

Can open source development drive energy transition?

PyPSA-Earth experience

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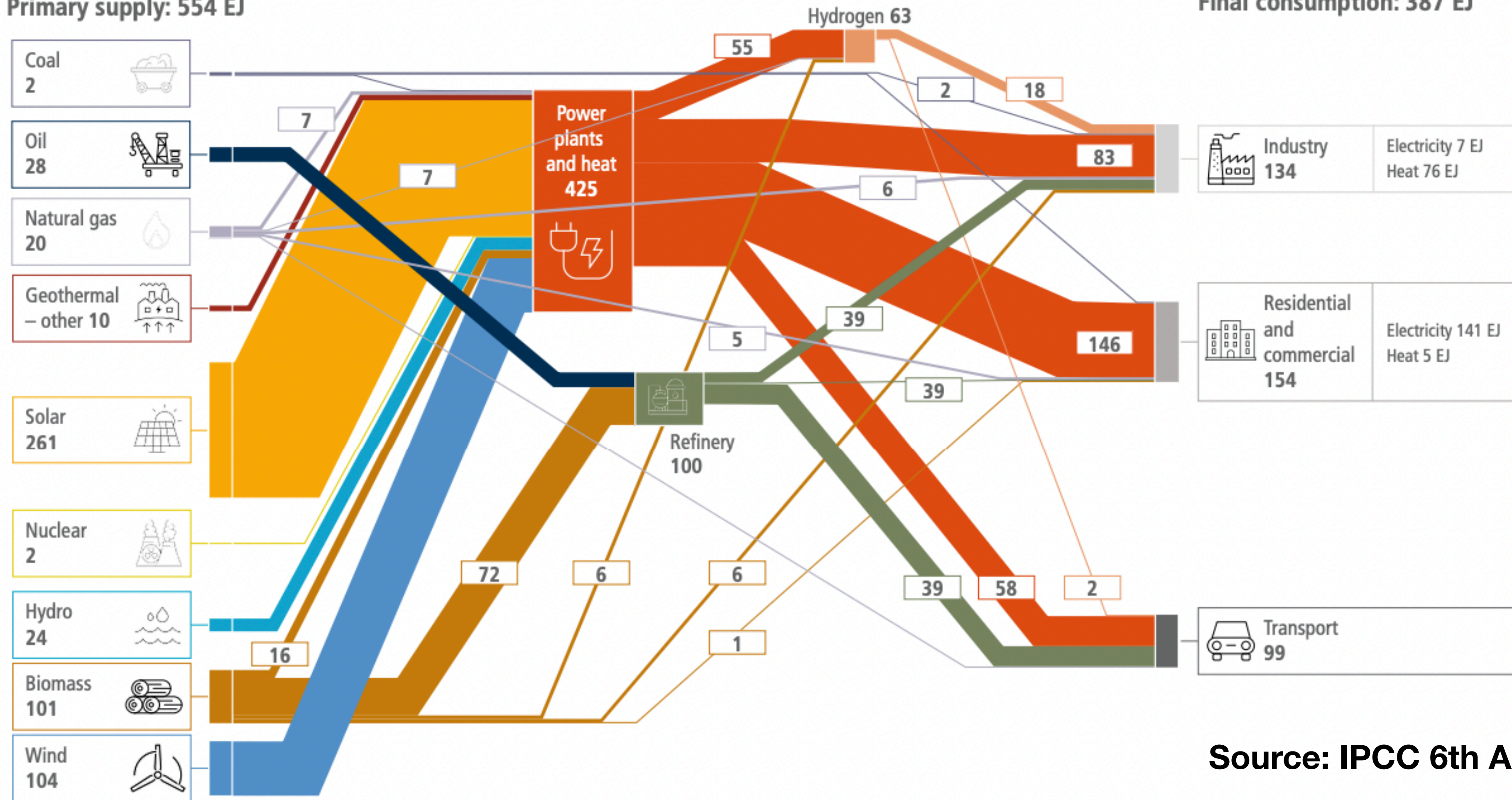


Shaping the future

Global energy use, 2060, Scenario IMP-REN-2.0

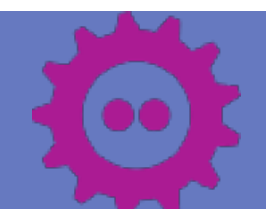
Primary supply: 554 EJ

Final consumption: 387 EJ



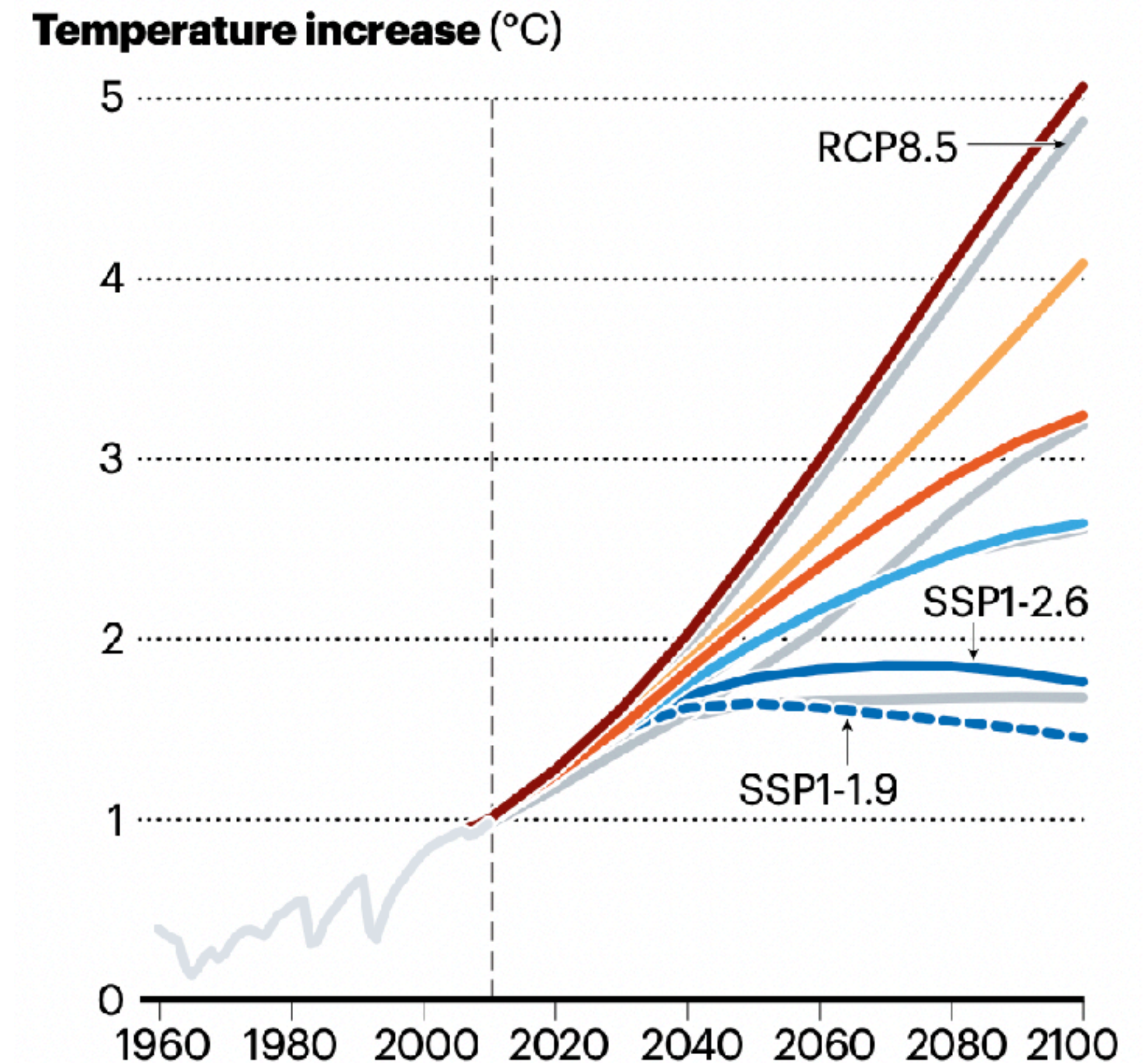
Source: IPCC 6th Assessment Report

Shaping the future

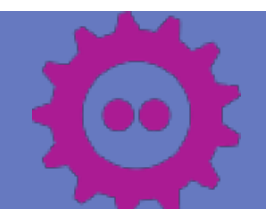


Planning under uncertainties

1. Uncertainty of a socio-economic scenario
2. Technologies development
3. Effects of climate variability and climate change
4. Regional specifics

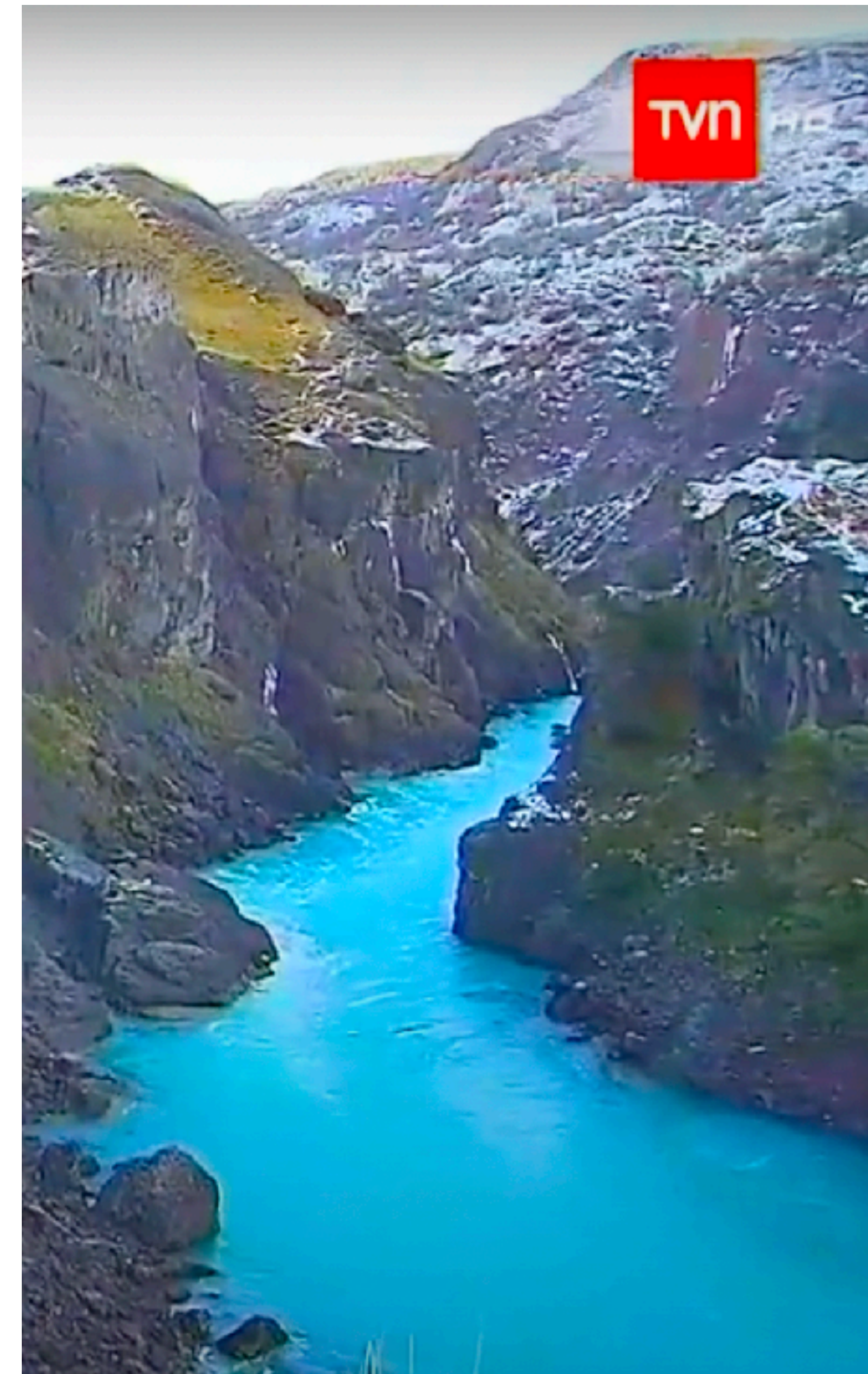


Tollefson (2023) How hot will Earth get by 2100



Planning under uncertainties

- unsuccessful early PV programme in Bhutan (1980s);
- plans to build large-scale hydropower plants in Chile: HidroAysén (2008 — 2012);
- failure of solar water heating programme in South Africa (2009 — 2014);
- repeal of carbon pricing in Australia (2014).

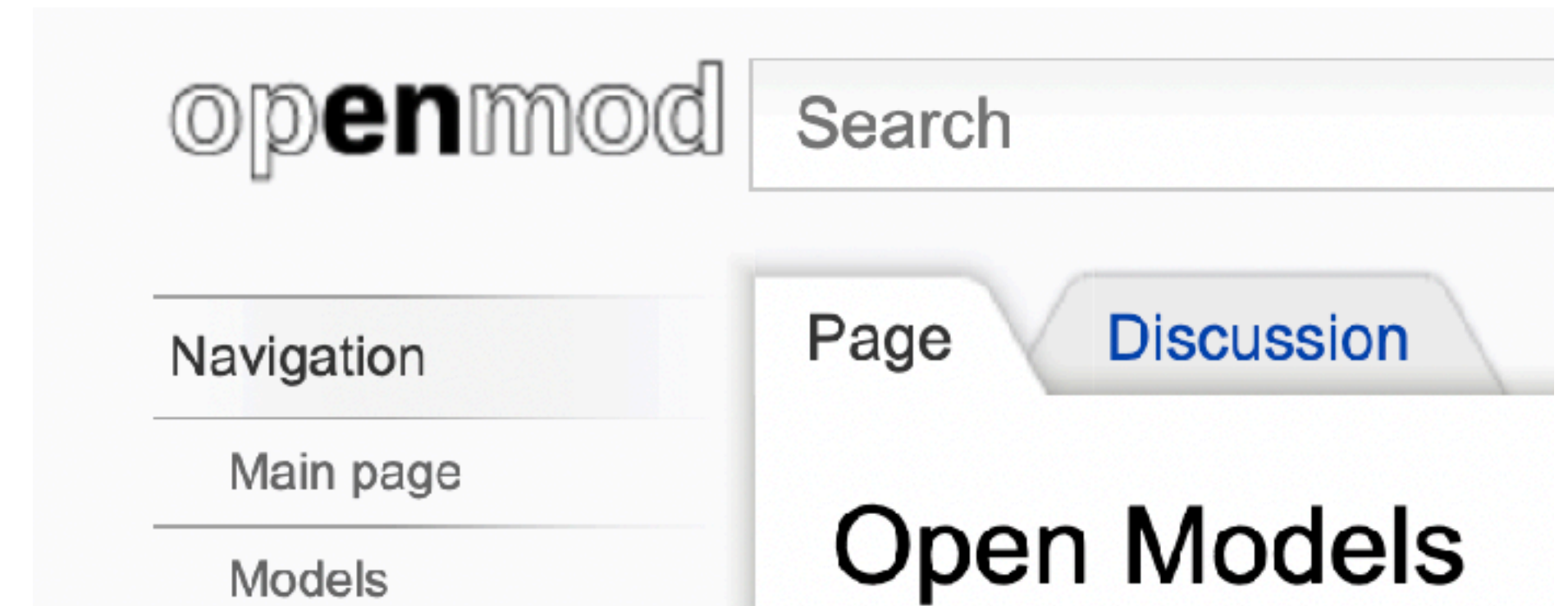


Source: <https://conservacionpatagonica.wordpress.com/>

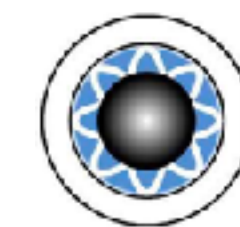
Replace painful experience of real-world failures with modeling experiments

Open energy modeling is gaining in interest

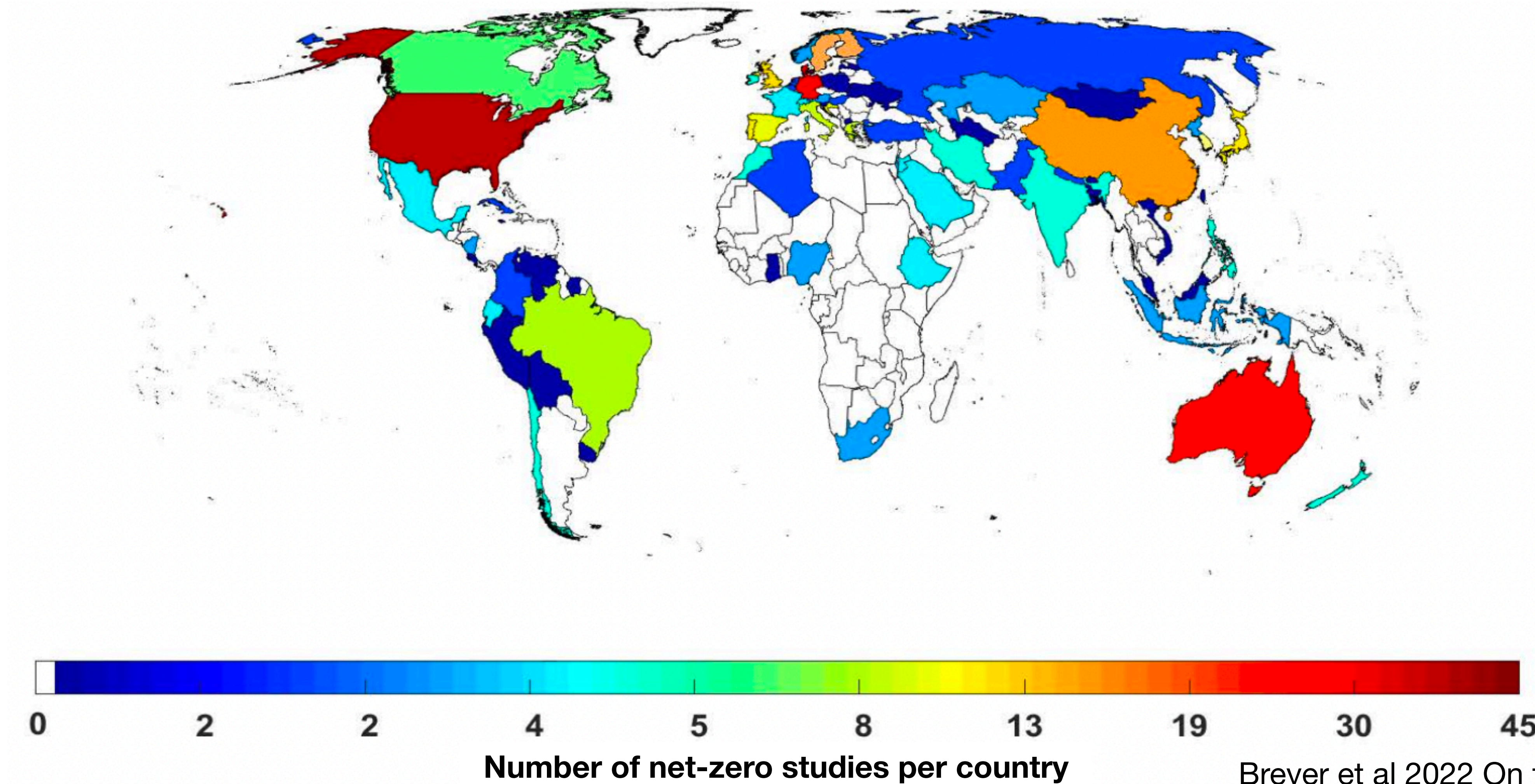
There are about 90 open source energy models at the moment



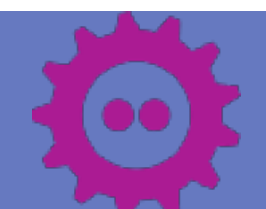
OSeMOSYS
Open Source Energy Modelling System



...but not all countries have a net-zero plan



Breyer et al 2022 On the History and Future of 100% Renewable Energy Systems Research



PyPSA-meets-Earth

Independent research initiative

Open code

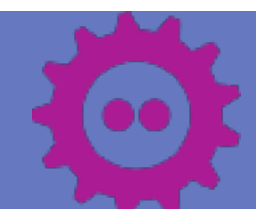
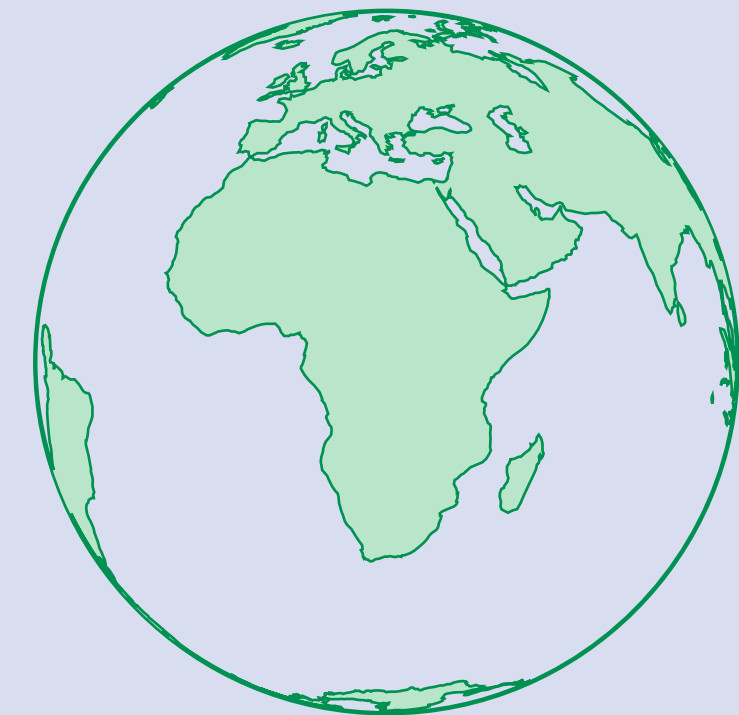
- Build upon existed approaches
- Generalised for global applicability

Open data

- Relays on open science outputs
- Crowdsourced validation

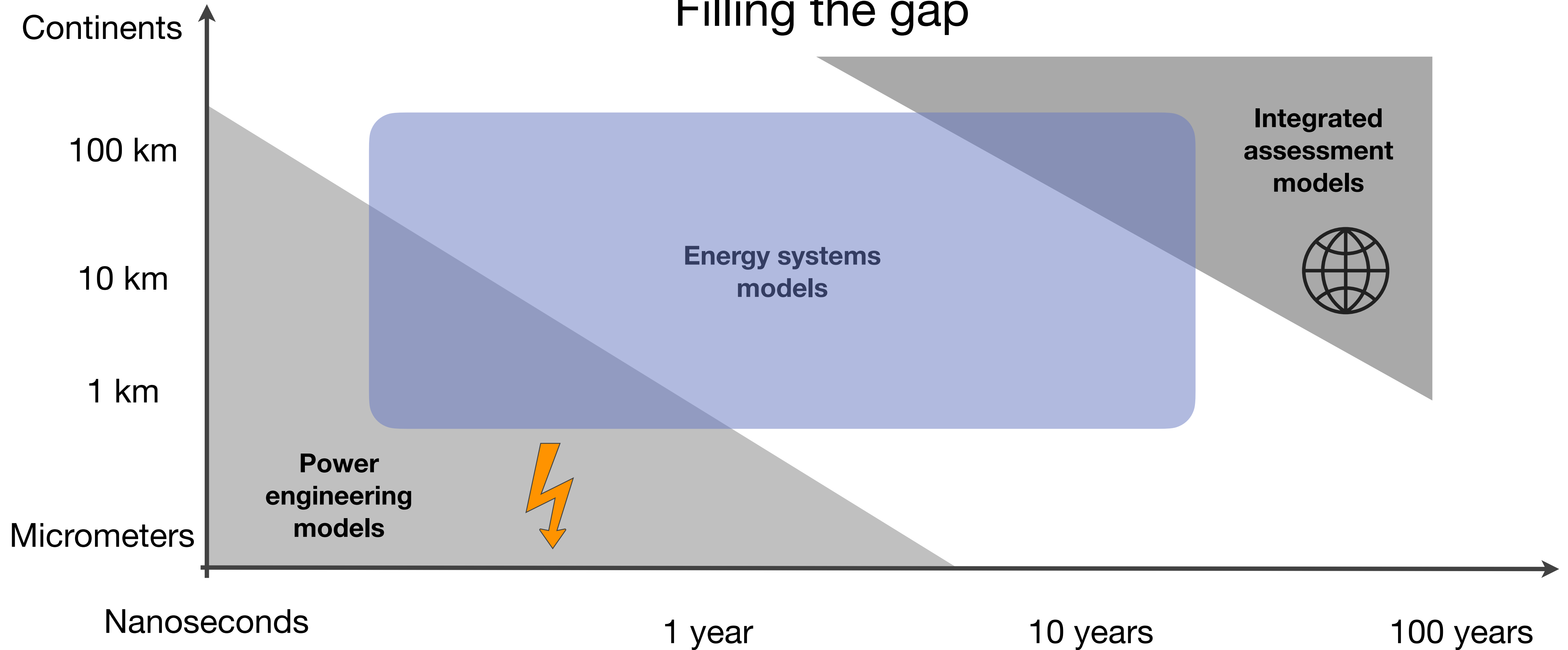
Open energy modeling community

- Focus on regional perspective
- Cross-national synergies
- Support of policy formulation
- Investment analysis
- Decarbonisation pathways

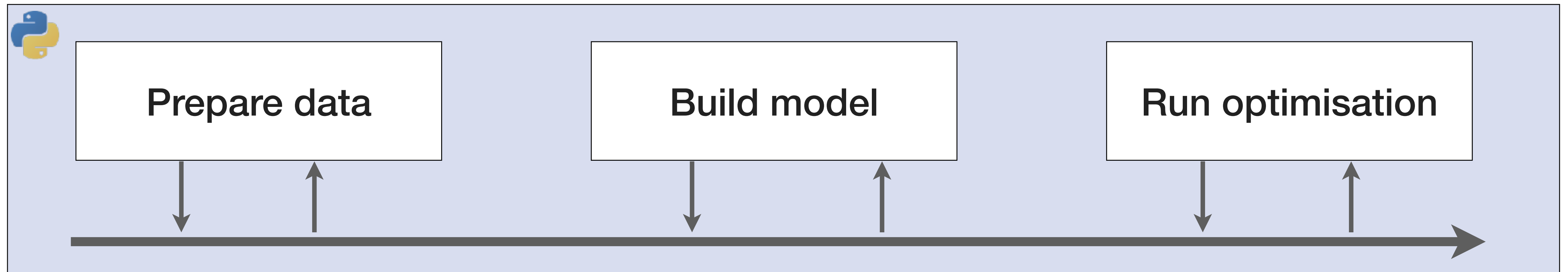


PyPSA-meets-Earth

Filling the gap



PyPSA-Earth: Open Code



 Dependencies management: conda

 Workflow orchestration: Snakemake

PyPSA-Earth: Prepare data



- Environment and climate
- Electricity demand
- Power infrastructure
- Technology costs

Retrieval vs load on demand: the difference in crucial to start with modeling

Data licensing matters

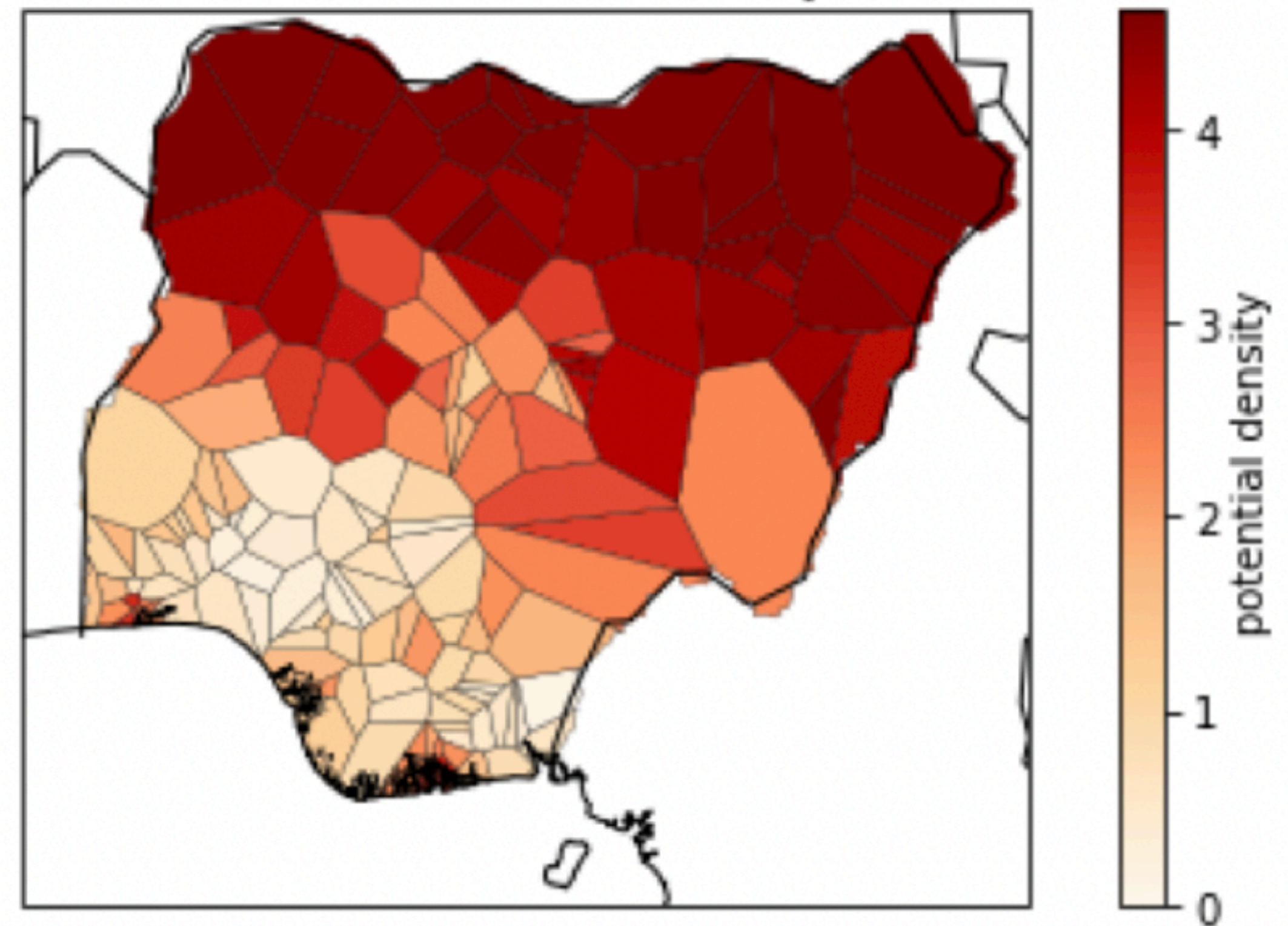
PyPSA-Earth: Prepare data

atlite package: translate geophysics into energy

- **Environment and climate**

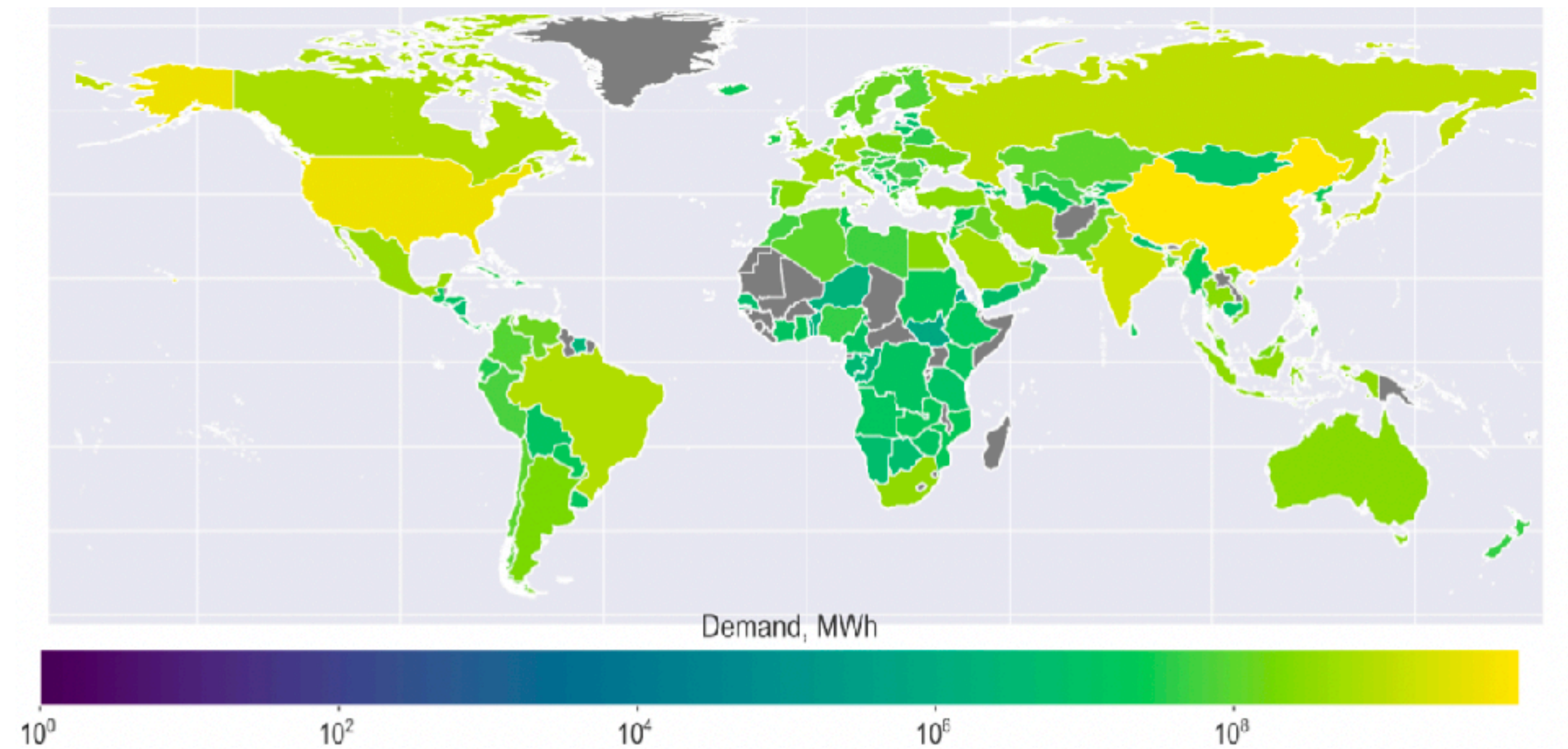
- Renewable potential
- Land usage
- Administrative boundaries
- Coast lines

Solar Photovoltaic Potential Density [MW/km²]



PyPSA-Earth: Prepare data

- **Electricity demand**
 - follows weather
 - depends on economics
 - governed by development scenarios

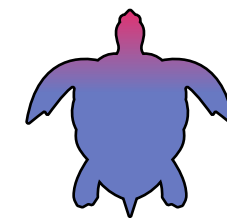


Availability of measured hourly demand profile is crucial

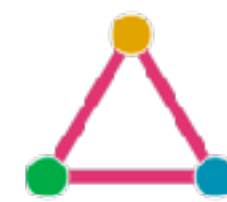
PyPSA-Earth: Prepare data

- **Power infrastructure**

- transmission grid
- power plants

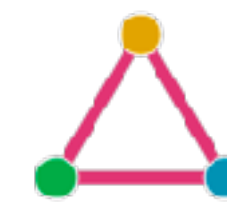


earth-osm package: load power features from OpenStreetMap



powerplantmatching package: merge and harmonise open datasets on generation capacity

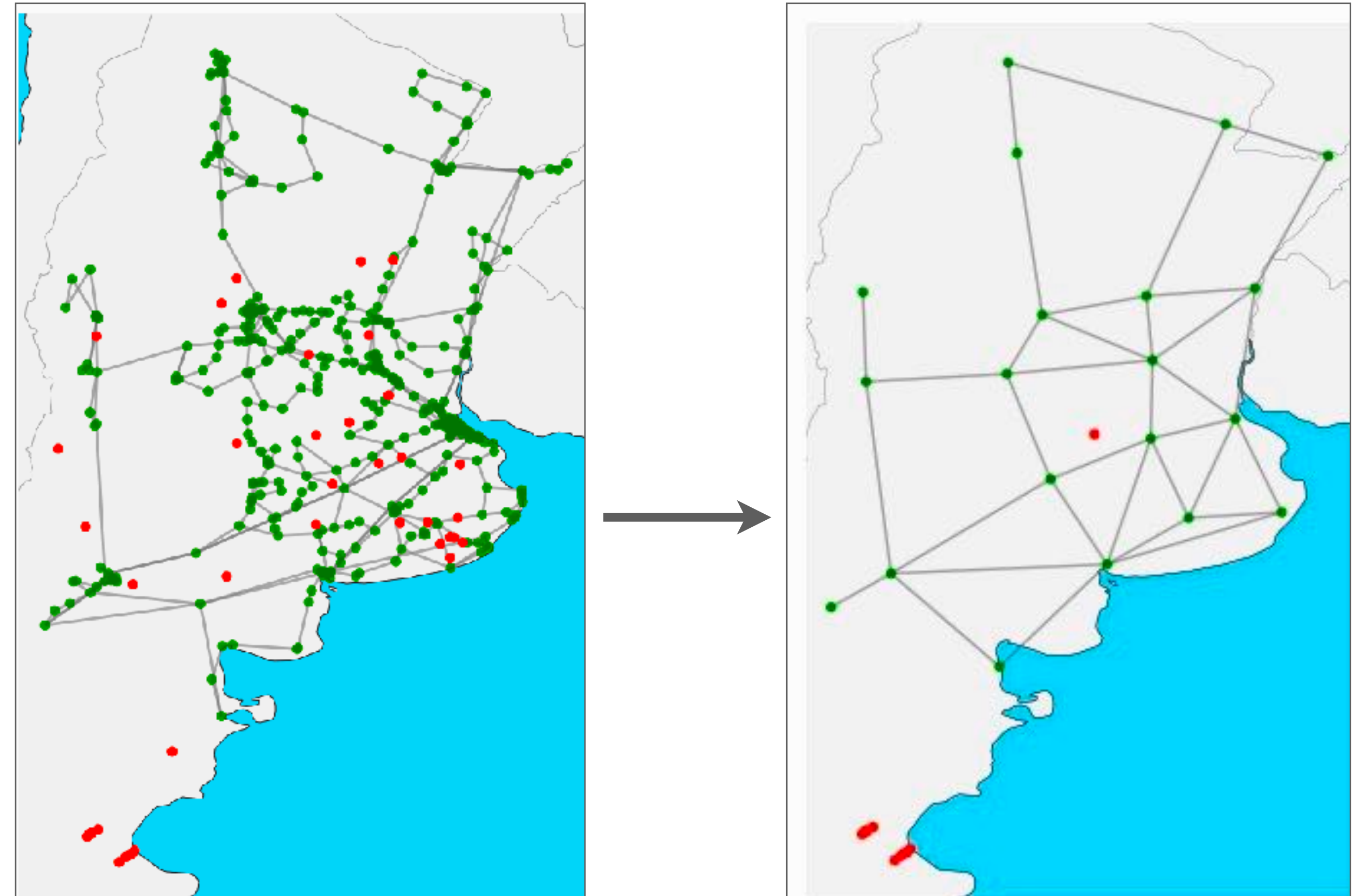
- **Technology costs**



PyPSA technology: collection of costs data accounting for evolution

PyPSA-Earth: Build model

- Build a power grid model:
 - create a grid topology
 - simplify and cluster
- Attach demand and generation
- Add extra-features (storage and transmission expansion, an emission constraint, load shedding)



PyPSA-Earth: Optimise model



- Translate the energy model into a linear program
- Run optimisation
- Split on blocks and apply decomposition

PyPSA-Earth: Applications

Energy modelling should be accessible
for any part of the world

```
pypsa-earth] Fix earth (PR #654)
```

PyPSA-Earth: Applications

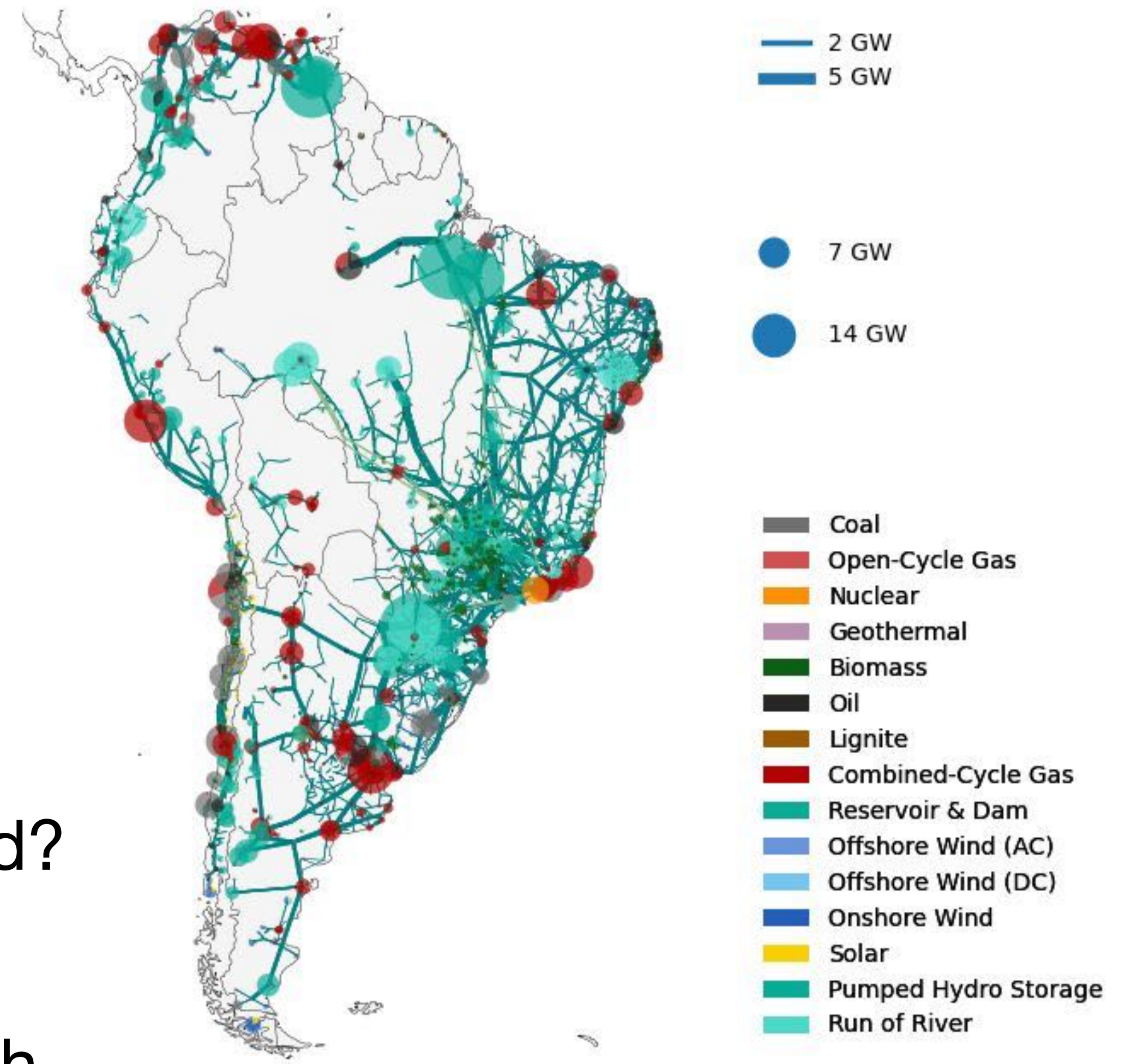
Energy modelling should be accessible for any part of the world

Done!

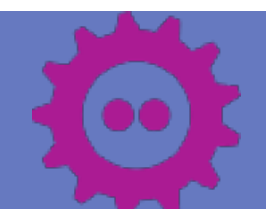
In which country would you be interested?



Feel free to explore:
[@pypsa-meets-earth/pypsa-earth](https://github.com/pypsa-meets-earth/pypsa-earth)

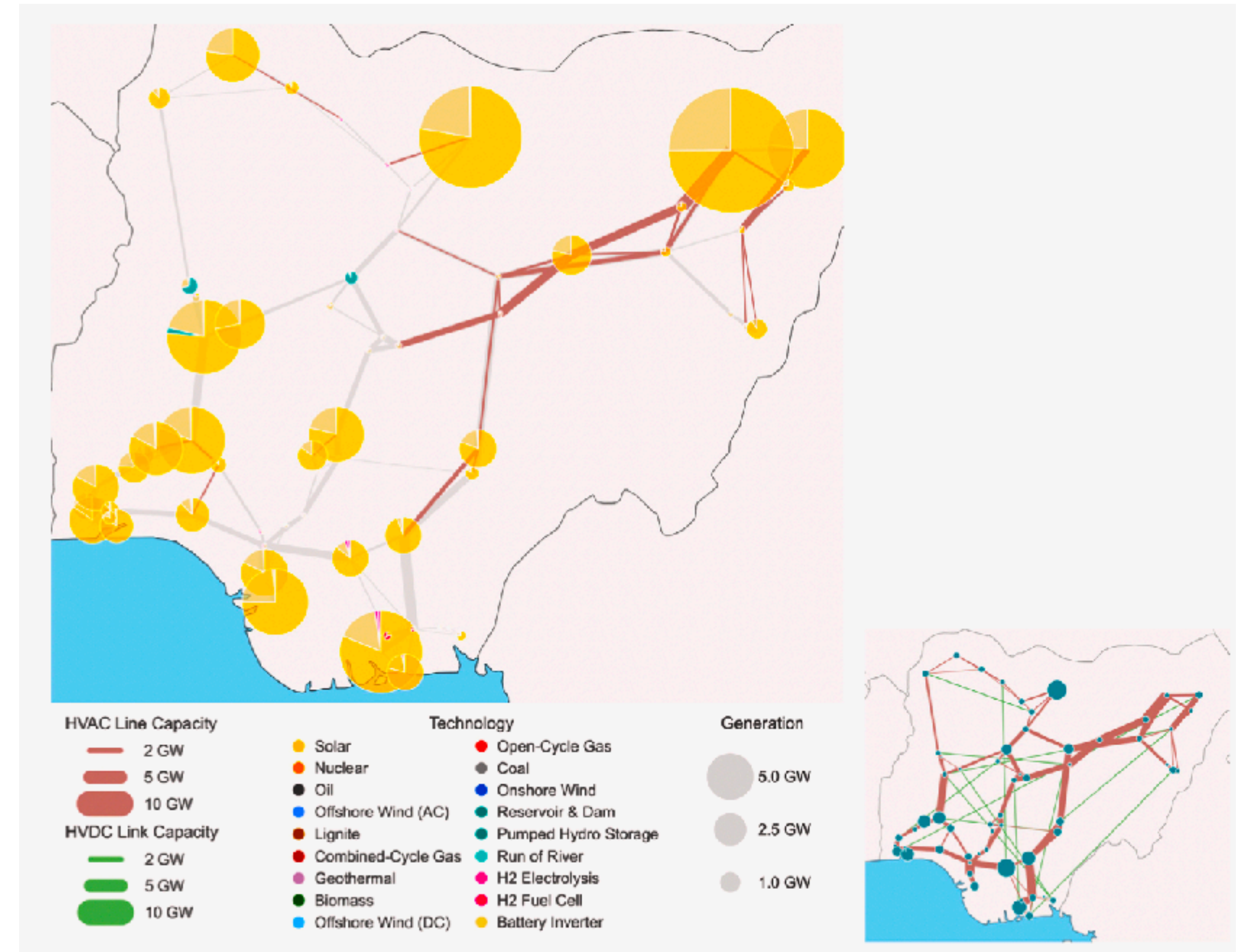


<https://zenodo.org/records/10080766>



PyPSA-Earth: Nigeria

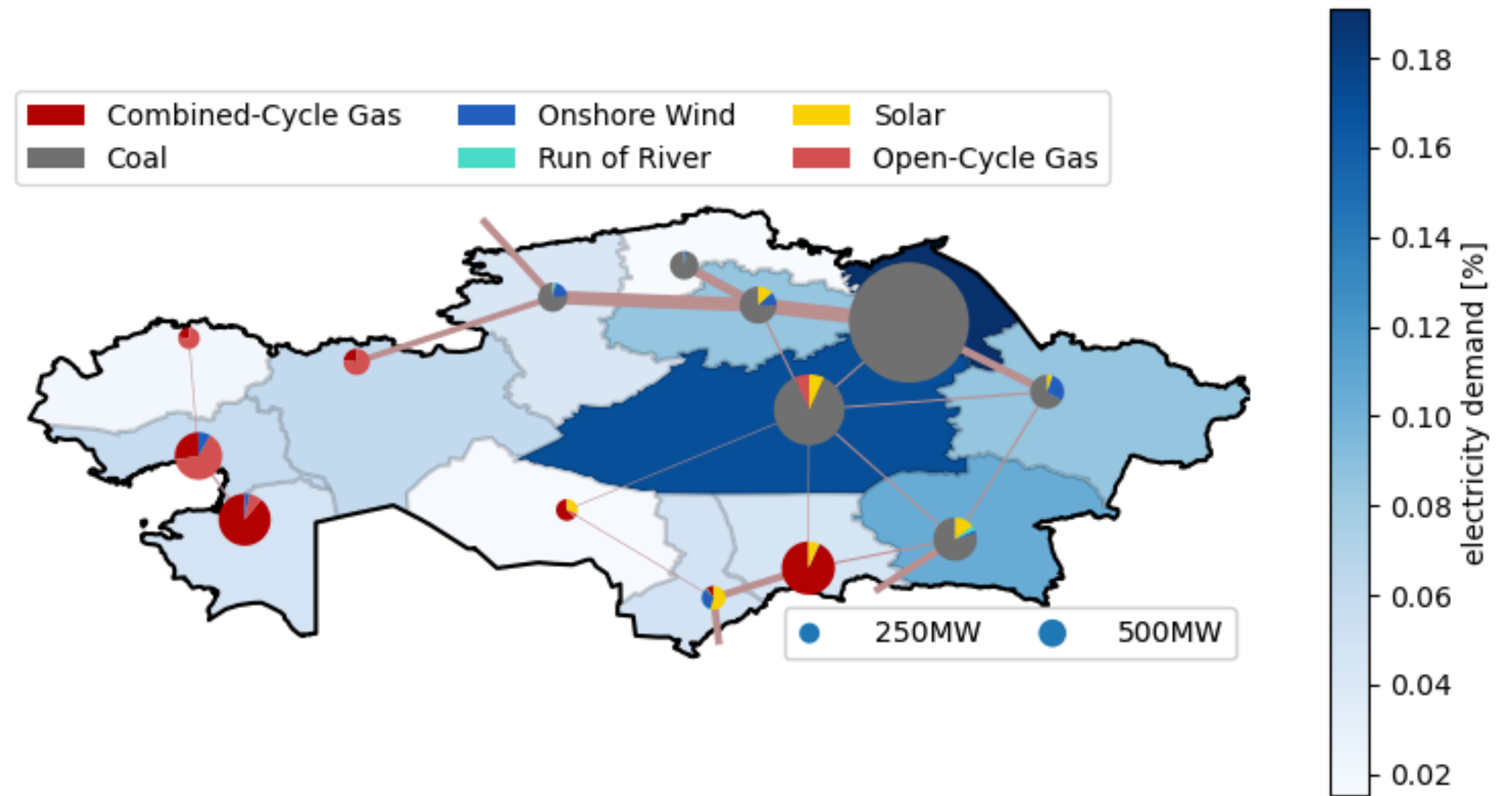
- **Problem statement:** brownfield capacity optimisation
- **Goal:** investigate a possible implementation of a net-zero scenario
- **Results:** optimised renewable electricity future for Nigeria could be cheaper than today
- **Impact:** proof-of-concept in academic field
- **Further work:** robust optimisation



Parzen et al. 2023 PyPSA-Earth. A new global open energy system optimization model demonstrated in Africa

PyPSA-Earth: Kazakhstan

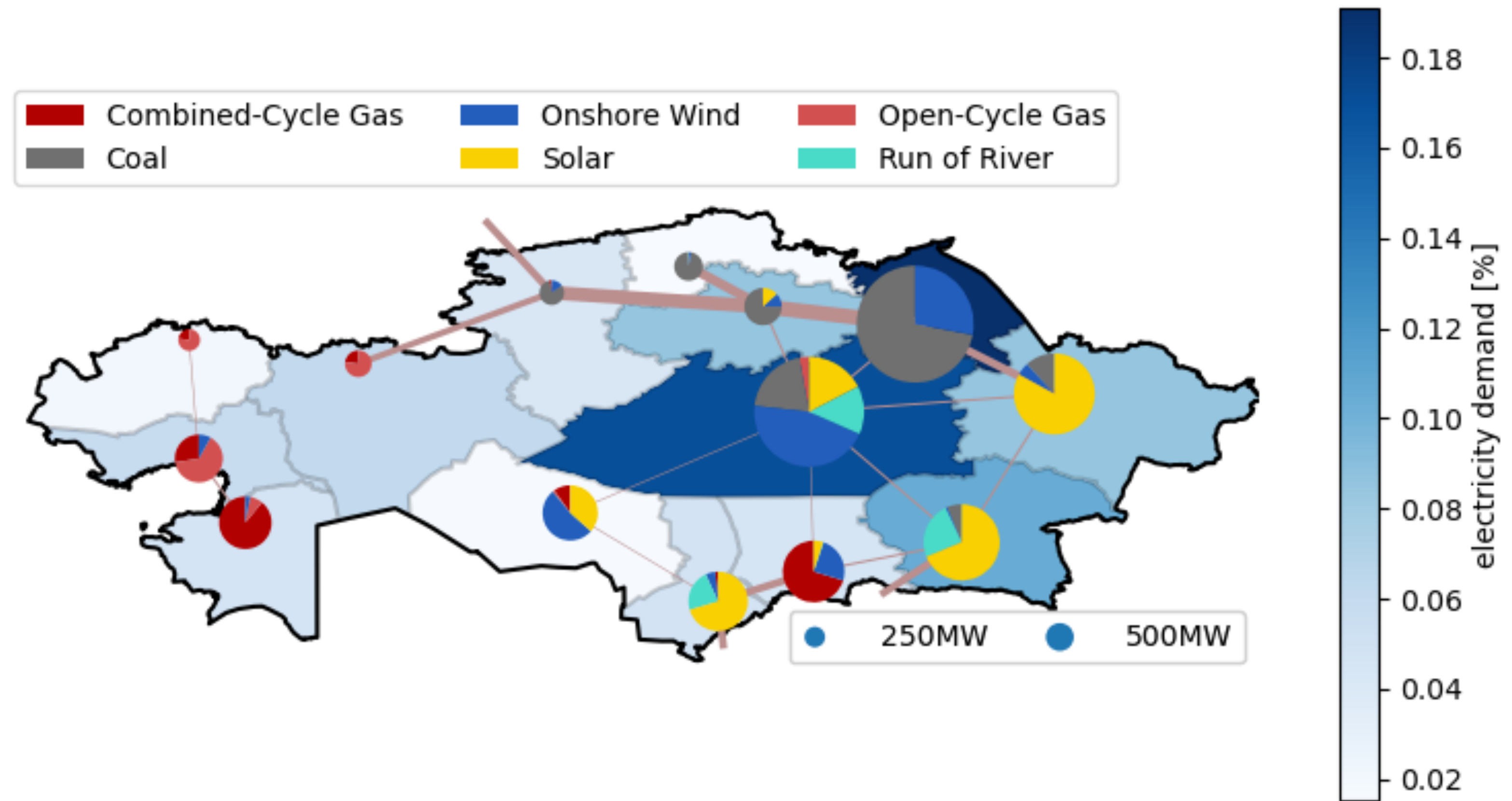
- **Problem statement:** shape the decarbonisation of the national power sector in a way consistent with development of the national economics
- **Goal:** play with decarbonisation scenarios considering different share of renewable power



<https://github.com/pypsa-meets-earth/pypsa-kz-data>

PyPSA-Earth: Kazakhstan

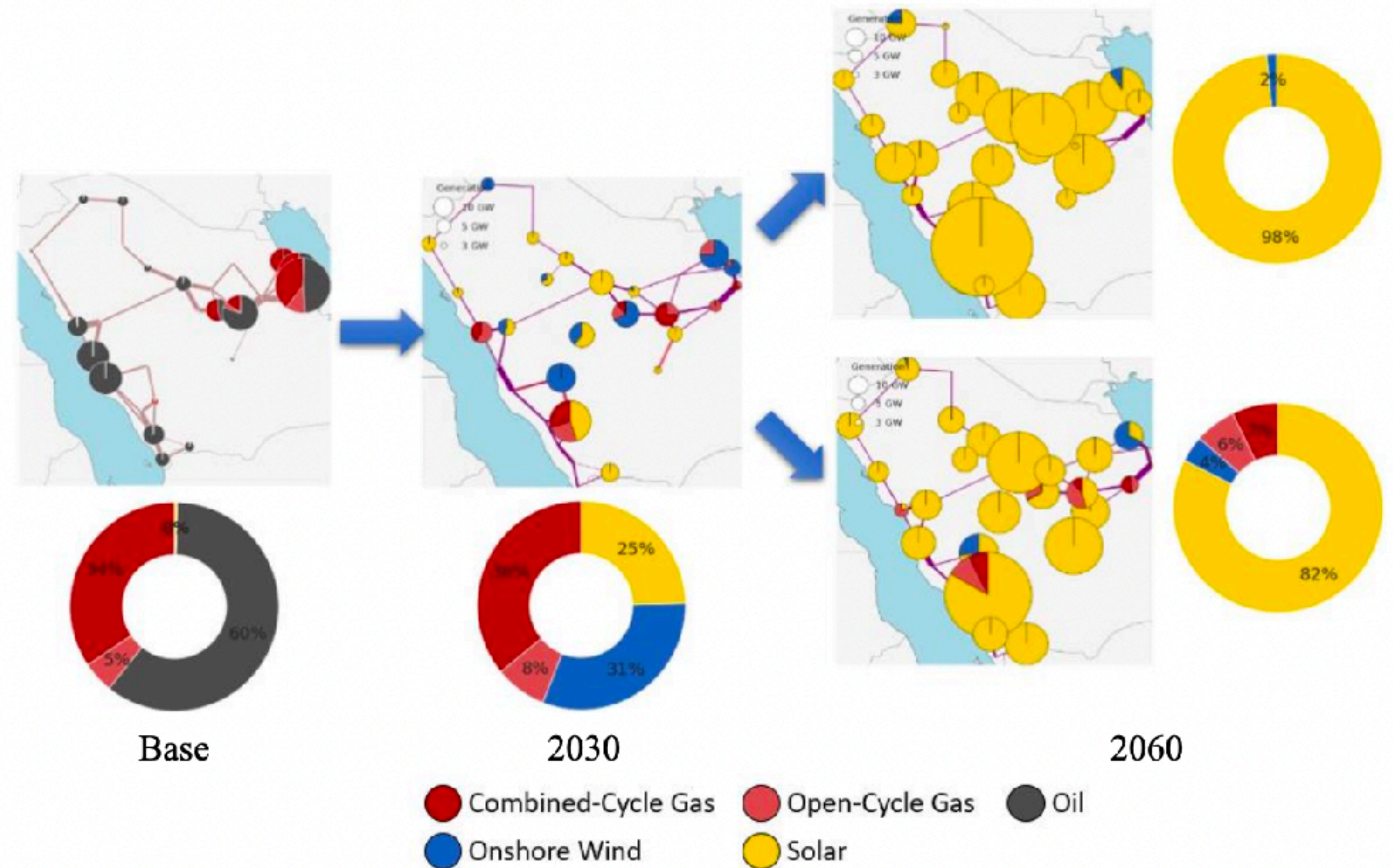
- **Results:** Renewable energy has been proven to be a plausible option
- **Impact:** Modeling evidence has been used in the policy discussions
- **Further work:** look into the climate change effects and cross-border interconnections



<https://github.com/pypsa-meets-earth/pypsa-kz-data>

PyPSA-Earth: Saudi Arabia

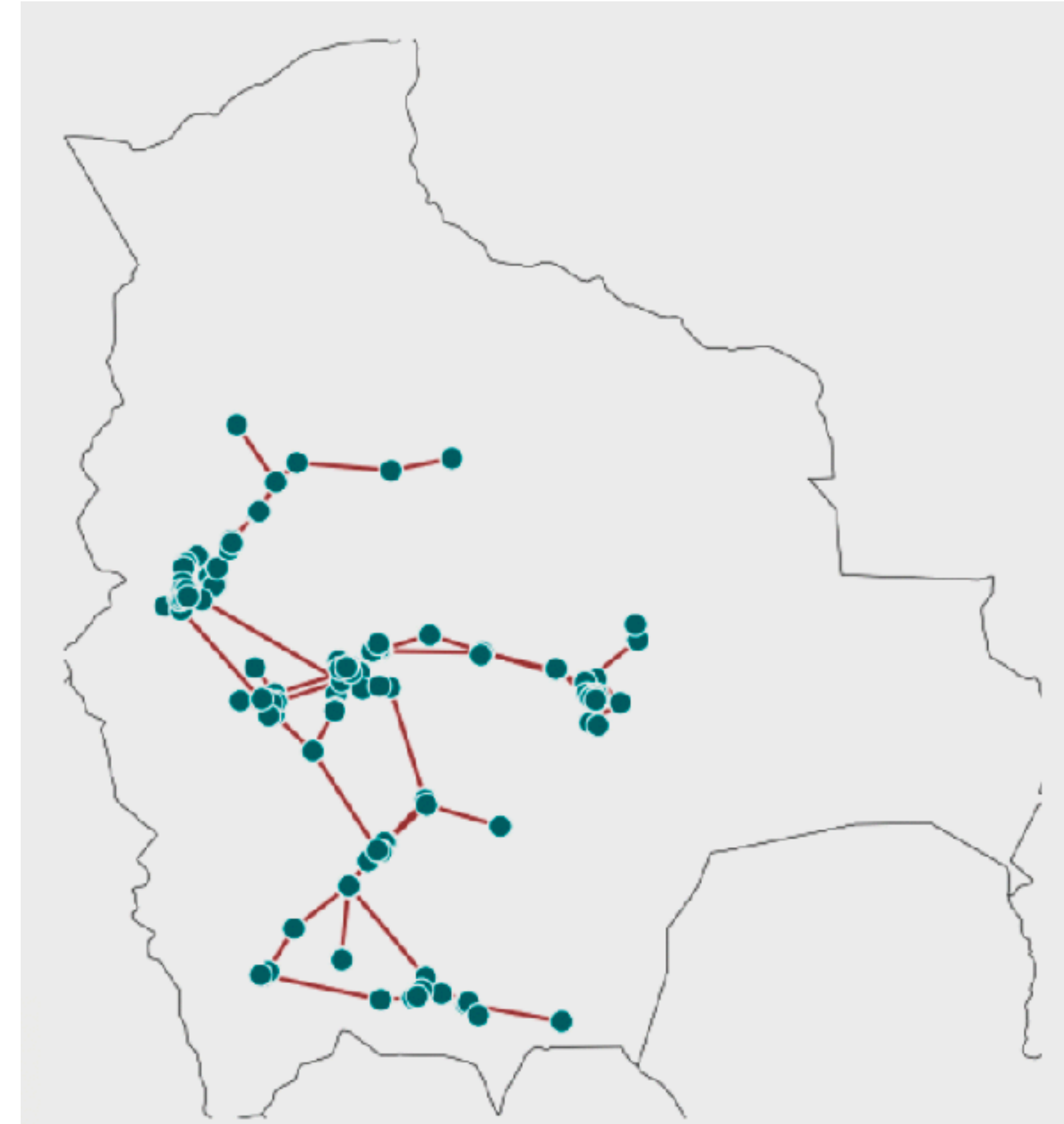
- **Problem statement:** Investigate a possible path to net-zero at 2060
- **Goal:** Look into alternatives to the current 99% reliance on fossil-fuel production
- **Results:** Renewable energy has been proven to be a plausible option
- **Impact:** The first open source model for the energy system of Saudi Arabia
- **Further work:** Address gaps in the data, investigate an effect of storage costs decrease, consider more generation technologies



A. Algarei 2022 Planning Saudi Arabia's Energy Transition for 2060 with PyPSA

PyPSA-Earth: Bolivia

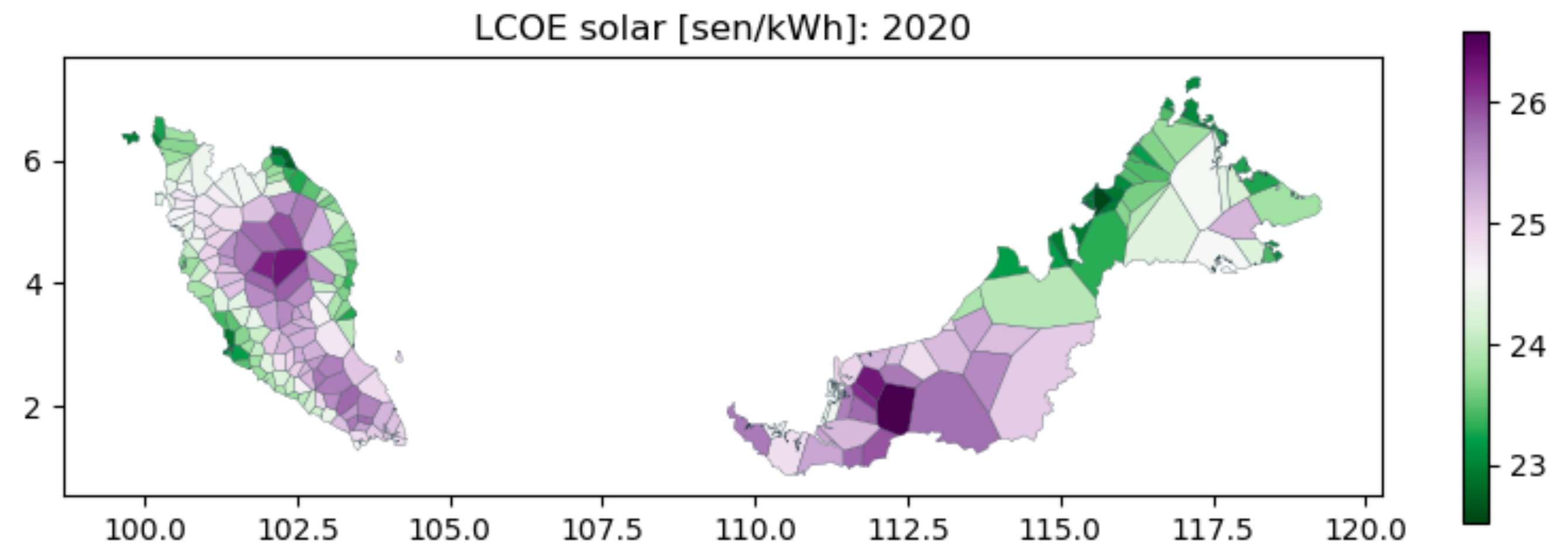
- **Problem statement:** Improve accuracy and transparency of power planning in South America
- **Goal:** Build an open energy system models tool
- **Results:** Successful validation of an open energy systems model for Bolivia
- **Impact:** Proof-of-concept of the open source approach for the area with limited data availability
- **Further work:** Improve representation of the power grid to adjust a modeling approach for the regional specifics



C.A.A.F. Vazquez et al. 2023 Using PyPSA-Earth to address energy systems modelling gaps in developing countries. A case study for Bolivia

PyPSA-Earth: Malaysia

- **Problem statement:** Look into options to decarbonise the national industry sector
- **Goal:** Assess cost-effective options of net-zero transition for the national economics
- **Preliminary results:** the energy transition is quite a challenge due to the limited renewable potential
- **Further work:** Consider cross-national interconnections



PyPSA-Earth: Community



Diverse but speaking the same language

Channels of communication:

- Github
- Discord
- Developers meetings
- LinkedIn



PyPSA-Earth: Community

The location-related diversity gaps in FOSS contributions are real*

Reasons:

- cross-cultural difference in communication patterns
- a narrow regional perspective of the state-of-the-art research
- lack of capacity/resources
- limited access to infrastructure

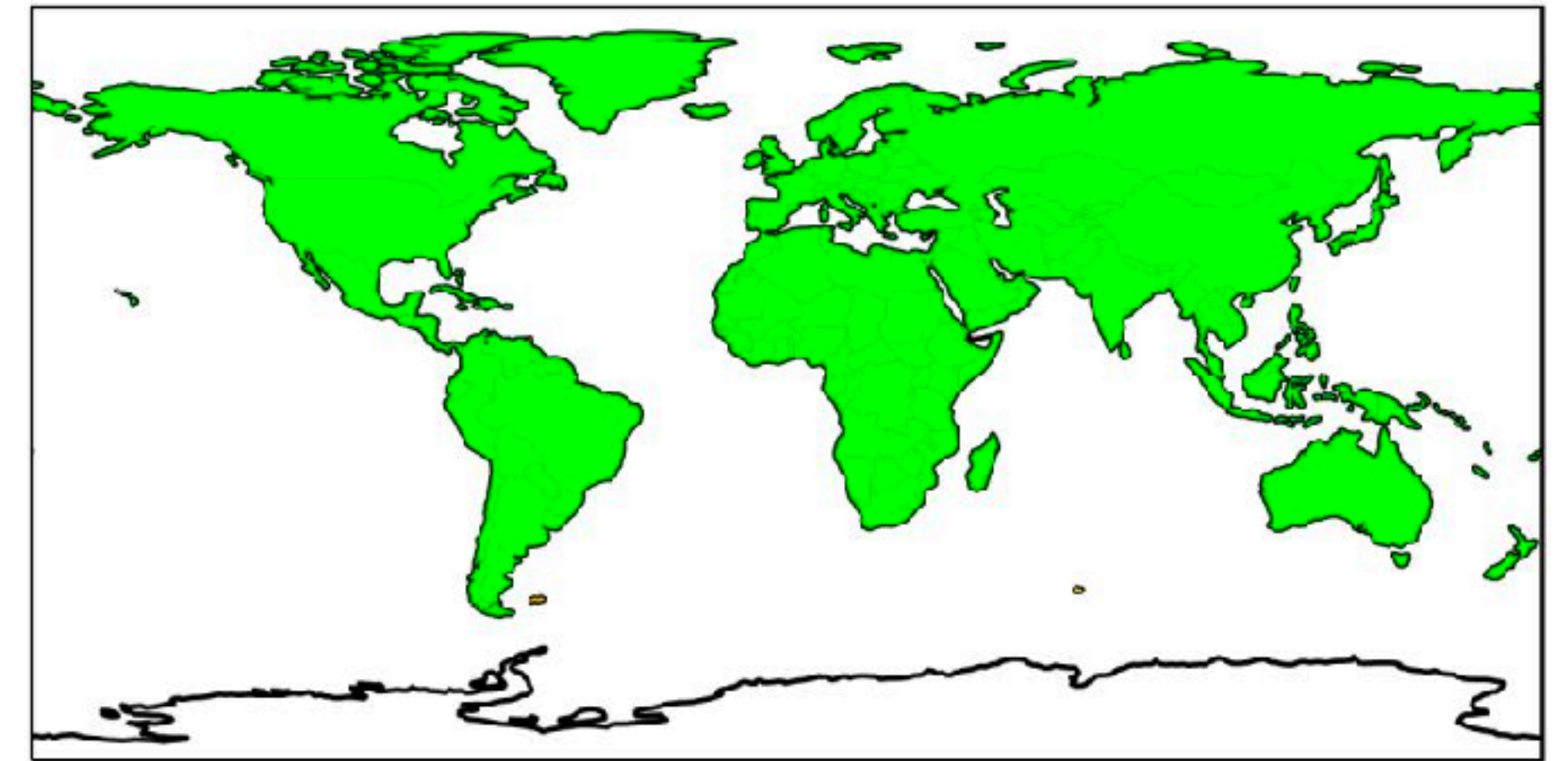


* Tobias Augspurger (FOSDEM 2023) Open Source in Environmental Sustainability

Lessons learned

... the gaps may be bridged!

- Open energy modeling works and makes an impact
- Geographic gaps exists but can be successfully addressed
- Accessibility is the main concern to increase adoption



To be continued

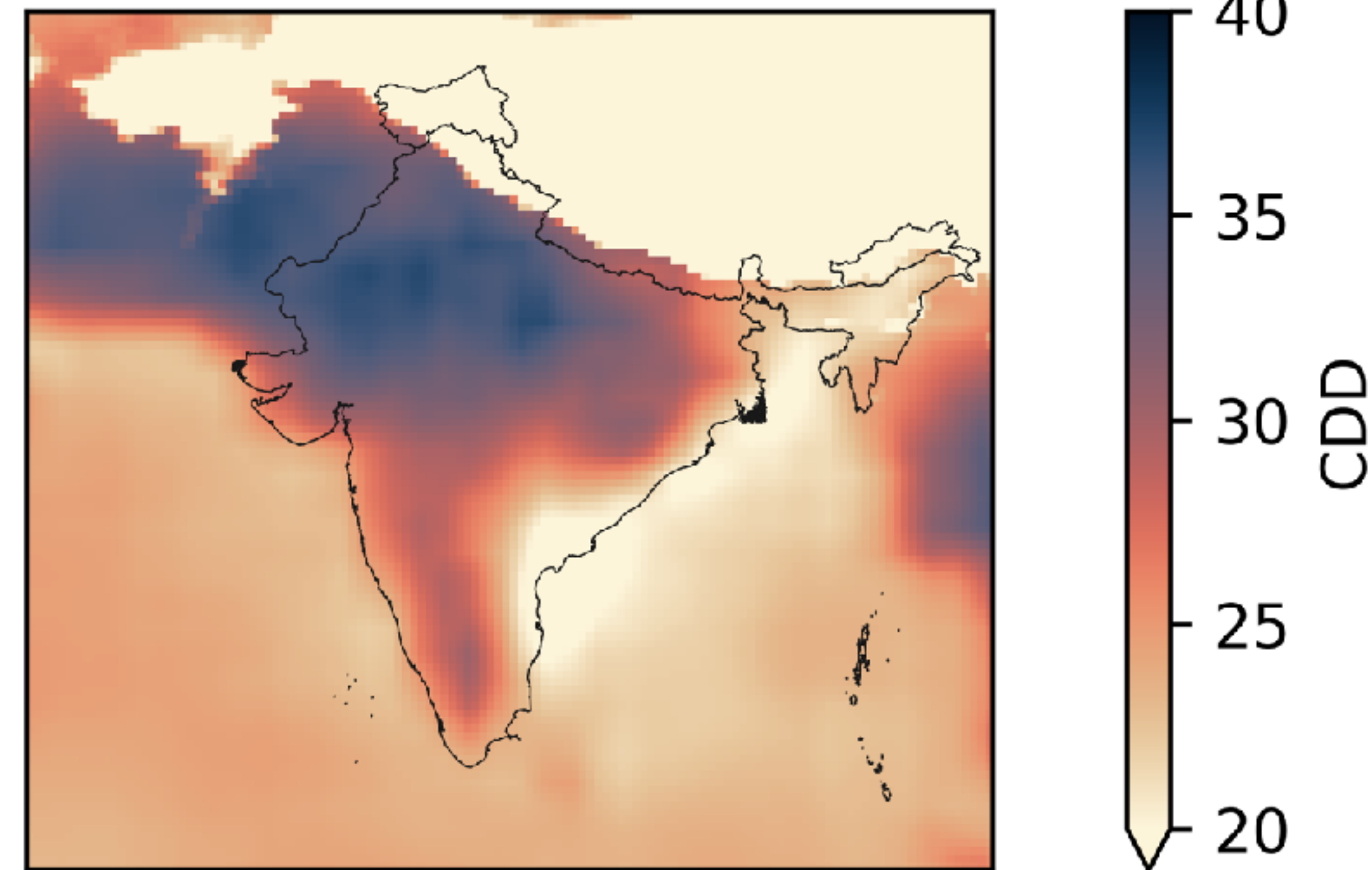
Address modeling challenges:

- Global-scale validation
- Bringing climate-energy gap
- Implement advanced optimisation methods

Increase usability:

- Improve docs & provide capacity building
- Enhance starter datakits
- Dependencies management

CDD|2070 - CDD|2020



You suggestions?

Energy transition knows no borders

