PyPSA-PL: Sectorally Coupled Energy Model to Inform Polish Energy Policy

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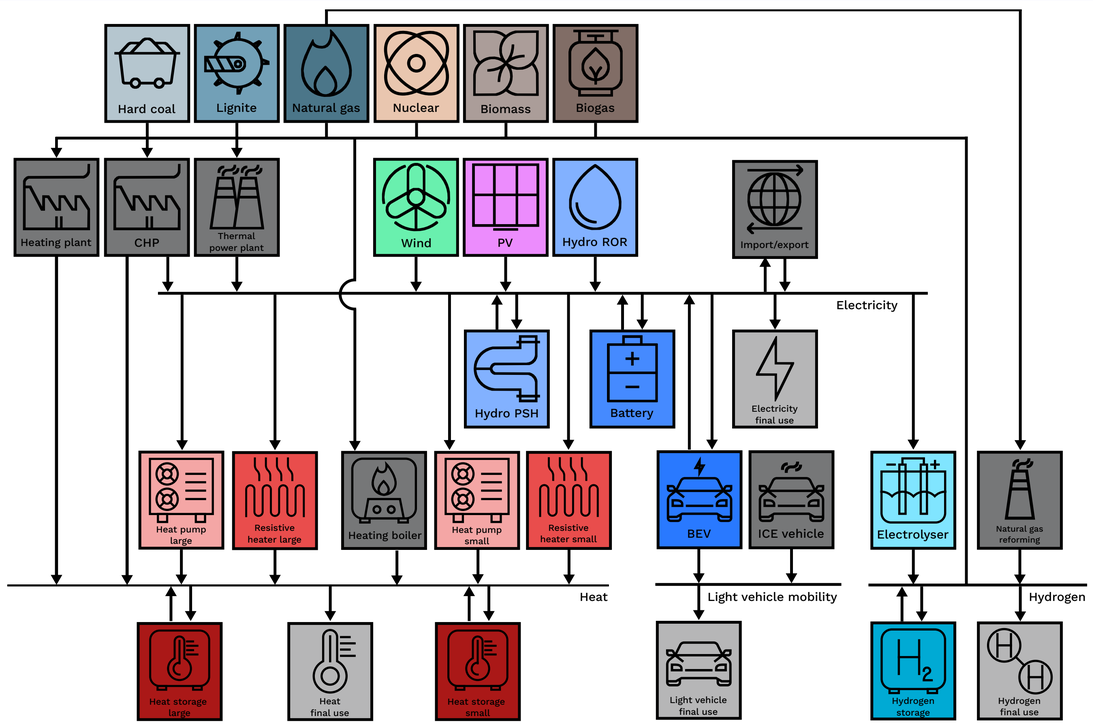
Motivation

- Poland is currently in the process of updating its **National Energy and Climate Plan** and shaping its official **energy policy until 2040**.
- To inform the ongoing public debate regarding the feasible energy transition pace and the achievable emission reduction targets, Instrat (Warsaw-based think tank) expanded its in-house **power system model PyPSA-PL** by **heating, mobility, and hydrogen sectors**.

Model and data

- In our most recent analysis [3], we focused on sectors with energy use of fossil fuels, which are responsible for around 75% of Poland's current GHG emissions. The PyPSA-PL model [4] directly covers sectors responsible for **60% of Poland's GHG emissions**.

Energy flows in PyPSA-PL v2.1 model



- We compiled an extensive dataset on infrastructure, energy consumption, fuel prices, and technology costs **tailored for the Polish energy system**.
- We attribute the same cost to all CO_2 emissions following **a predefined carbon pricing pathway**.

CO_2 prices [EUR'2022/tCO_2]

2020	2025	2030	2035	2040
30	103	139	159	180

- To account for the current reliance of the Polish power system on the ancillary services provided by conventional power plants, we apply a constraint on the maximum hourly **System Non-Synchronous Penetration (SNSP)** – concept developed by TSOs in Ireland.
- For each of the modelled 5-year period, we sequentially search for a solution satisfying energy carrier demands (see section *Modelled scenarios*) throughout **8760 hours** at the lowest annual **CAPEX and OPEX costs**.

Modelled scenarios

S1: RES+NUC

Ambitious RES and nuclear power deployment scenario: fast deployment of RES and nuclear possible; high electricity demand; low heating and mobility demand; high SNSP permitted.

S2: RES

Ambitious RES deployment scenario w/o nuclear power: fast deployment of RES possible; no nuclear; high electricity demand; low heating and mobility demand; high SNSP permitted.

S3: BASE

Baseline scenario: deployment of RES up to unofficial Ministry of Climate forecast possible; nuclear as fast as S1; medium electricity, mobility, and heating demand; medium SNSP permitted.

S4: SLOW

Slow transition scenario: delayed deployment of RES and nuclear; low electricity demand; high heating and mobility demand; low SNSP permitted.

- Differences in final use carrier demand improve **scenario self-consistency** (e.g., the abundance of RES enables far-reaching electrification of industry, which increases electricity demand), but they also make scenario comparison more nuanced.

Assumed final use demand for electricity and heat [TWh]

Electricity

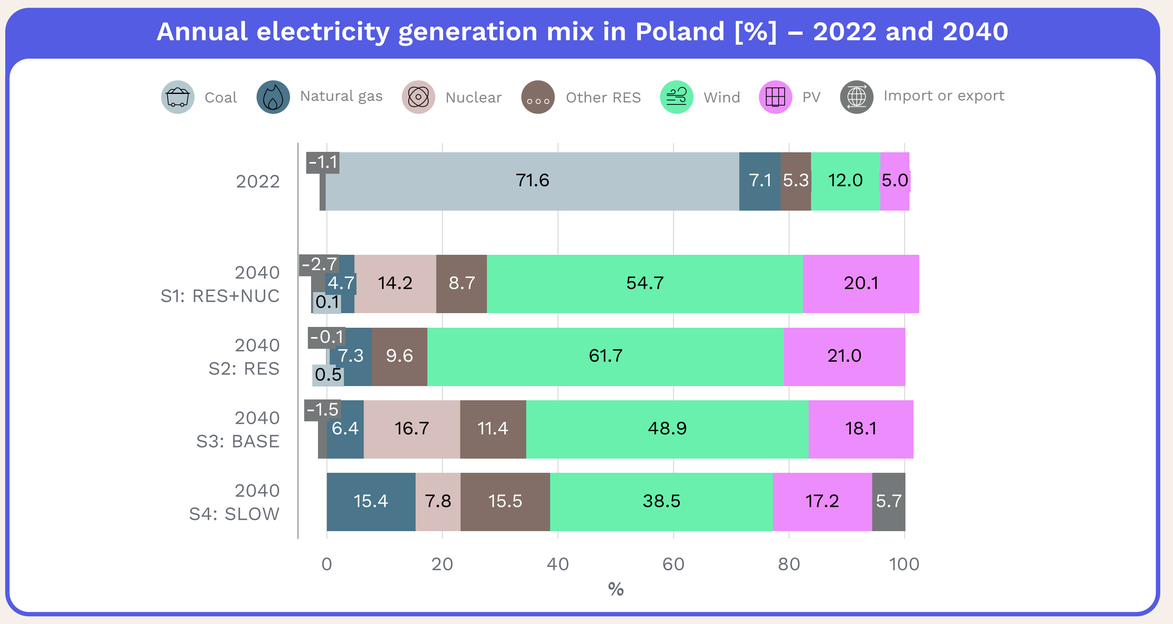
Scenario	2020	2025	2030	2035	2040
S1 & S2	159.4	168.3	177.2	190.3	202.0
S3	159.4	168.3	177.2	187.4	196.9
S4	159.4	168.3	177.2	184.1	190.9

Heat

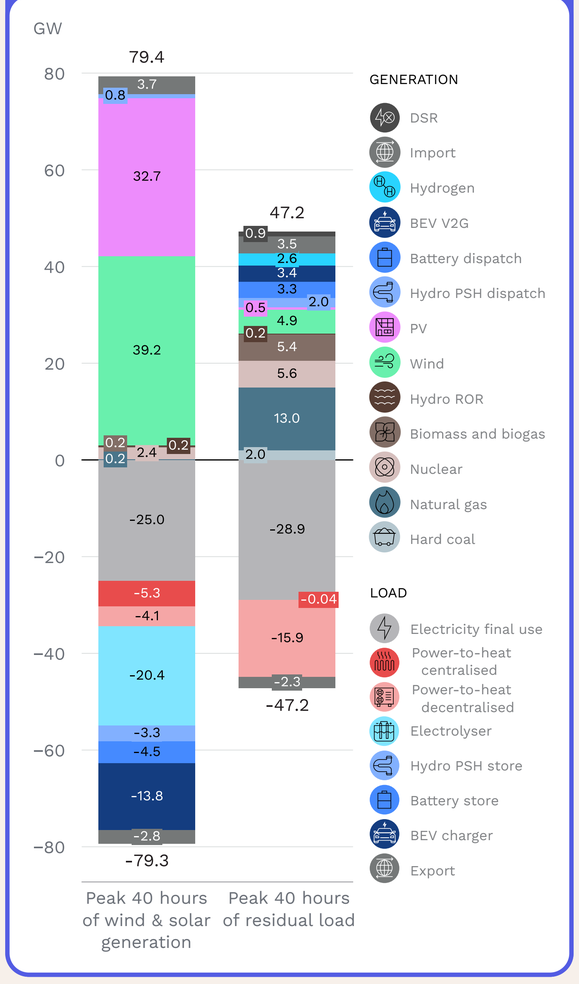
Scenario	2020	2025	2030	2035	2040
S1 & S2	227.1	224.4	221.8	192.9	169.6
S3	227.1	224.4	221.8	203.5	187.5
S4	227.1	224.4	221.8	218.6	215.6

Results and recommendations

Annual electricity generation mix in Poland [%] – 2022 and 2040



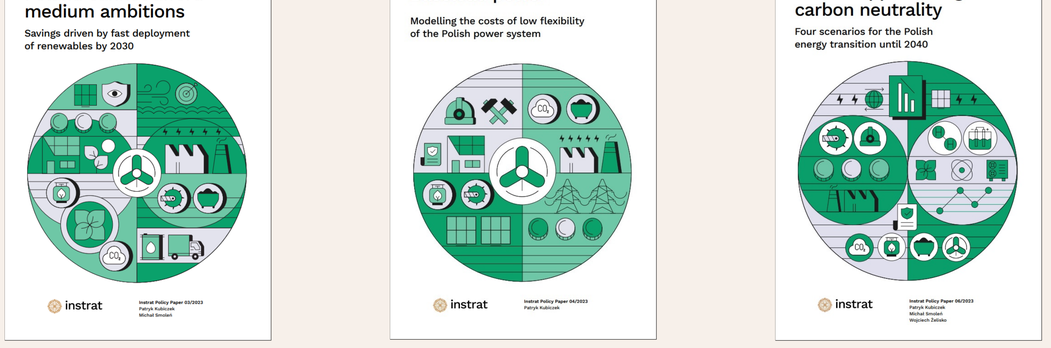
Average electricity mix in extreme hours [GW] – S1: RES+NUC, 2040



- **Wind and solar** dominate the 2040 electricity production mix **in all scenarios**. The faster the RES deployment, the faster the cost-effective decarbonisation and electrification of the economy.
- **Nuclear** may be part of a cost-effective electricity mix in 2040 – but **not its pillar**. However, nuclear units could provide carbon-free synchronous baseload power if it is still required by 2040.
- Even though widespread use of **decentralised heat pumps** is cost-effective, it will **increase peak residual power demand**. This will drive the need for rarely used firm capacities, such as new hydrogen-fired generators or retrofitted coal-fired backup units.
- **Flexible electricity consumption** by heating, mobility, and hydrogen sectors are key to making good use of solar and wind energy. The peak electricity generation might be as high as **80 GW**, which is 2.8 times higher than the historical maximum load in the Polish grid – local consumption will be helpful.
- Ambitious RES scenarios (S1 & S2) lead to **lowest GHG emissions** (65-70% reduction by 2040 vs. 2020 value) and **lowest systemic costs**. However, we do not model the grid expansion – including its cost would likely decrease systemic cost differences between scenarios.

Policy impact

- Our three 2023 modelling-based reports [1–3] gained significant **national and international media coverage**; the findings of *Poland approaching carbon neutrality* report [3] were cited by Bloomberg [5].



- The Civic Coalition (a political alliance ruling currently in Poland), in its energy program for the 2023 parliamentary election, **adopted Instrat's recommendations for the 2030 RES target** from *Poland cannot afford medium ambitions* report [1] .
- The current CEO of **the Polish TSO** (PSE) in his communication **refers to Instrat's modelling** indicating it as a useful resource in the context of grid development planning.
- PyPSA-PL is the only optimisation-based model of the Polish energy system which is **open source** and whose inputs and outputs are **open access** – which, we believe, enhances its impact.

References

[1] Kubiczek, P., Smoleń, M. (2023). Poland cannot afford medium ambitions. Savings driven by fast deployment of renewables by 2030. Instrat Policy Paper 03/2023. Instrat. https://instrat.pl/pypsa-march-2023

[2] Kubiczek, P. (2023). Baseload power. Modelling the costs of low flexibility of the Polish power system. Instrat Policy Paper 04/2023. https://instrat.pl/baseload-power

[3] Kubiczek, P., Smoleń, M., Żelisko, W. (2023). Poland approaching carbon neutrality. Four scenarios for the Polish energy transition until 2040. Instrat Policy Paper 06/2023. https://instrat.pl/poland-2040

[4] Kubiczek, P. (2023). PyPSA-PL: Optimisation model of the Polish energy system [Python]. Instrat. https://github.com/instrat-pl/pypsa-pl

[5] Bloomberg. (2023) Poland Could Rely Mostly on Clean Energy by 2040, Think Tank Finds. https://www.bloomberg.com/news/articles/2023-12-11/poland-may-replace-coal-with-clean-energy-sources-by-2040-report-finds

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