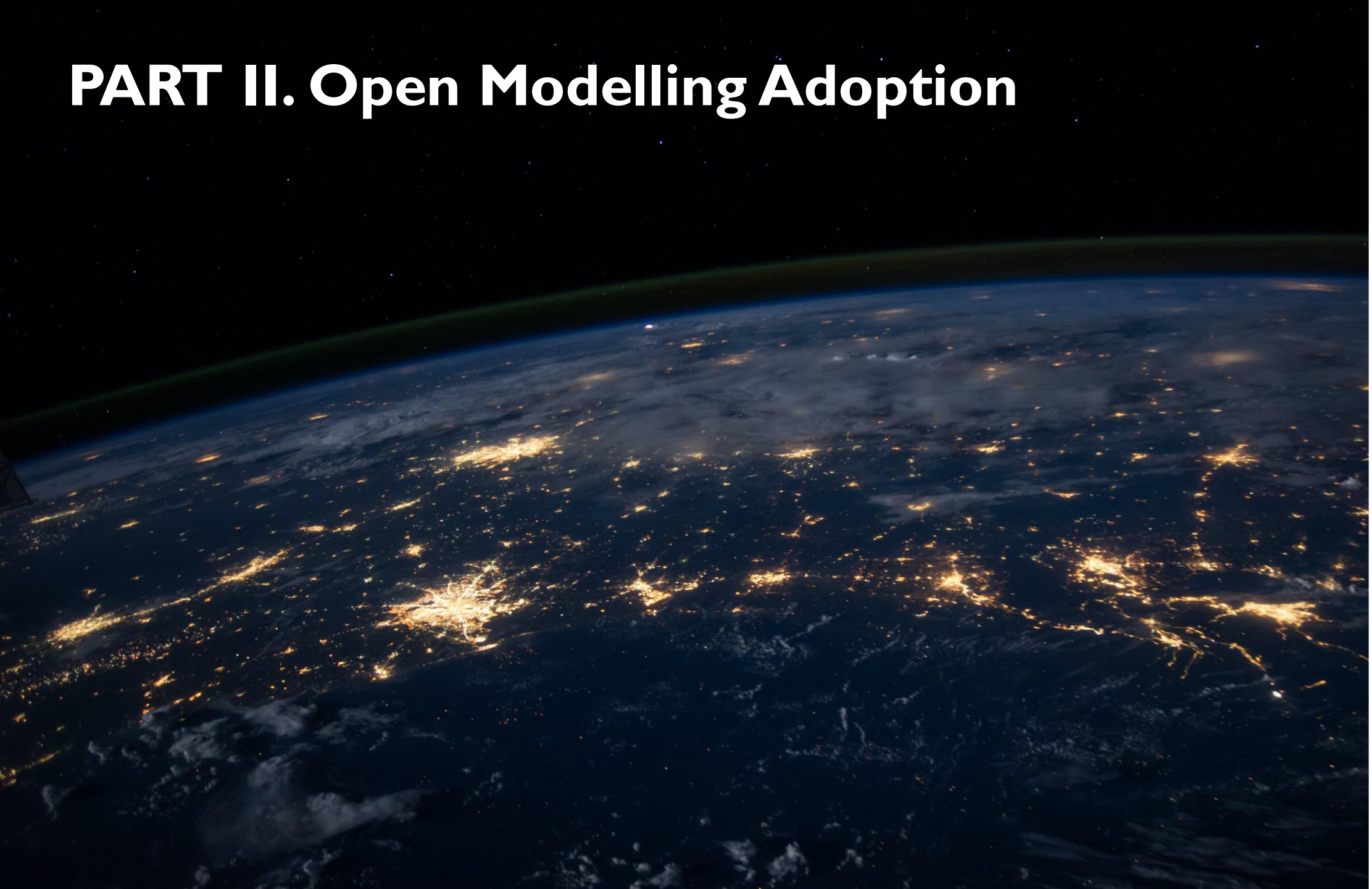
openness . . .

- increases **transparency**, **reproducibility** and **credibility**, which lead to better research and policy advice (no more 'black boxes' determining hundreds of billions of energy spending)
- reduces **duplication of effort** and frees time/money to develop **new ideas**
- allows a **high level of customisability** given code is open
- enables **new actors to participate in debate** (e.g. NGOs, researchers, public)
- *can* improve research **quality** through feedback and correction
- allows easier **collaboration** (no need for contracts, NDAs, etc.)
- is essential given the increasing **complexity** of the energy system - we all need data from different domains (grids, buildings, transport, industry) and cannot collect it alone
- can increase **public acceptance** of difficult infrastructure trade-offs

PART II. Open Modelling Adoption



PyPSA meets Earth

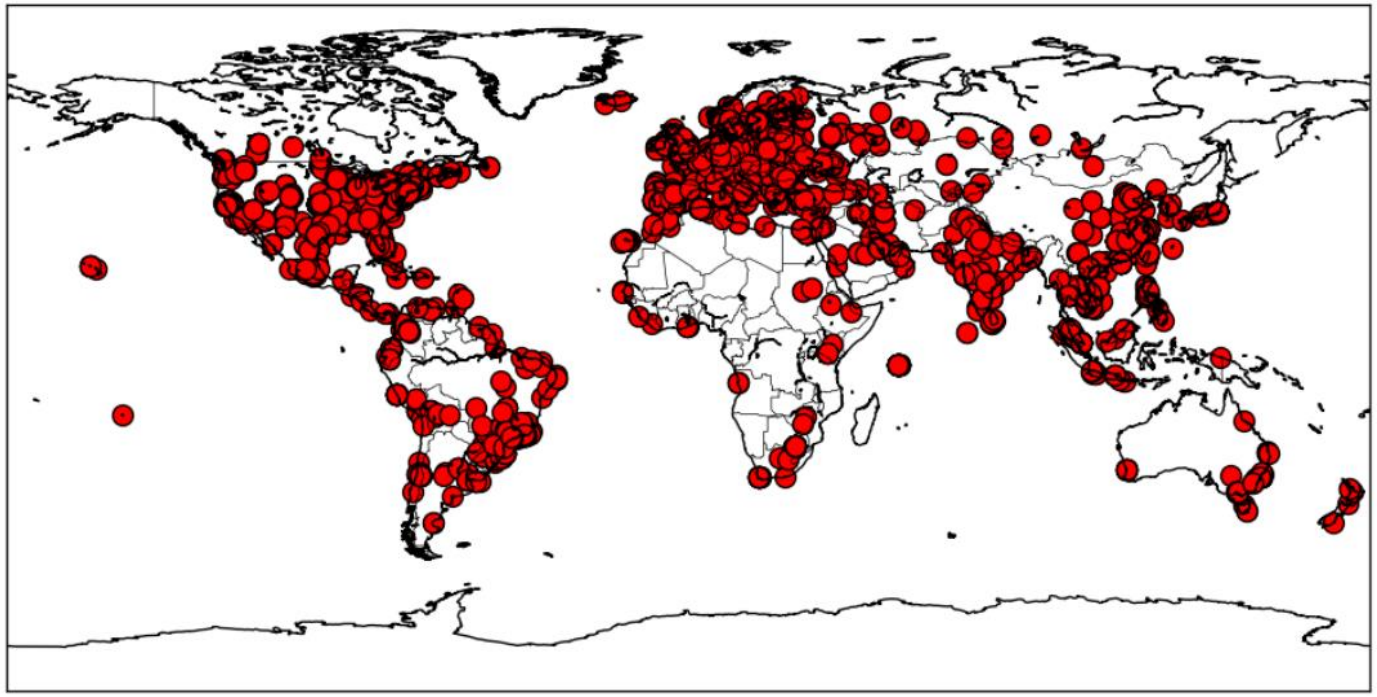
WORLDWIDE ADOPTION

PyPSA meets Earth

Python for Power System Analysis: Worldwide Usage

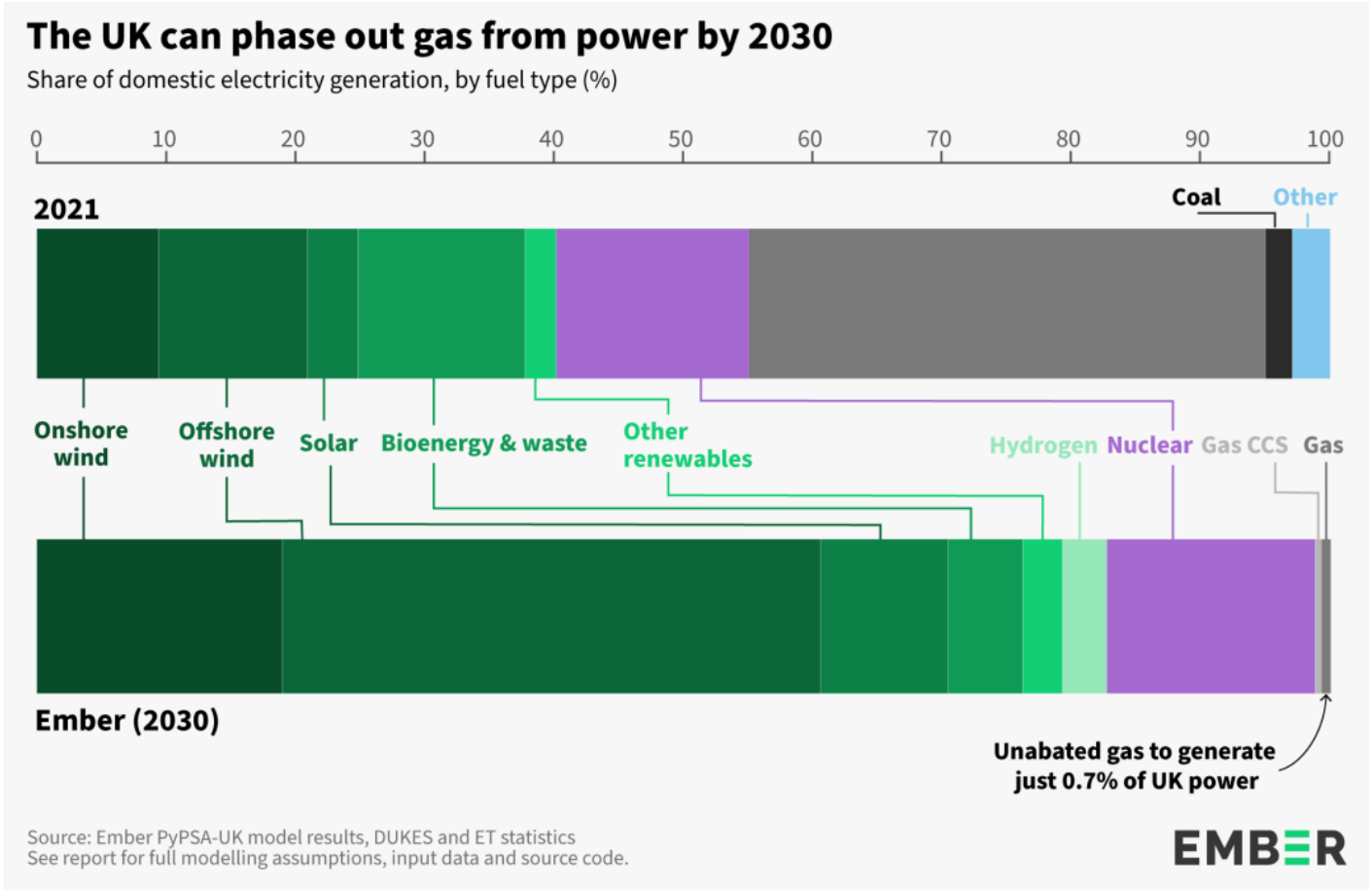
Technische Universität Berlin

PyPSA is used worldwide by **dozens of research institutes and companies** (TU Delft, KIT, Shell, TSO TransnetBW, TERI, Agora Energiewende, RMI, Ember, Instrat, Fraunhofer ISE, Climate Analytics, DLR, FZJ, RLI, Saudi Aramco, Edison Energy, spire and many others). See **list of users**.



EXAMPLES

NGO Ember used PyPSA to model a gas phase out in the UK by 2030, releasing all code on **github**.

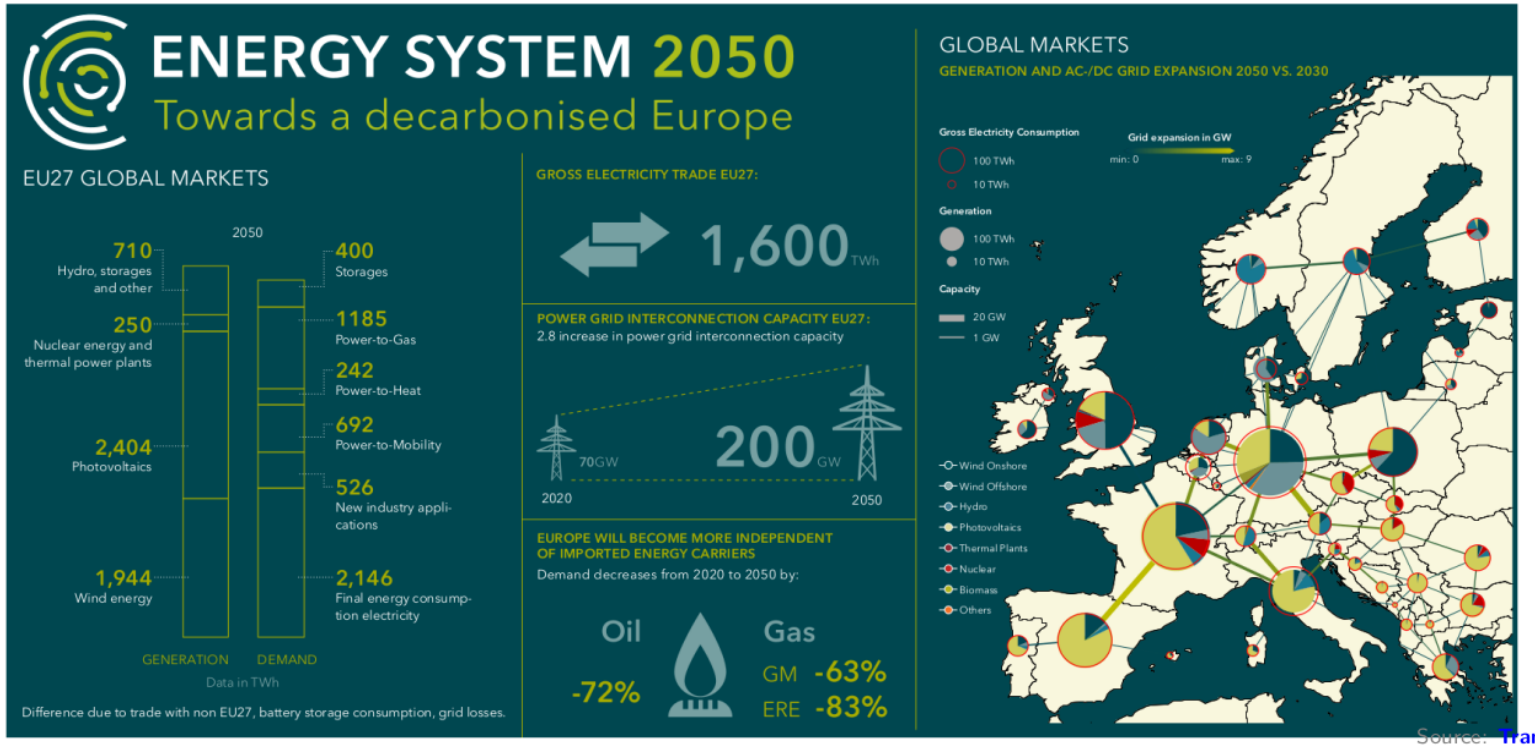


Source: **Ember, 2022**

EXAMPLES

PyPSA example: TransnetBW used PyPSA-Eur-Sec

German **Transmission System Operator (TSO) TransnetBW** used an open model (PyPSA-Eur-Sec) to model the European energy system in 2050. Why? Easier to build on an existing model than reinvent the wheel.



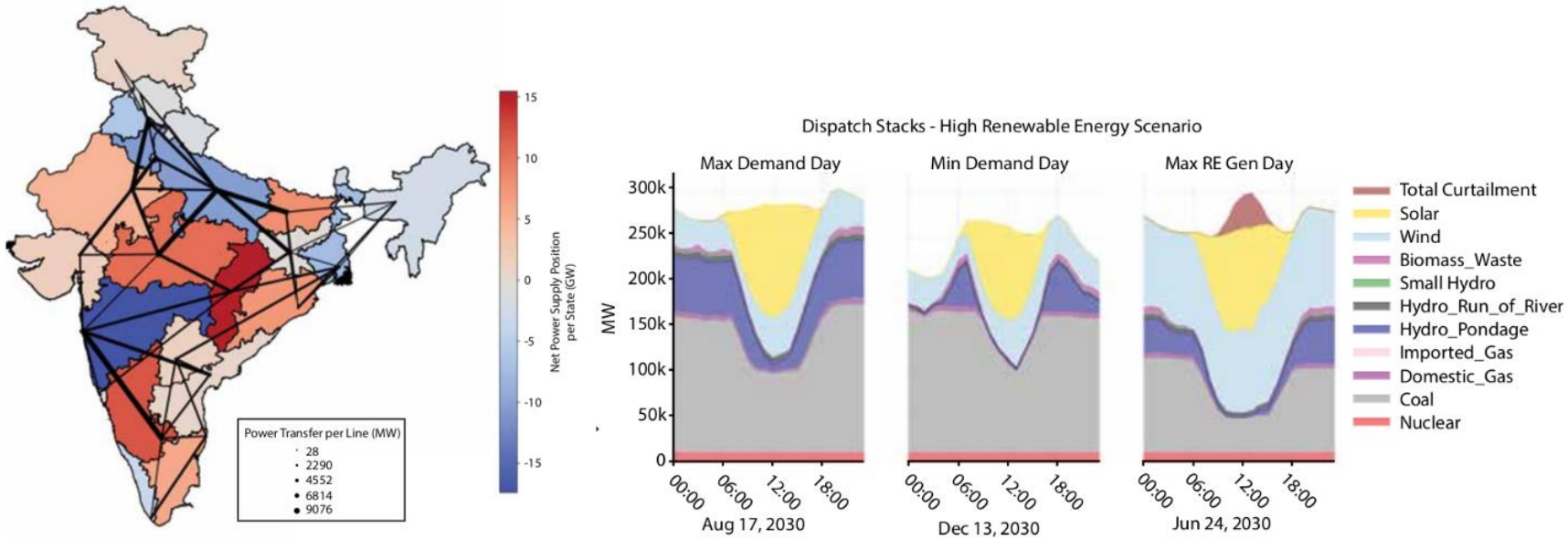
Source: TransnetBW, 2022

EXAMPLES

PyPSA example: TERI in India

Technische Universität Berlin

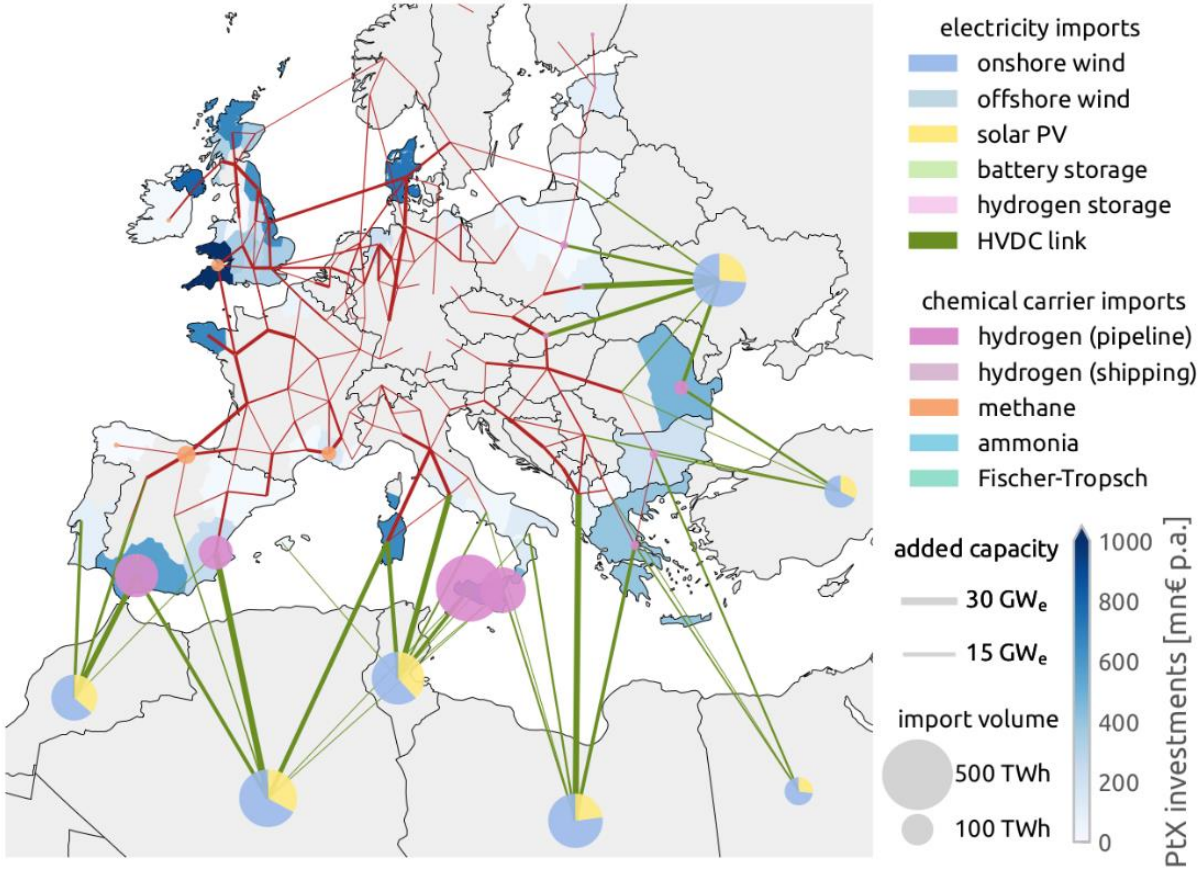
For a government-backed study of India's power system in 2030, The Energy and Resources Institute (TERI) in New Delhi used open framework PyPSA. Why? **Easy to customize**, lower cost than commercial alternatives like PLEXOS, good for building up skills and reproducible by other stakeholders.



PyPSA meets Earth

EXAMPLES

With e-fuel imports instead of autarky

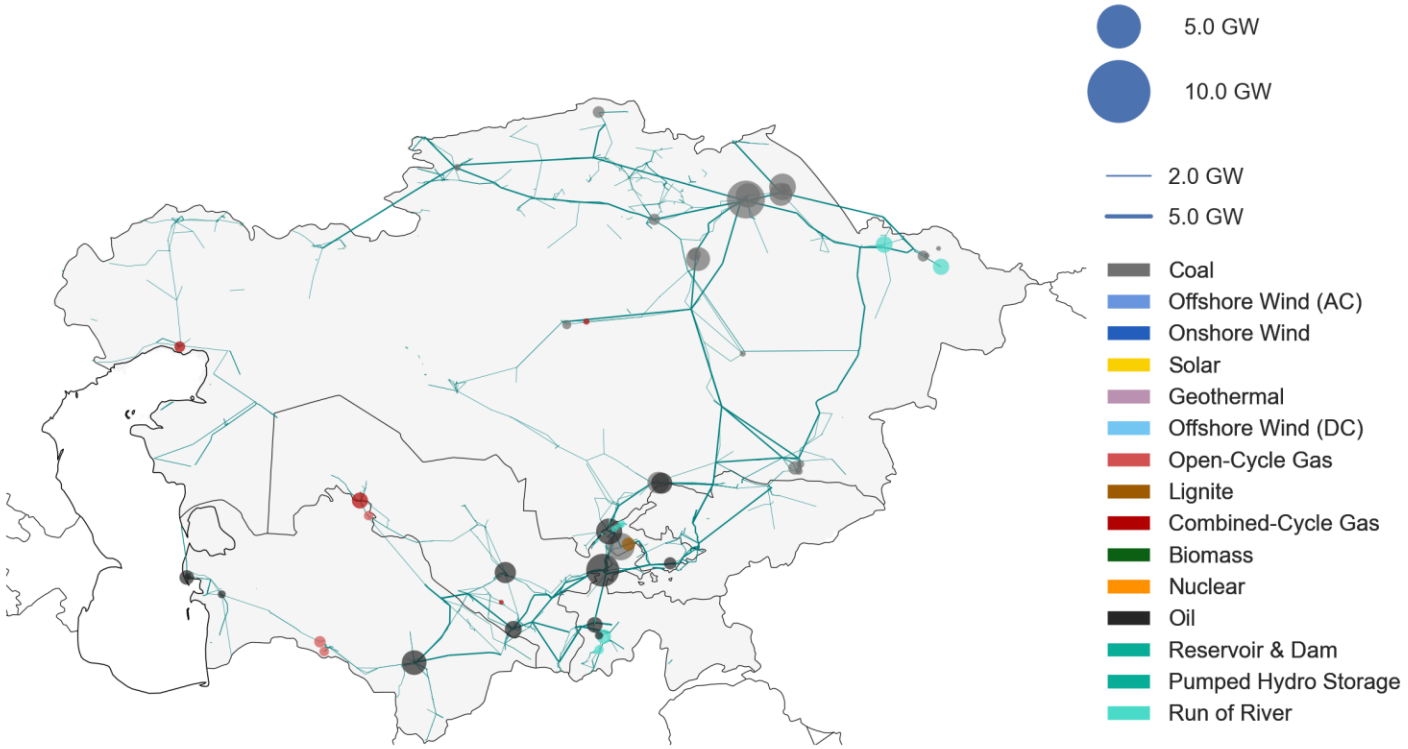


- Allowing imports of electricity, green hydrogen, e-fuels, **changes infrastructure needs completely**
- PtX out-sourced from Europe
- Electricity imported too, providing seasonal balancing

Source: Hampp, Brown, Neumann; 2022/3

EXAMPLES

NGO Agora Energiewende uses PyPSA-Earth for exploring viable renewable energy systems in Kazakhstan. Why? It's cheaper, benefits of transparency, **support is available**, and long-term sustainable since **people can reuse** and **build up on existing work**.



PyPSA meets Earth

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"

PART III. PyPSA & PyPSA meets Earth

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

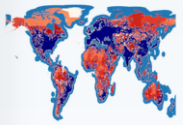
PyPSA-Eur
An open optimisation model of the European transmission system.

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

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

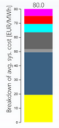
Documentation | Source Code | Category: Model | Maintained: pypsa.org

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



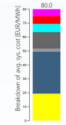
Documentation | Source Code | Category: Model | Maintained: pypsa-meets-earth

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

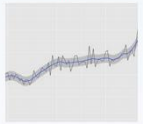
Check out our Documentation
The documentation describes in more detail how you can contribute, how our project is structured and further provides the code documentation. Additionally, we share learning materials and some relevant talks and papers in the roam of PyPSA and Earth modelling. The documentation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

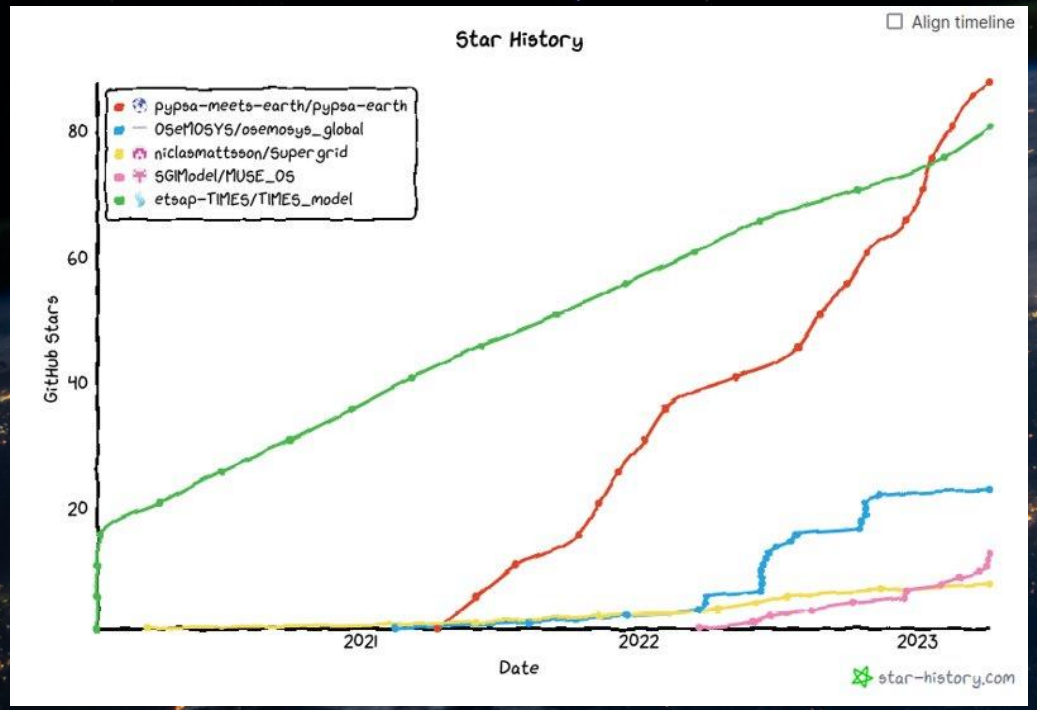
Documentation | Source Code | Category: Solver interface | Maintained: pypsa.org

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

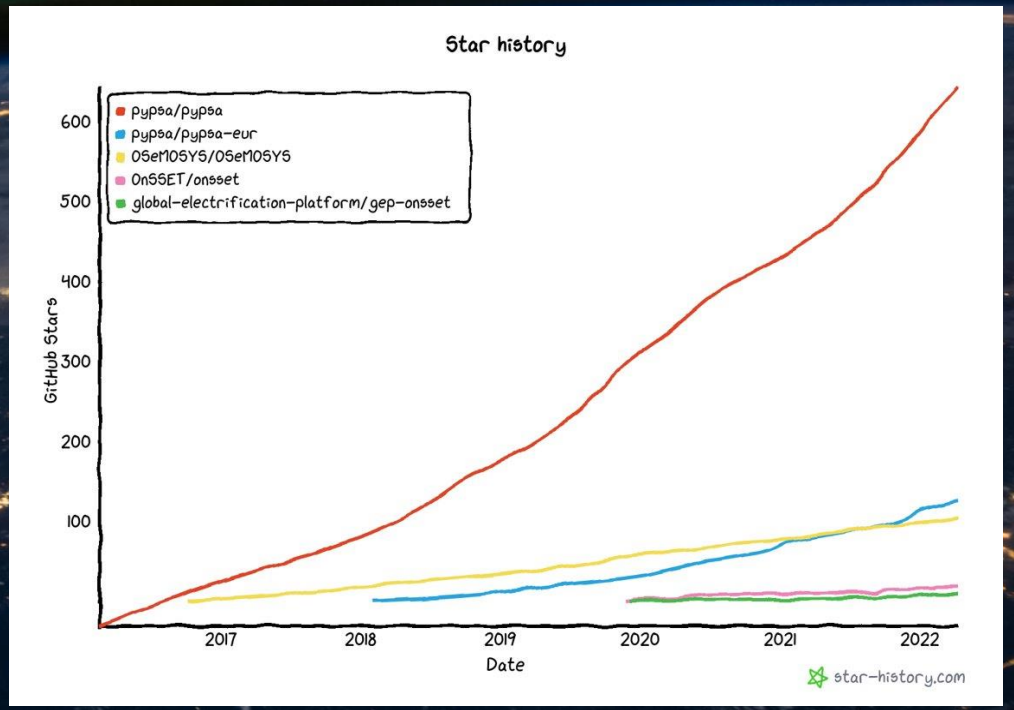
Public Proposal | Source Code | Category: Campaign | Lead by: pypsa-meets-earth

Most popular model ecosystem

#1 Global Model



#1 Model Framework



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

TABLE III

A COMPARISON OF SELECTED FEATURES OF SELECTED SOFTWARE TOOLS THAT ARE SIMILAR TO PYPSA.

PyPSA meets Earth

PART IV. Summary

PyPSA meets Earth

SUMMARY

PyPSA meets Earth

- Open data and software is **essential** for decision-making
- Open solutions are **trusted** by industry & research
- Open and active **community** is key

SUMMARY

PyPSA meets Earth

BE CAREFUL, CONSIDERED OPEN BUT TROUBLEMAKERS:

- **Inactive** user/ development community (e.g. TIMES, IRENA)
- **Licenses** to run the software (e.g. GAMS/Matlab based tools)
- Tools with **missing features** for study purpose
- Tools that come **without data/ non-evolving data**

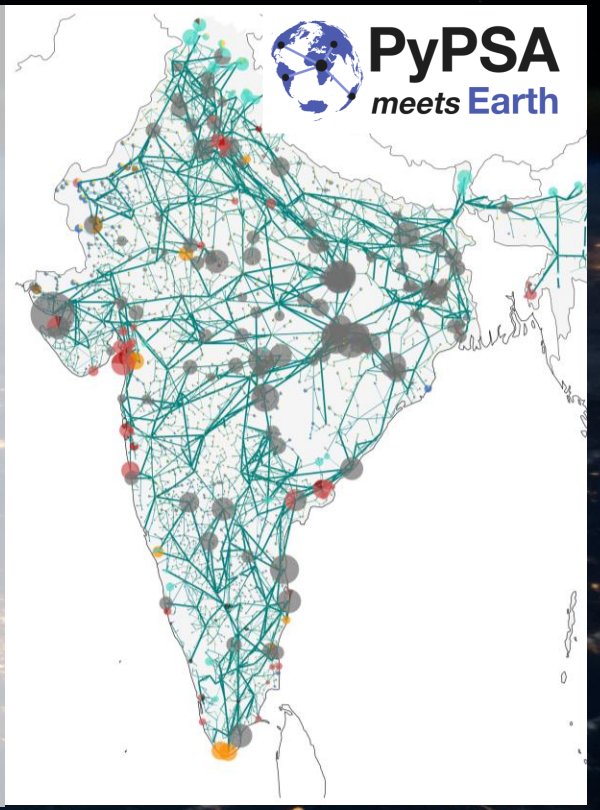
Thank you for listening 'n' stay open.

Website: https://pypsa-meets-earth.github.io/

Davide

Martha

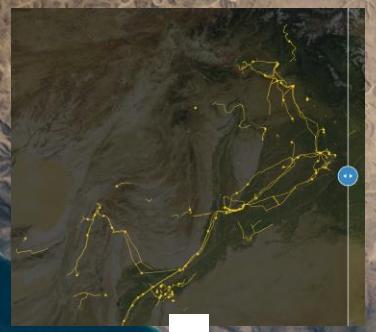
Max



AI 'n' Digital Twins for Net-Zero Planning

Scalable Infrastructure Monitoring from Satellites

PyPSA meets Earth



PROBLEM

- **Energy system planning** requires better data

SOLUTION

- **AI object detection** map infrastructure updates

IMPACT

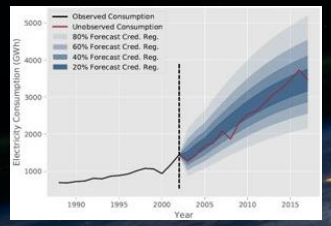
- **Faster and better** energy system planning
- **Accelerated** renewable energy expansion
- **More affordable** electricity and energy
- **Reduction** of CO2 emissions
- **Solution** global useful and improving over time

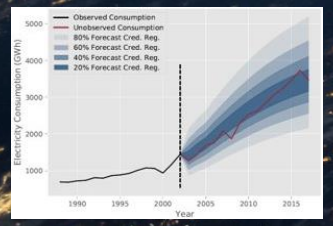
USERS: UoE, GE, NationalGrid, SSE, UK Gov, ...

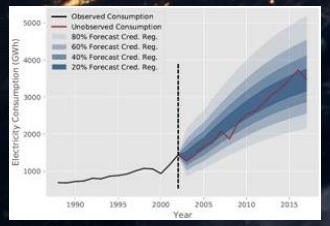
AI 'n' Digital Twins for Net-Zero Planning

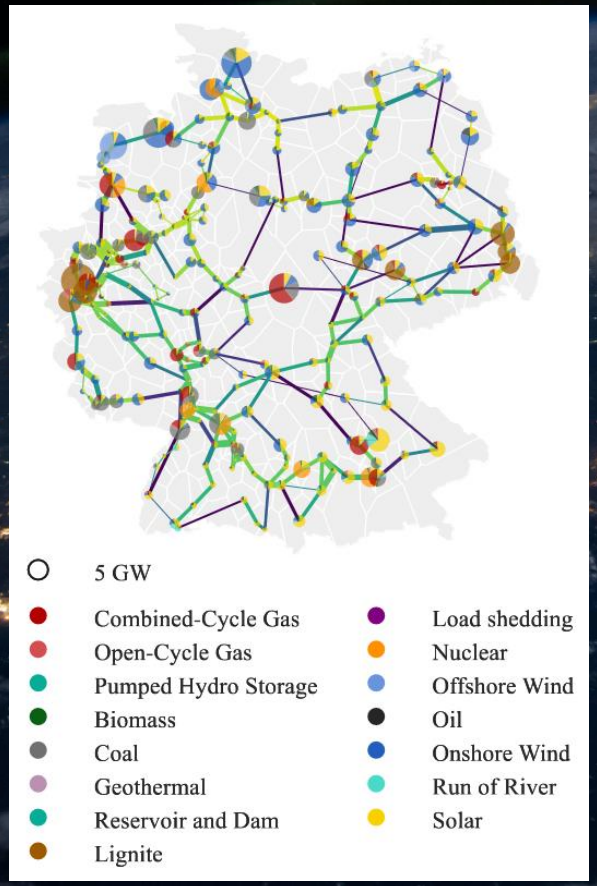
Intelligent Demand Prediction

PyPSA meets Earth









PROBLEM

- **Energy system planning** in EU based on poor demand data

SOLUTION

- **AI prediction** of electricity demand with big data

IMPACT

- **Faster and better** energy system planning
- **Accelerated** renewable energy expansion
- **More affordable** electricity and energy
- **Reduction** of CO2 emissions
- **Solution** global useful and improving over time

USERS: UoE, GE, NationalGrid, SSE, UK Gov, ...

YOU ARE ONLY COOL IF YOU USE/CONTRIBUTE TO OPEN DATA 'N' OPEN SOURCE

More details in the manifesto: ttps://openmod--initiative.org/manifesto.html

PyPSA meets Earth