In our most recent analysis [3], we focused on sectors with energy use of fossil fuels. We compiled an extensive dataset on infrastructure and technologies tailored for the Polish energy system. We attribute the same cost to all CO₂ emissions following a predefined carbon pricing pathway.

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.

Results and recommendations

- 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 of RES could 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 lower system costs. However, we do not model the grid expansion – including its cost would likely decrease system 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.

Modelled scenarios

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

Different 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)

<table>
<thead>
<tr>
<th>Scenario</th>
<th>2020</th>
<th>2025</th>
<th>2030</th>
<th>2035</th>
<th>2040</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1 &amp; S2</td>
<td>159.4</td>
<td>168.3</td>
<td>177.2</td>
<td>184.3</td>
<td>190.9</td>
</tr>
<tr>
<td>S3</td>
<td>159.4</td>
<td>168.3</td>
<td>177.2</td>
<td>184.3</td>
<td>190.9</td>
</tr>
<tr>
<td>S4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Annual electricity generation mix in Poland (% – 2022 and 2040)

<table>
<thead>
<tr>
<th>Year</th>
<th>Coal</th>
<th>Natural gas</th>
<th>Nuclear</th>
<th>Other RES</th>
<th>Wind</th>
<th>PV</th>
<th>BEV charger</th>
</tr>
</thead>
<tbody>
<tr>
<td>2022</td>
<td>71.8</td>
<td>19.2</td>
<td>7.3</td>
<td>1.7</td>
<td>10.3</td>
<td>4.3</td>
<td>20.5</td>
</tr>
<tr>
<td>2040</td>
<td>53.7</td>
<td>18.7</td>
<td>16.1</td>
<td>1.7</td>
<td>20.5</td>
<td>27.0</td>
<td></td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Hour</th>
<th>Coal</th>
<th>Natural gas</th>
<th>Nuclear</th>
<th>Other RES</th>
<th>Wind</th>
<th>PV</th>
<th>BEV charger</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>11.6</td>
<td>7.9</td>
<td>11.3</td>
<td>8.9</td>
<td>17.3</td>
<td>27.9</td>
<td></td>
</tr>
</tbody>
</table>

Policy impact

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References