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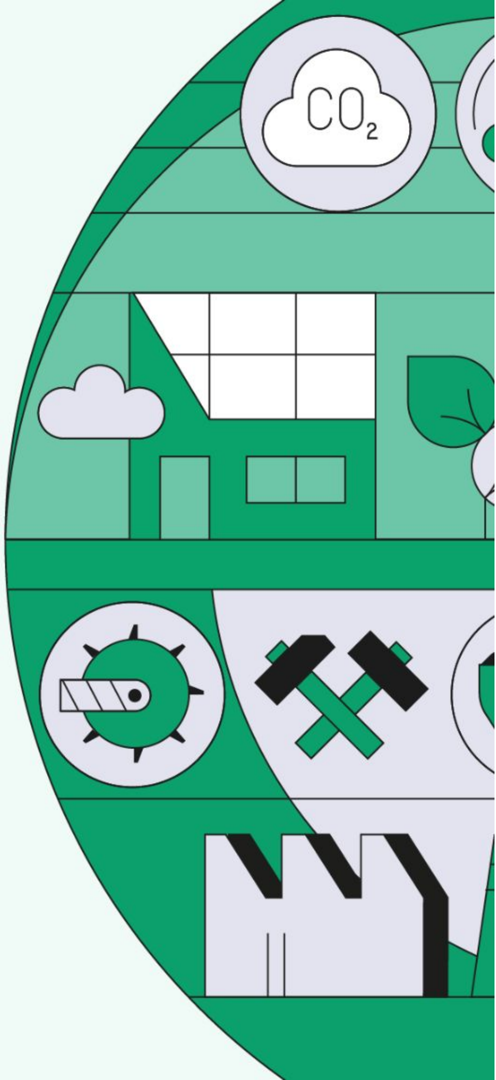
Poland nearing net-zero?

Modelling decarbonisation pathways
for the Polish energy sector
and economy up to 2040

12 December 2023 | 9:30-14:00

Centralny Dom Technologii



Instrat in a nutshell

Supercharging policies and public opinion with open data and research for a fair, green and digital economy

energy.instrat.pl

PyPSA

Strong R&D fundamentals: in-house energy modelling & data intelligence tools

Strong network with policy makers, investors and campaigners

Poland based, scaling up towards Brussels and Eastern Europe

> 25 researchers, data analysts and policy experts on the same goal

7 years in action on the ground

> 6m monthly views in PL Growing internationally

Green and just transition: data-driven and evidence--based. Demystifying, not strengthening beliefs

Supercharging public debate, policy- and decision-making

The data and modelling results responding to the needs of the users

Beyond the world of *black box*

Open by design: better access to energy data, methodologies and tools enables greater understanding and participation – of civil society and the private sector

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Poland nearing net-zero

Four scenarios for the Polish energy transition until 2040

Authors: Patryk Kubiczek, Michał Smoleń, Wojciech Żelisko

Collaboration: Bernard Swoczyna, Jarosław Kopeć, Michał Hetmański

Warsaw • 12.12.2023

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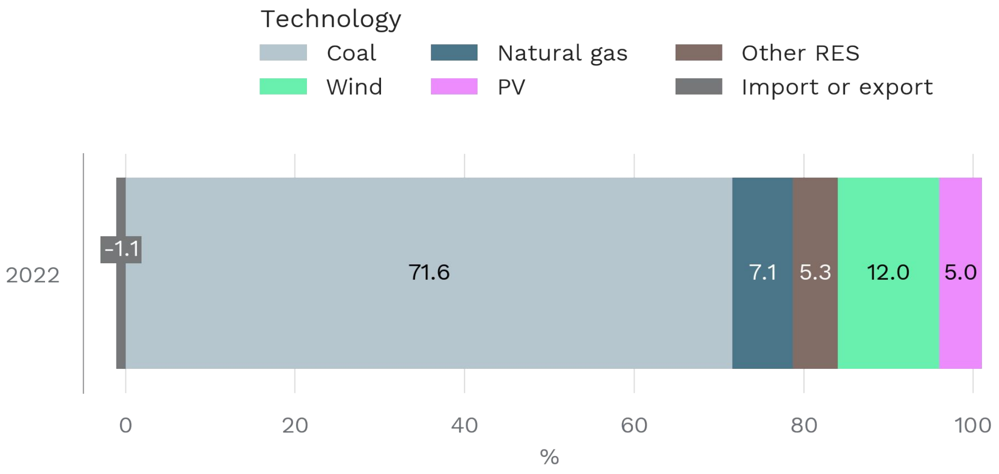
01

Four scenarios and five insights for the Polish energy transition until 2040

Patryk Kubiczek

Coal is now the foundation of the Polish energy sector

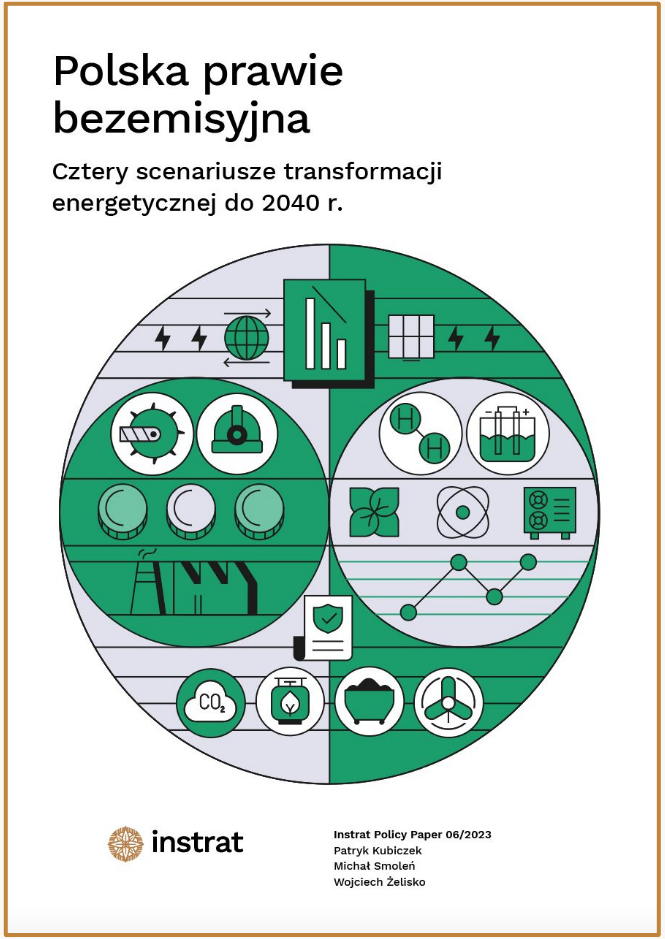
Share of generation technologies and trade in satisfying domestic electricity demand in 2022 (%)



Fossil fuels burned in the power sector in 2022 resulted in emissions of around **130 million t CO_2**.

This is one third of Poland's annual greenhouse gas emissions.

Source: Instrat's own analysis based on the historical net electricity production and demand (ARE). The presence of trade means that the total share of generation technologies in satisfying domestic demand can exceed 100%.



What will Poland be like in 2040?

Nearing net-zero?
With energy system based on RES or nuclear?
Or will we fall into the gas trap?
No one knows.

And what kind of energy transition would be profitable?
It depends.

Assessing cost-effectiveness requires the systematisation of data and ideas about reality – *modelling*.
We have done this at Instrat and created four alternative worlds – *scenarios*.

* the English version of the report will be released in the near future

Energy modelling

What exactly do we do – and how?

Define the system

In this analysis we are interested in sectors with energy use of fossil fuels*

➔ 75% of GHG emissions

*or hydrogen production use

Put the price on carbon

We attribute the same cost to all CO_2 emissions – this guarantees a reasonable prioritisation in the decarbonisation

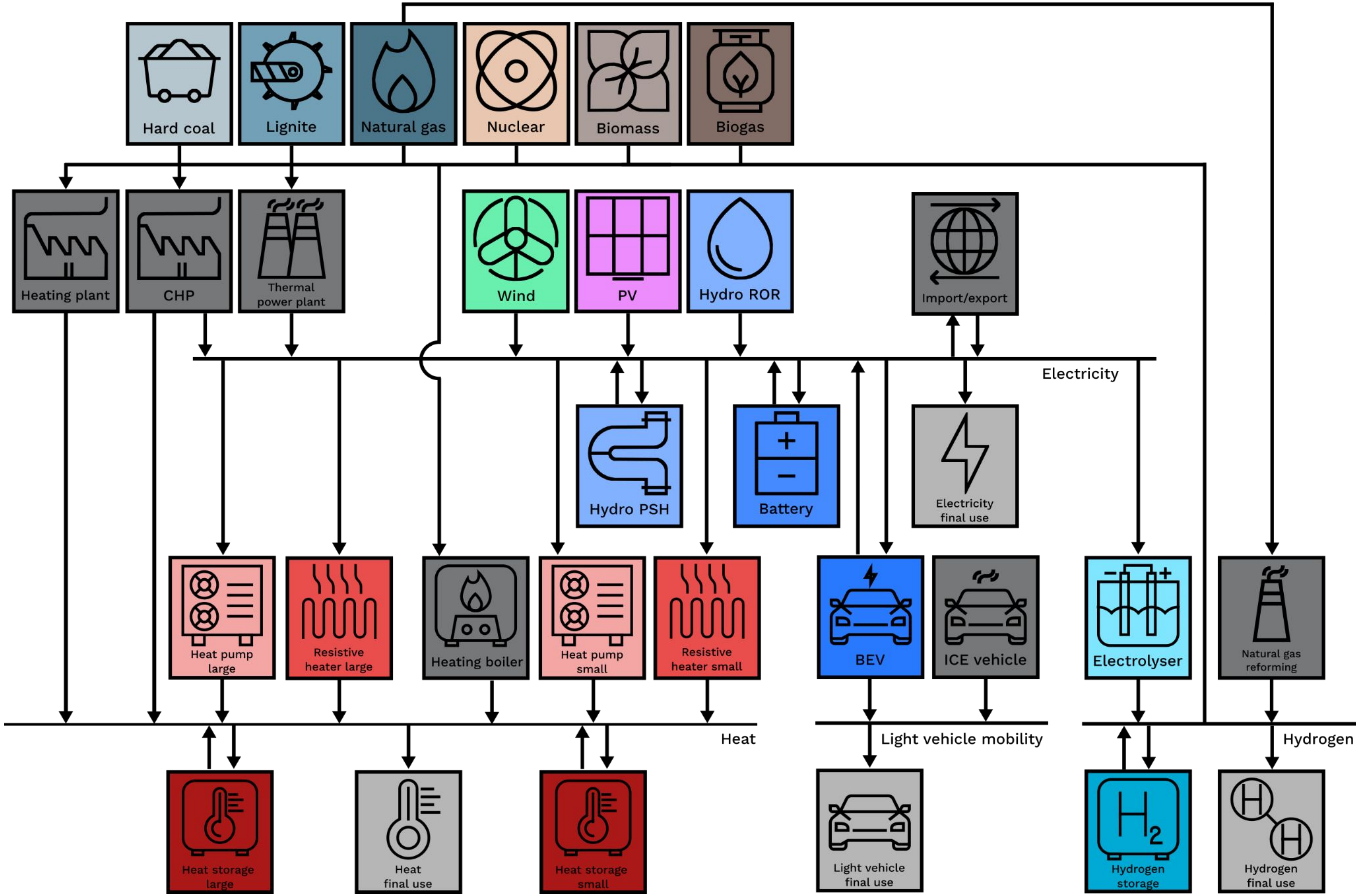
Compile the data

We combine data from various sources on the energy consumption, existing infrastructure, and costs

Optimise the costs

We search for a solution satisfying demand at the lowest CAPEX and OPEX costs

➔ PyPSA-PL



PyPSA-PL is Instrat's in-house open energy system model inspired by the PyPSA-Eur project.

We extended the latest version by heat, mobility, and hydrogen sectors.

Find out more at github.com/instrat-pl/pypsa-pl.

Four scenarios

How do we define them?

Our scenarios differ by:

- energy carrier demand pathways (electricity, heat, hydrogen, energy to power cars),
- pathways of the attainable levels of installed capacity in various technologies – or the maximum rate of new additions,
- allowed level of hourly system penetration by non-synchronous sources (e.g. wind and solar).

Cost assumptions are the same for all scenarios.

All the scenarios are cost-optimal under their respective assumptions.

AMBITIOUS RES AND NUCLEAR SCENARIO

S1: RES+NUC

Fast deployment of RES and nuclear possible, high electricity demand, low heating demand, high RES penetration possible

AMBITIOUS RES W/O NUCLEAR SCENARIO

S2: RES

Fast deployment of RES possible, no nuclear, high electricity demand, low heating demand, high RES penetration possible

BASELINE SCENARIO

S3: BASE

Deployment of RES up to latest unofficial forecasts of Ministry of Climate possible, nuclear as fast as S1, medium electricity and heating demand

SLOW TRANSFORMATION SCENARIO

S4: SLOW

Delayed deployment of RES and nuclear, low electricity demand, high heating demand, RES penetration limited

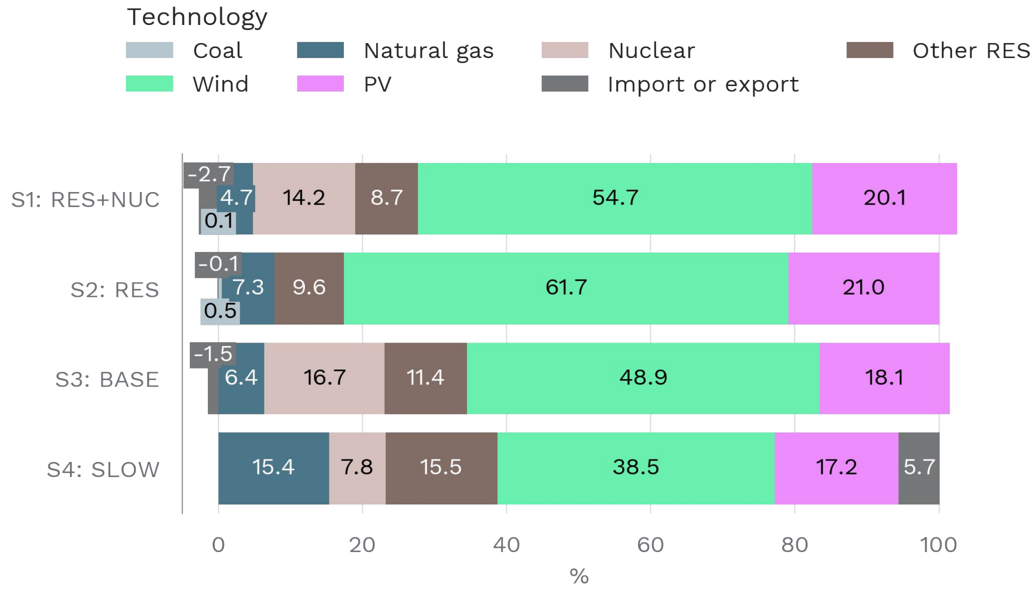
01

Insight 1

Wind and solar are cost-efficient basis of the future Polish energy system.

Wind and solar dominate the 2040 electricity production mix in all scenarios

Share of generation technologies and trade in satisfying domestic electricity demand in 2040 (%)

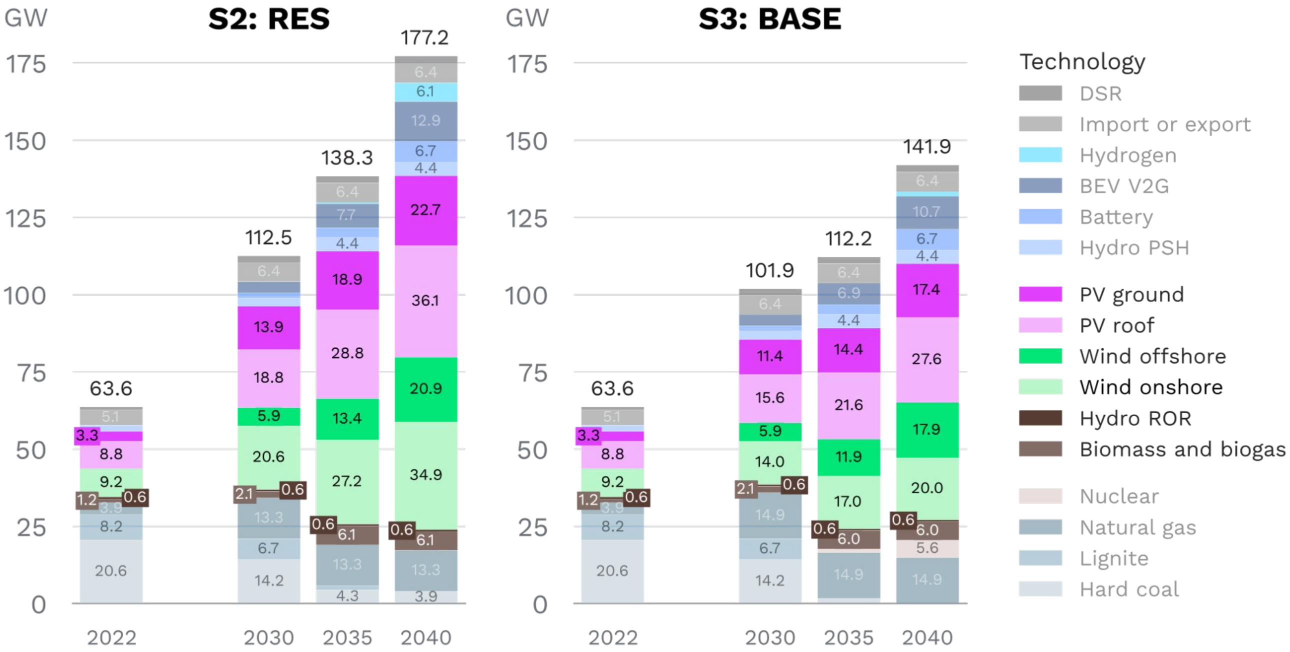


RES constitute **92%** of the electricity mix in the RES scenario and **84%** in the RES+NUC scenario.

Source: Instrat's own analysis based on the results of the PyPSA-PL optimisation model. The presence of trade means that the total share of generation technologies in satisfying domestic demand can exceed 100%.

In 2040, we could reach as much as 56 GW of wind power and 59 GW of PV power

Installed capacities in the power sector (GW)



Source: Instrat's own analysis based on historical data (ARE, PSE) and results of the optimisation model PyPSA-PL. Shown capacities of thermal power plants are net capacities.

In the RES+NUC scenario, 3.5 GW less offshore wind farms are developed by 2040 compared to RES.

The BASE scenario means much slower development of onshore wind farms, a slightly slower development of PV and a similarly rapid development of offshore wind farms.

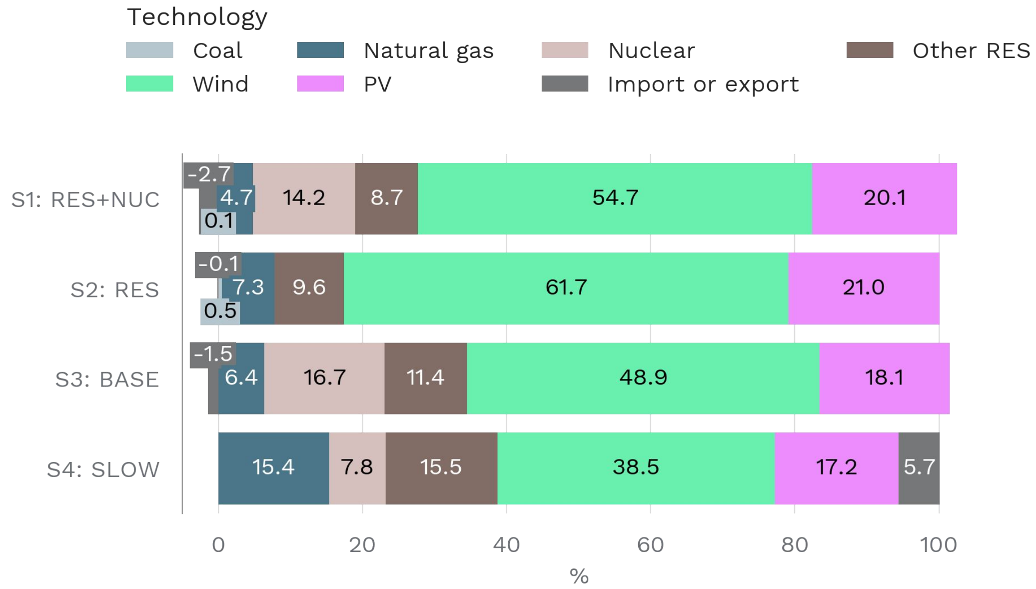
02

Insight 2

Nuclear may be part of a cost-efficient electricity mix in 2040 – but not its pillar.

Nuclear power does not exceed 17% share of the mix by 2040

Share of generation technologies and trade in satisfying domestic electricity demand in 2040 (%)



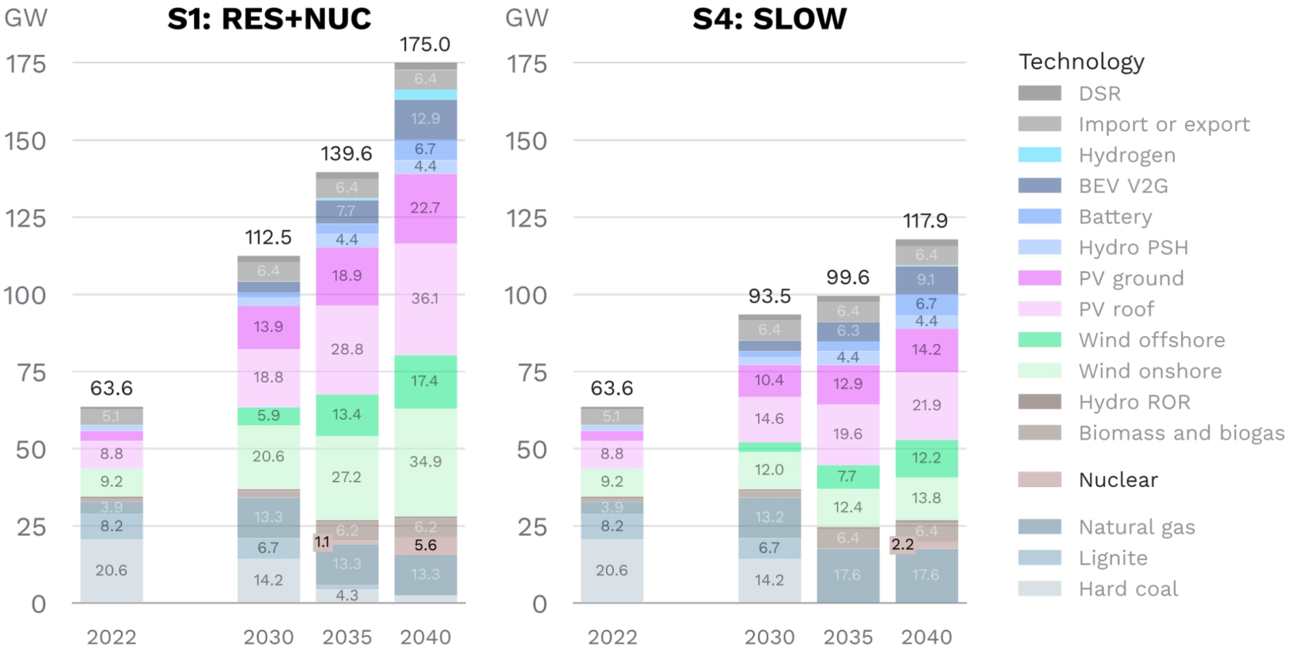
Source: Instrat's own analysis based on the results of the PyPSA-PL optimisation model. The presence of trade means that the total share of generation technologies in satisfying domestic demand can exceed 100%.

Nuclear's share is **14%** in the RES+NUC scenario and **17%** in the BASE scenario.

Nuclear plants help stabilise the system and decrease the share of natural gas in the mix.

The ambitious nuclear power deployment means 1.1 GW in 2035 and 5.6 GW in 2040

Installed capacities in the power sector (GW)



Source: Instrat's own analysis based on historical data (ARE, PSE) and results of the optimisation model PyPSA-PL. Shown capacities of thermal power plants are net capacities.

The optimum level of nuclear capacity coincides in the RES+NUC and BASE scenarios.

The realistic delivery dates of nuclear units are the limitation. Under the SLOW scenario, no unit is being built in Poland by 2035.

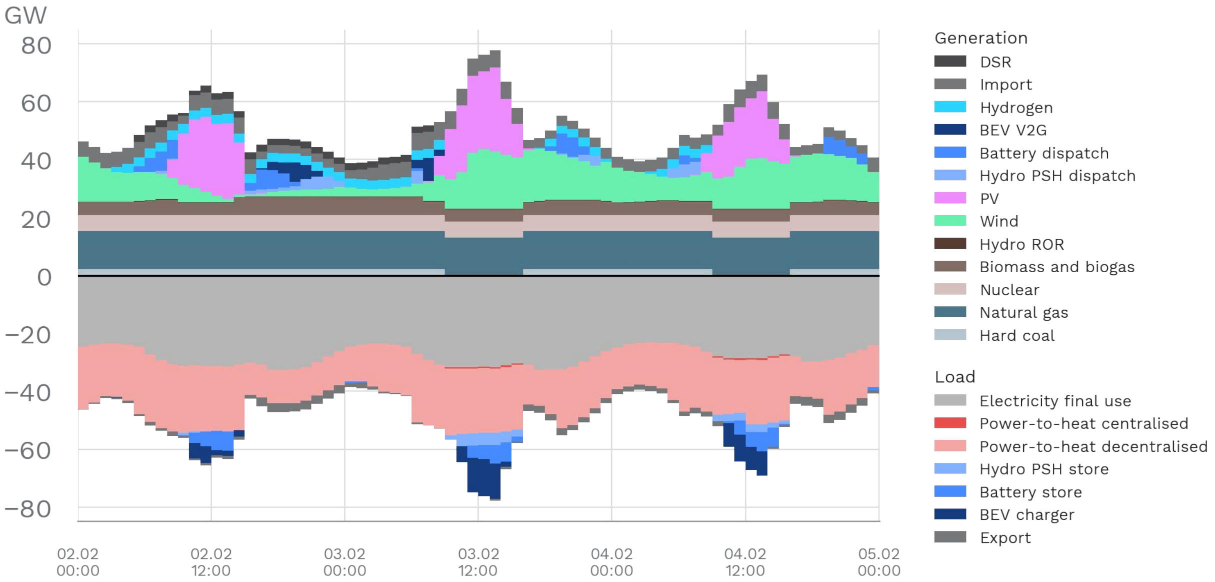
03

Insight 3

Widespread use of heat pumps will increase peak power demand. That drives the need for rarely used firm capacities.

Firm power generation capacities are needed also in ambitious RES scenarios

Electricity generation and load structure (GW)
during selected days in winter 2040 – **S1: RES+NUC scenario**



Source: Instrat's own analysis based on the results of the PyPSA-PL optimisation model.

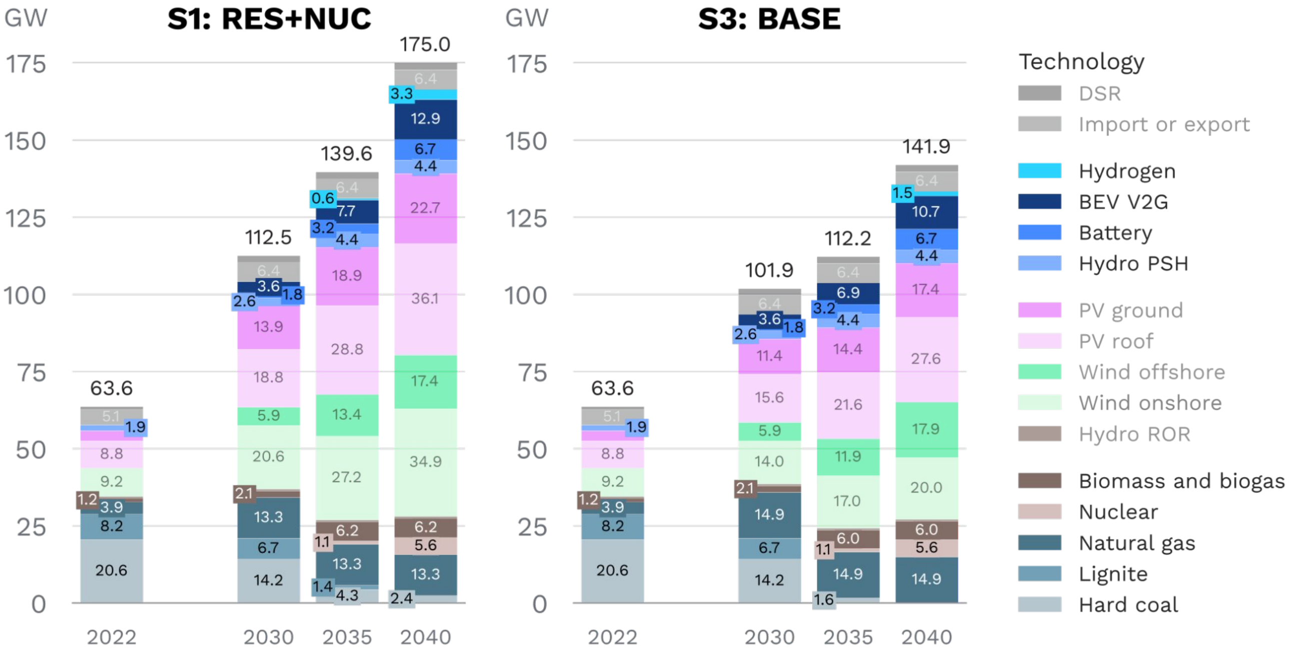
The rapid deployment of heat pumps in buildings is cost-effective, even though the power requirement of the pumps can amount to around **16 GWe** on cold windless days after dark (RES+NUC scenario).

At such times, dispatchable capacities* are crucial to ensure electricity supply.

* natural gas, coal, nuclear, biomass/biogas, hydrogen, energy storage

Firm capacities are a mixture of clean and CO_2-emitting technologies

Installed capacities in the power sector (GW)



Source: Instrat's own analysis based on historical data (ARE, PSE) and results of the optimisation model PyPSA-PL. Shown capacities of thermal power plants are net capacities.

We assume that no natural gas units are built after 2030*. Instead, hydrogen peaking units may be built.

Some of the coal-fired units can act as peak backup sources even until 2040 – this happens in the RES+NUC and RES scenarios.

* with the exception of the OT scenario, where 2035 is the last year for new gas units

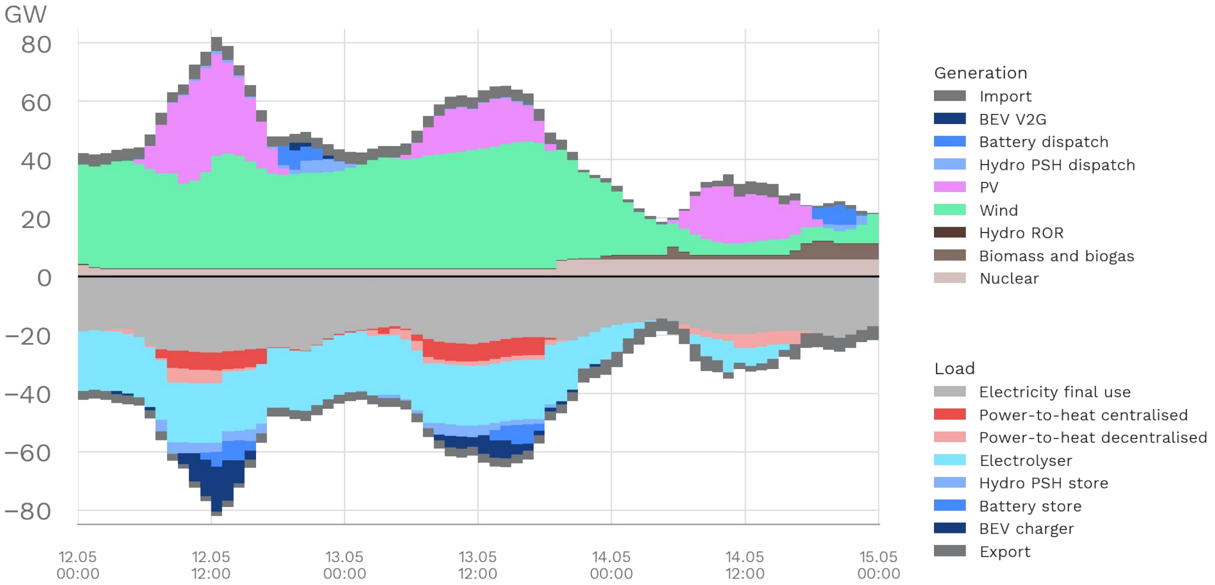
04

Insight 4

Flexible electricity consumption by sector enables wind and solar energy to be well used.

Solar and wind generation can exceed 70 GW at some hours

Electricity generation and load structure (GW)
during selected days in late spring 2040 – scenario **S1: RES+NUC**



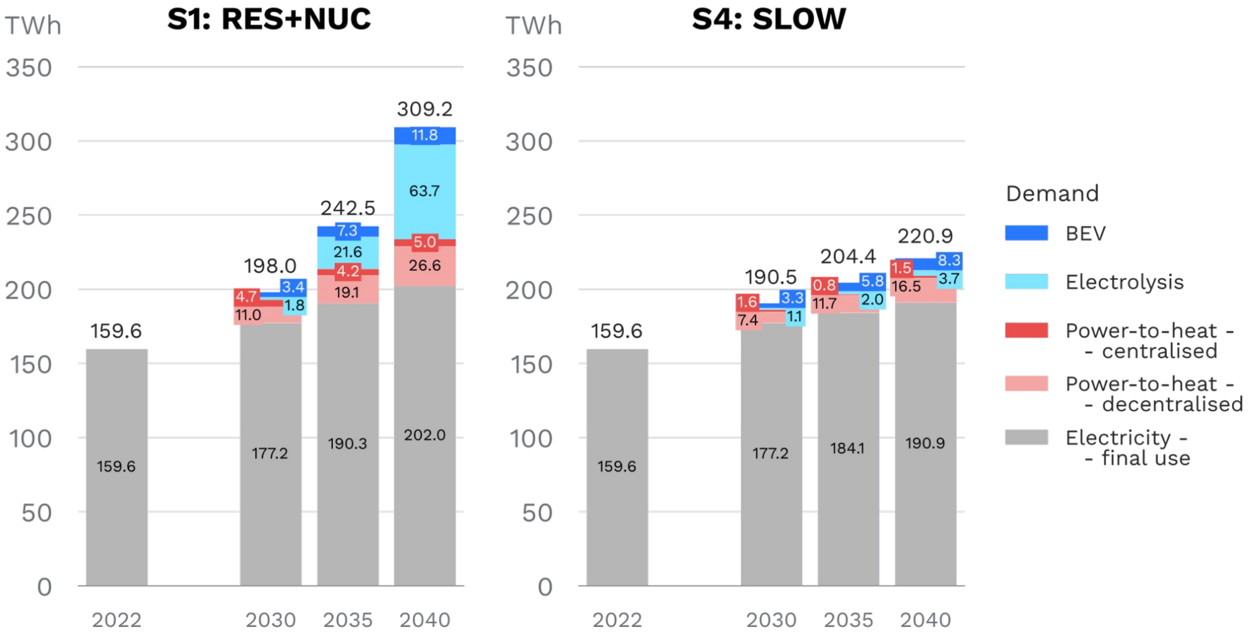
Source: Instrat's own analysis based on the results of the PyPSA-PL optimisation model.

On days with high solar and wind generation electrolysers work at their maximum capacity of around **20 GWe** in RES+NUC and RES scenarios.

Other important sources of demand elasticity are provided by BEV charging and power-to-heat technologies.

Electrification of the economy is leading to a significant increase in electricity demand

Structure of domestic electricity demand (TWh)



The difference in total electricity demand in 2040 between the two extreme scenarios: RES+NUC and SLOW is as much as **90 TWh**.

Source: Instrat's own analysis based on historical ARE data and the results of the PyPSA-PL optimisation model. Electricity demand includes transmission and distribution losses, but excludes the own needs of thermal power plants.

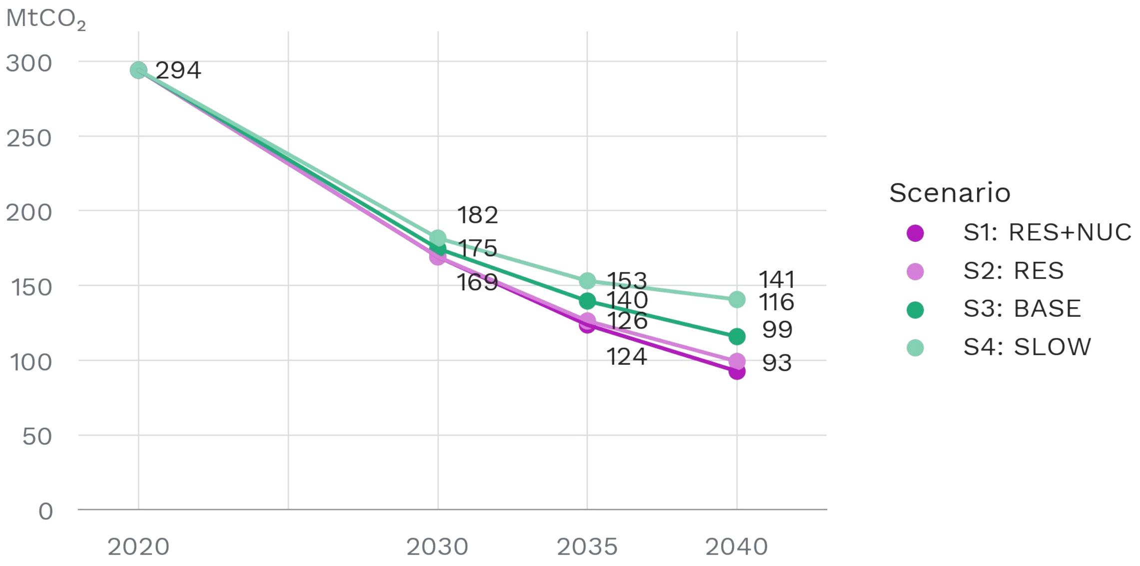
05

Insight 5

Ambitious RES scenarios lead to lowest emissions and lowest systemic costs.

Ambitious RES scenarios lead to the lowest CO_2 emissions…

Annual CO_2 emissions from energy use of fossil fuels and hydrogen production (Mt)



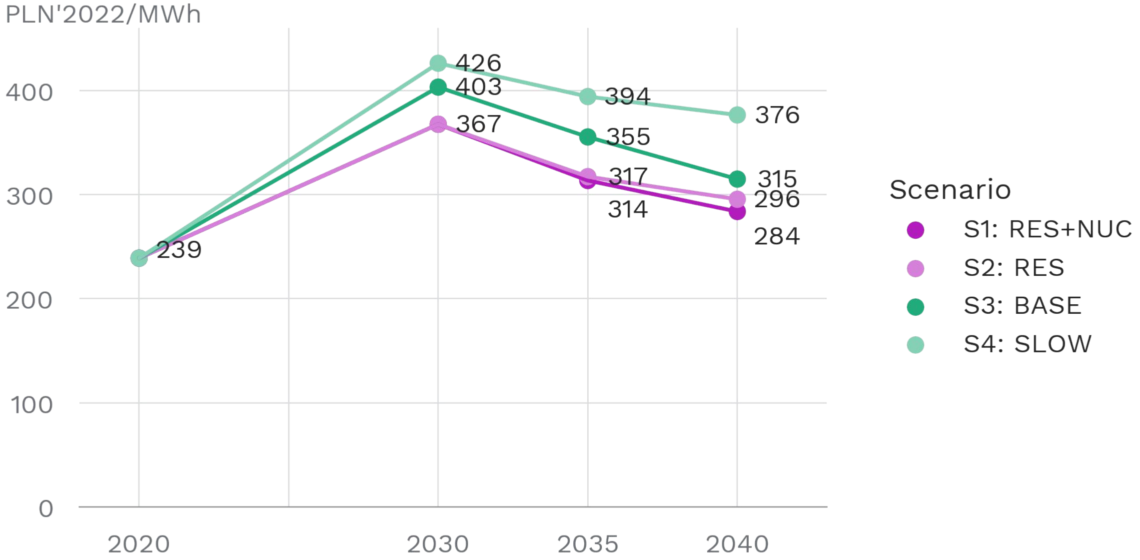
Source: Instrat's own analysis. 2020 – average of historical data for 2019-2021 based on KOBiZE, Eurostat and own assumptions. 2030-2040 – numbers based on PyPSA-PL results and assumptions on emissions from non-modelled energy use of fossil fuels.

RES+NUC scenario leads to **68% reduction** in annual emissions from considered sectors* by 2040 with respect to 2020.

* in 2020 they accounted for approx. 75% of all GHG emissions in Poland

... and to the lowest costs of energy production

Average unit cost of electricity production (PLN'2022/MWh)



Source: Instrat's own analysis. 2020 – average historical data for 2019-2021 based on ARE. 2030-2040 – numbers based on PyPSA-PL results: cost includes annuitised CAPEX, fixed OPEX, and variable OPEX (incl. CO_2 emission fee) associated with electricity generation and storage infrastructure; only 2026-2040 investments are included in the calculation of the CAPEX component.

Not only unit, but also total systemic costs are lower in the ambitious scenarios.

For example, annual systemic cost of electricity, heat, and hydrogen production by 2040 in RES+NUC amounts to circa **120 bln PLN***.

BASE is **6 bln PLN** more. SLOW is **21 bln PLN** more.

* costs of power grid expansion and insulation retrofits in buildings are not included

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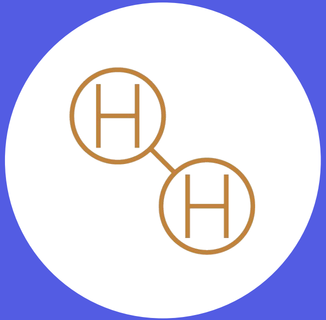
02

Will hydrogen be a missing link to the decarbonisation of Polish economy?

Wojciech Żelisko



Tank under pressure

Why have we modelled hydrogen?

Scale and importance

Domestic hydrogen production is **1 million tonnes** – virtually all from fossil gas; it is used in "upgrading" **crude oil** and **ammonia** production

Decarbonisation tool

Hydrogen generated by **electrolysis** can help mitigate emissions, particularly those from the **industry** and **heavy transport**

Confronting beliefs

There are many **conflicting visions** of the development of green hydrogen economy – our modelling is a **signpost** to aid their assessment

How to capture an invisible gas?

Incorporating the hydrogen sector into PyPSA-PL

Production modes

Our model assumes competition between **grey** and **green** hydrogen powered from the **grid**

Electrolyser deployment

For 2030 the goal from **PHS**, then optimising **systemic costs** of modelled sectors

Assumptions

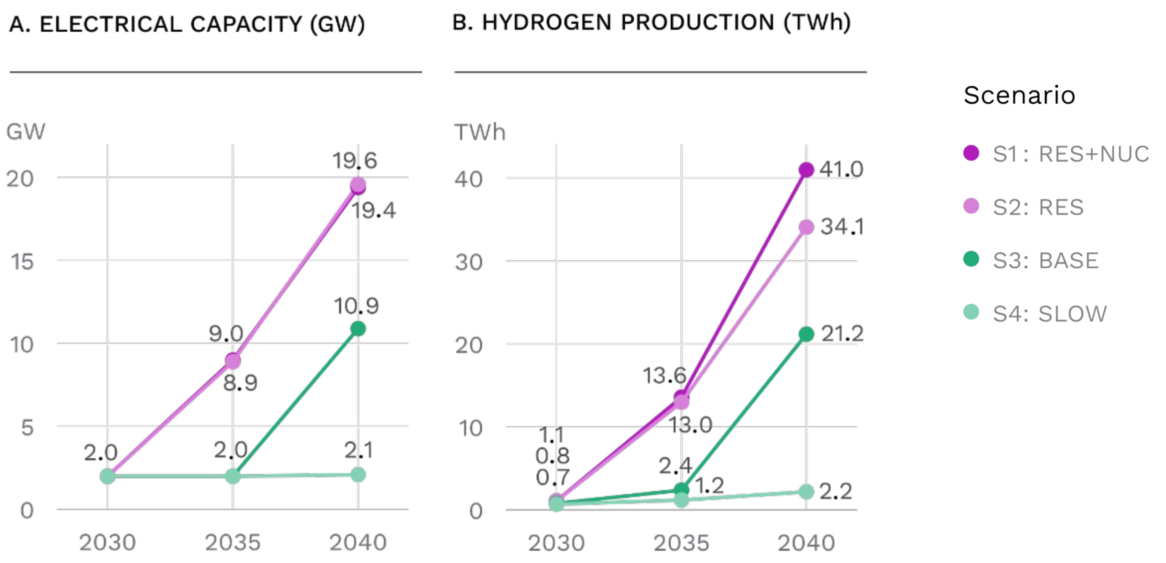
The model does not take **support programmes** (e.g. CfDs) or hydrogen **imports** into account

Demand

The more **ambitious** a scenario, the **higher** hydrogen demand (**industry, heavy-duty transport and power**)

Green hydrogen economy will properly develop no sooner than in 2030s

Electrical capacity installed in electrolysers (GW) and their hydrogen production (TWh) in respective scenarios



Source: Instrat's own analysis based on the results of the PyPSA-PL optimisation model.

The result of the model is an **optimised electrolyser capacity** in terms of systemic costs.

Our scenarios are different in **hydrogen production potential,** dependent on the availability of clean electricity and electrolyser load.

It ranges from **0.07 in SLOW to 1.2 million tonnes in RES+NUC (in 2040).**

Potential not so explosive

Selected findings from modelling hydrogen

1

Scarce hydrogen

Electrolyser load in 2030 is minimal, which implies **high production costs** influencing the issues of **support programmes** and hydrogen **imports**

2

Screwdriver, not Swiss army knife

Grey hydrogen is not fully replaced by the green one **in any scenarios** – limited availability of hydrogen for **new uses**

3

Interdependence

The scale of hydrogen economy hinges on successful energy transition – it **must not be a goal in itself,** rather serve the latter

Good starting platform is not enough

Selected recommendations from modelling hydrogen

No-regret end-uses

Criteria for utilising green hydrogen should be **simplicity** and potential of **mitigating emissions**

Analysis of potential

Sound **assessment of the potential and costs** of green hydrogen would allow for more realistic demand and set sectoral goals

Regional ecosystem

High costs (production, transmission, storage) show the viability of **decentralising** hydrogen sector

Tough beginnings

Subsidies may accelerate the growth of the hydrogen sector, but in 2030 **clean energy** is needed **elsewhere**

03

Conclusions for the Polish transition strategy: RES targets and other policies in need of attention of the new government

Michał Smoleń

Polish transition needs strategic shift

2030 is coming

We can't wait any longer to start key investments.

Clear goals

The matter is too complex to be done without comprehensive plan.

NECP and other plans

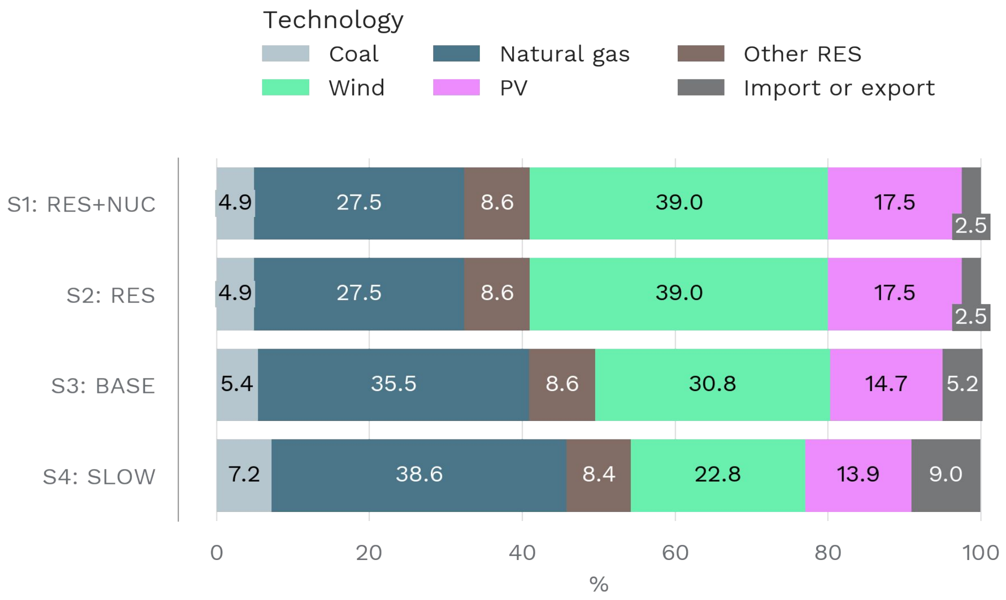
Update of key documents required also on the EU level.

Public dialogue

We can't make it without honest communication with stakeholders.

1. There is no alternative to fast expansion of wind and solar power.

Share of technology in covering Poland's electricity demand in 2030 (%).



Source: Instrat's own analysis based on the results of the PyPSA-PL optimisation model.

Wind and solar are major, scalable sources of clean electricity.

Faster modernisation and expansion of the **power grids** and improvement of **regulatory environment** are necessary conditions for RES build-up in upcoming years.

2. We need a more flexible power system.

Simple addition of clean energy sources is just not enough.

Transition based on wind and solar sources makes it necessary to:

- develop electricity and heat storage,
- gradually lower the conventional baseload requirements,
- have more flexible heat generation (including biomass and biogas),
- have more flexible demand.

Ambitious RES+NUC scenario – 2040.

95%

System Non-Synchronous Penetration – achievable momentary share of wind, solar and batteries in power mix

52 GW

Average demand from energy storage, electric vehicles, electrolysers and electric heating in 40 hours with highest wind and solar power production

Power grid limitations and flexibility gaps lead to additional costs, but there are ways to mitigate this problem

Energy storage

Helps to manage local power grid overloads.

Electrolysis and power-to-heat

A way to use renewable energy that would be curtailed due to limitations of power system.

Cable pooling

A way to connect additional renewables at the cost of limited peak output.

Non Standard RES

E.g. East-West placed solar panels or more diverse locations for wind turbines.

3. We need a lot of dispatchable peak generators even in 2040.

Our weather does not help.

Even in the scenario that allows for quick nuclear and bioenergy build-up, seldom-run fossil fuel power plants are optimal way to cover peak winter-time demand.

Keeping those plants in place, as well as investment in the new hydrogen power plants, would require appropriate market design measures.

Ambitious RES+NUC and RES scenarios – 2040.

16-17 GW

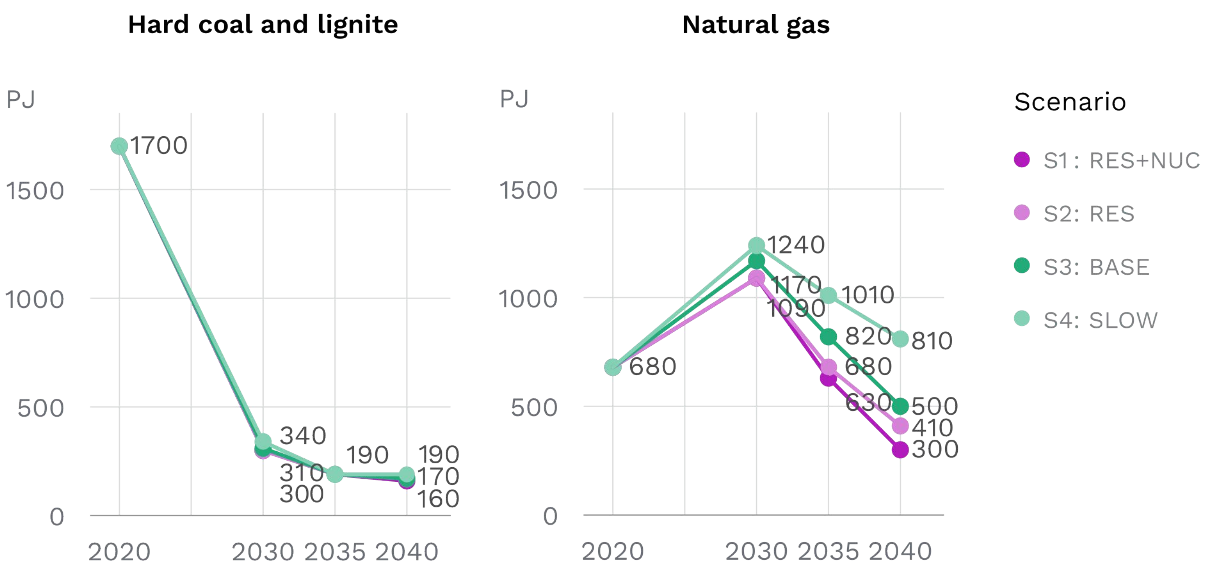
Capacity in coal and gas power plants. There is also 3-6 GW of hydrogen power plants.

5-8%

Joint share of coal and gas power plants in annual electricity production.

Price signals favour quick lowering of coal use

Energy and hydrogen-production use of coal and natural gas (PJ)



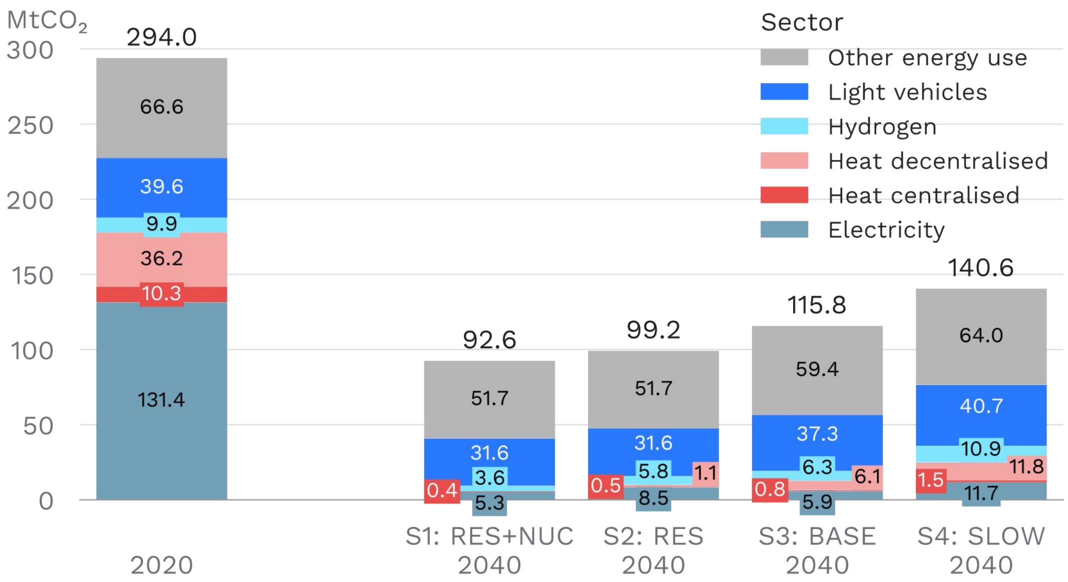
Source: Instrat's own analysis. 2020 – average of historical data for 2019-2021 based on Eurostat, KOBiZE, and own assumptions. 2030-2040 – numbers based on PyPSA-PL results and assumptions on non-modelled energy use of fossil fuels.

Due to EU ETS prices and coal phase-out in household heating, by 2030 we will need only around **15 mln tonnes** of hard coal per year, roughly independent of scenario. That's yearly output of 3-5 mines.

Peak consumption of natural gas by 2030 may amount to **30–34 bln m³**. Then it drops – however, in SLOW much slower than in other scenarios.

4. Emissions from hard-to-abate sectors will be ever more relevant.

CO_2 emissions from fossil fuel energy use and H_2 production (Mt), 2020 vs. 2040



Source: Instrat's own analysis. 2020 – average of historical data for 2019-2021 based on Eurostat, KOBiZE, and own assumptions. 2030-2040 – numbers based on PyPSA-PL results and assumptions on non-modelled energy use of fossil fuels.

In 2020, emissions from electricity and heating sectors accounted for **60%** of all energy and hydrogen-related emissions.

In 2040, this number may drop to as low as **6%** (RES+NUC) or **18%** (SLOW).

Policies will need to target more strongly other sectors such as transport and industry.

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We are looking forward to hearing from you

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