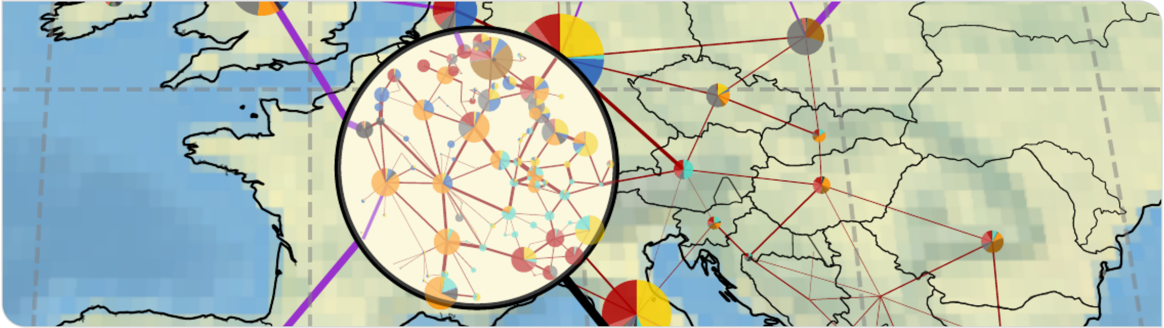
Open Energy Transition

PyPSA

The Power of Open Source: Transparent Global Energy Planning, Accessible to Everyone

Gurobi Live! The Decision Intelligence Summit

Dr. Martha Maria Frysztacki | October 18, 2023



Transforming Energy Planning with Open Technology.

Accelerating the World's Transition to
Sustainable Energy Through
Open Source Tools and Open Data.

The Challenge

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Traditional **’black-box’ modeling approach**

- lacks transparency
- slows down the energy transition

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Hurdles in **open-source tool adoption**:

- lack of support
- software requirement gaps

Our Goal and Approach

Open Energy Transition

Address challenges! ⇒ We aim to make energy planning more:

Our Goal and Approach

Address challenges! $\Rightarrow$ We aim to make energy planning more:

- **transparent**: We use open data and open source tools only

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- **transparent**: We use open data and open source tools only
- **accessible**: We provide reliable modeling support & aim to close software requirement gaps

Our Goal and Approach

Address challenges! ⇒ We aim to make energy planning more:

- **transparent**: We use open data and open source tools only
- **accessible**: We provide reliable modeling support & aim to close software requirement gaps
- **collaborative**: We expand our user & developer community

The Change We Want to See

Outputs:

- more studies using open data & open tools
- better quality of open data & open tools
- ...

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Outcomes:

- more robust and sustainable energy systems
- lower costs of the whole energy infrastructure & electricity
- ...

Sneak-Peak into our modelling workflow:

Our modelling solutions build on
PyPSA [1], PyPSA-Eur [2] & PyPSA-Earth [3], thus utilizing
Open Source Models and Open Data.

Case Study: Decarbonise the Kazakh Electricity System

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Goal of the study:

- Simulate today's Kazakh electricity system (validation)
- Simulate various future decarbonisation scenarios (energy transition)

⇒ **Reproducible, 100% transparent, reliable and open energy transition pathway**

model & data available here: `https://github.com/pypsa-meets-earth/pypsa-kz-data`.
Includes extensive workflow documentation!

Case Study: Visualize Today's Kazakh Electricity System

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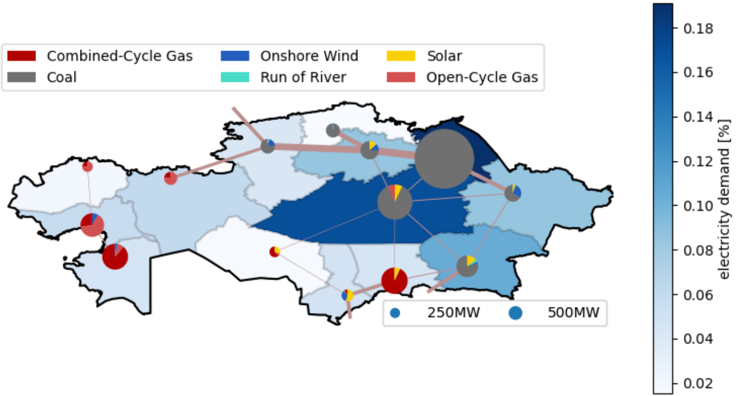
Input assumptions can be visualized and checked:



Case Study: Validate Today's Kazakh Electricity Mix

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Optimized modelling results can be validated against national reports

carrier	PyPSA [TWh]	national report [TWh]	error [TWh]	PyPSA [%]	national report [%]	error [%]
gas	20.358883	21.73	1.371117	18.753352	20.103617	1.350265
coal	74.573022	74.47	0.103022	68.692087	68.896290	0.204203
onwind	1.718037	1.08	0.638037	1.582550	0.999167	0.583383
hydro	10.862888	9.51	1.352888	10.006225	8.798224	1.208001
solar	1.048470	1.30	0.251530	0.965786	1.202701	0.236915

$\Rightarrow$ **Error <5% in all cases, mostly $\approx$ 1%**

Case Study: Paths towards 40% Renewable Electricity

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A **validated model** is a good starting point to make **projections** for the future to include more **renewable technologies**. Exemplary results (40% share of RE):

carrier	installed capacity [GW]	capacity projection (2030) [GW]
Combined-Cycle Gas	3.48000	3.480000
Open-Cycle Gas	1.62540	1.625400
Coal	12.96700	12.967000
Onshore Wind	0.64870	8.239741
Run of River	0.06278	2.132999
Solar	0.82182	4.568450

Case Study: Visualize the Projected Electricity System

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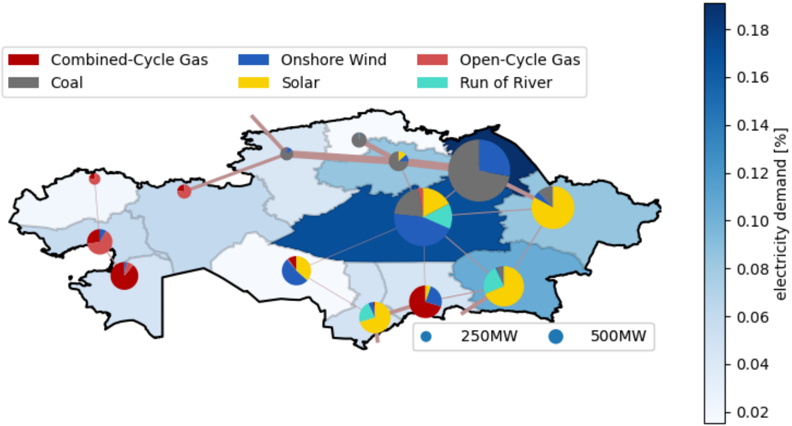
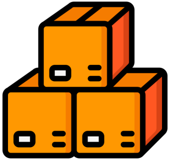
Projected results can be visualized:



How to Make Investment Decisions for Renewable Technologies?

&



How much?

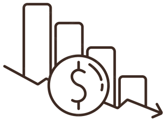
&

What does it cost?

Investment Decisions using PyPSA

Objective: minimise the total system cost that consist of

- investment costs in new generation projects
- investment costs in new storage capacity
- investment costs in new transmission line projects
- variable costs, such as costs for fuels or maintenance



$$\min_{\substack{G_{v,s},\, H_{v,r} \\ g_{v,s,t},\, h^{\pm}_{v,r,t} \\ f_{(v,w),t}}} \left[\sum_{v\in\mathcal{V},\, s\in\mathcal{S}} \left(c_{v,s} G_{v,s} + \sum_{v\in\mathcal{V},\, r\in\mathcal{R}} c_{v,r} H_{v,r} + \sum_{(v,w)\in E} c_{(v,w)} F_{(v,w)} + \sum_{t\in\mathcal{T}} w_t o_{v,s} g_{v,s,t} \right) \right]$$

[1], [2]

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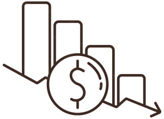

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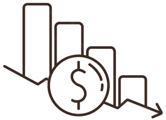

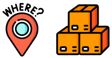

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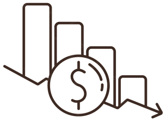

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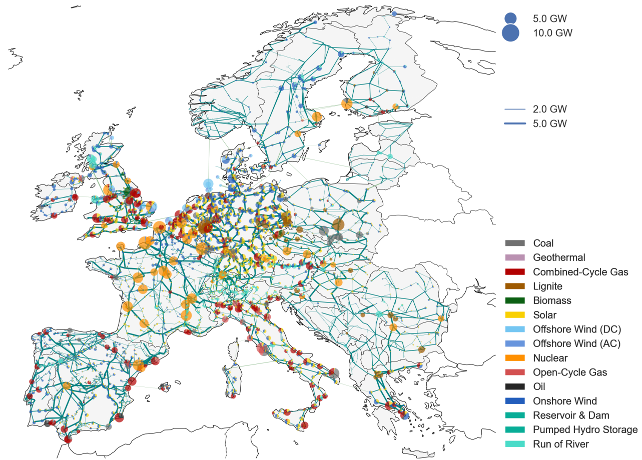


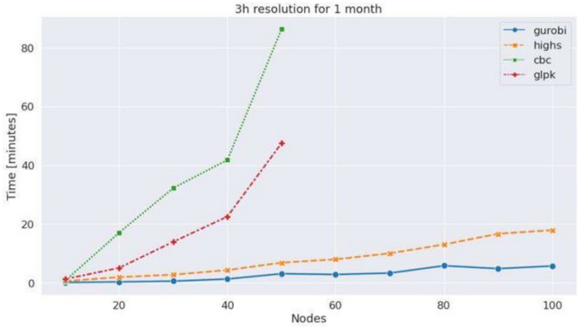
Optimization subject to:

- electricity circuit rules
- capacity of transmission lines & generators
- meeting electricity demands (everywhere & at all times!)
- variability of the weather
- ...

How to solve such large problems?

This is where optimisation **solvers** come into play:

- small instances and testing: open-source solvers,
- larger scale and for business cases: gurobi [4]



more solving times for large models using *gurobi* are available at: [5]

Literature I

[1] Tom Brown, Jonas Hörsch, and David Schlachtberger. “PyPSA: Python for Power System Analysis”. In: *Journal of Open Research Software* 6 (2018), p. 4. DOI: `https://doi.org/10.5334/jors.188`.

[2] Jonas Hörsch, Fabian Hofmann, David Schlachtberger, et al. “PyPSA-Eur: An Open Optimisation Model of the European Transmission System”. In: *Energy Strategy Reviews* 22.v3 (2018), pp. 207–215. DOI: `doi.org/10.1016/j.esr.2018.08.012`.

[3] Maximilian Parzen, Hazem Abdel-Khalek, Ekaterina Fedotova, et al. “PyPSA-Earth. A new global open energy system optimization model demonstrated in Africa”. In: *Applied Energy* 341 (2023), p. 121096. ISSN: 0306-2619. DOI: `https://doi.org/10.1016/j.apenergy.2023.121096`. URL: `https://www.sciencedirect.com/science/article/pii/S0306261923004609`.

[4] Gurobi Optimzation. URL: `https://www.gurobi.com/`.

Literature II

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[5] Martha Maria Frysztacki, Jonas Hörsch, Veit Hagenmeyer, et al. “The strong effect of network resolution on electricity system models with high shares of wind and solar”. In: *Applied Energy* 291 (2021), p. 116726. ISSN: 0306-2619. DOI: doi.org/10.1016/j.apenergy.2021.116726.

