Can open source development drive energy transition?

PyPSA-Earth experience

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Shaping the future
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
...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

- Energy systems models
- Power engineering models
- Integrated assessment models

Continents

100 km
10 km
1 km

Micrometers

Nanoseconds
1 year
10 years
100 years
PyPSA-Earth: Open Code

- Prepare data
- Build model
- Run optimisation

_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 is crucial to start with modeling

Data licensing matters
PyPSA-Earth: Prepare data

- Environment and climate
  - Renewable potential
  - Land usage
  - Administrative boundaries
  - Coast lines

**atlite** package: translate geophysics into energy
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

- **Technology costs**

  - earth-osm package: load power features from OpenStreetMap
  - powerplantmatching package: merge and harmonise open datasets on generation capacity
  - 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

[highlight: pypsa-earth] Fix earth (PR #654)
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://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
**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
• **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 exist 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

You suggestions?
Energy transition knows no borders