CARBON-FREE EUROPE

MEMO

Poland's Pathways to Net-Zero Emissions

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In anticipation of Poland's submission of its updated National Energy and Climate Plan (NECP/KPEiK) to the European Commission in June 2024, **Carbon-Free Europe (CFE)** commissioned Evolved Energy Research, in collaboration with the Silesian University of Technology (SUT), the Institute of Power Engineering - National Research Institute, and Princeton University's Andlinger Center, to conduct an **extensive energy systems modelling study**. The objective of the two-phase project is to **delineate pathways for Poland to achieve net-zero emissions by 2050**, thereby informing not only the NECP revision but also future policies, national strategies, and long-term investments.

The **two-phase Net-Zero Poland (NZP) study** provides a first-of-its-kind, detailed and transparent articulation of alternative pathways for Poland to transition to net-zero emissions by 2050. The study aims to inform energy-transition strategy, policy formulation, and investment decision making in both the public and private sectors. Below you can find the results of the **first phase** of the project, which was **led by CFE** and provides critical and data-based insights on a national and international level. The **second phase, led by SUT**, will use the data to run a higher spatial resolution model that enables key land-use, socio-technical, environmental, and investment challenges to be discussed at the voivodeship, powiat, and gminas level.

Poland's energy landscape remains **more heavily reliant on fossil fuels** compared to other EU Member States. Because of this, Poland faces unique challenges to meet the EU's ambitious emissions reduction targets under the Fit for 55 package, while ensuring coal regions are not left behind and energy prices remain affordable. The NECP draft update sets **ambitious targets for Poland**, aiming for a 29.8% share of renewable energy sources (RES) in gross final energy consumption by 2030 (compared to 9.4% in 2022).[1]

With a well-designed implementation strategy, Poland can achieve a just transition, zero-emission energy system, and improved air quality as outlined in the proposed Energy Policy of Poland until 2040 (PEP2040). This strategy relies on a **diverse energy mix to be successful**, including accelerating renewable deployment alongside nuclear energy.

Our analysis explored **eight different pathways for Poland to reach net-zero**, each of which has different cost implications and feasibility risks. In this report, we **highlight results in six key areas**: 1) achieving clean heat, 2) future of coal with carbon capture and storage, 3) role of nuclear energy, 4) renewable resource availability, 5) essential hydrogen interconnector, and 6) electric vehicles.

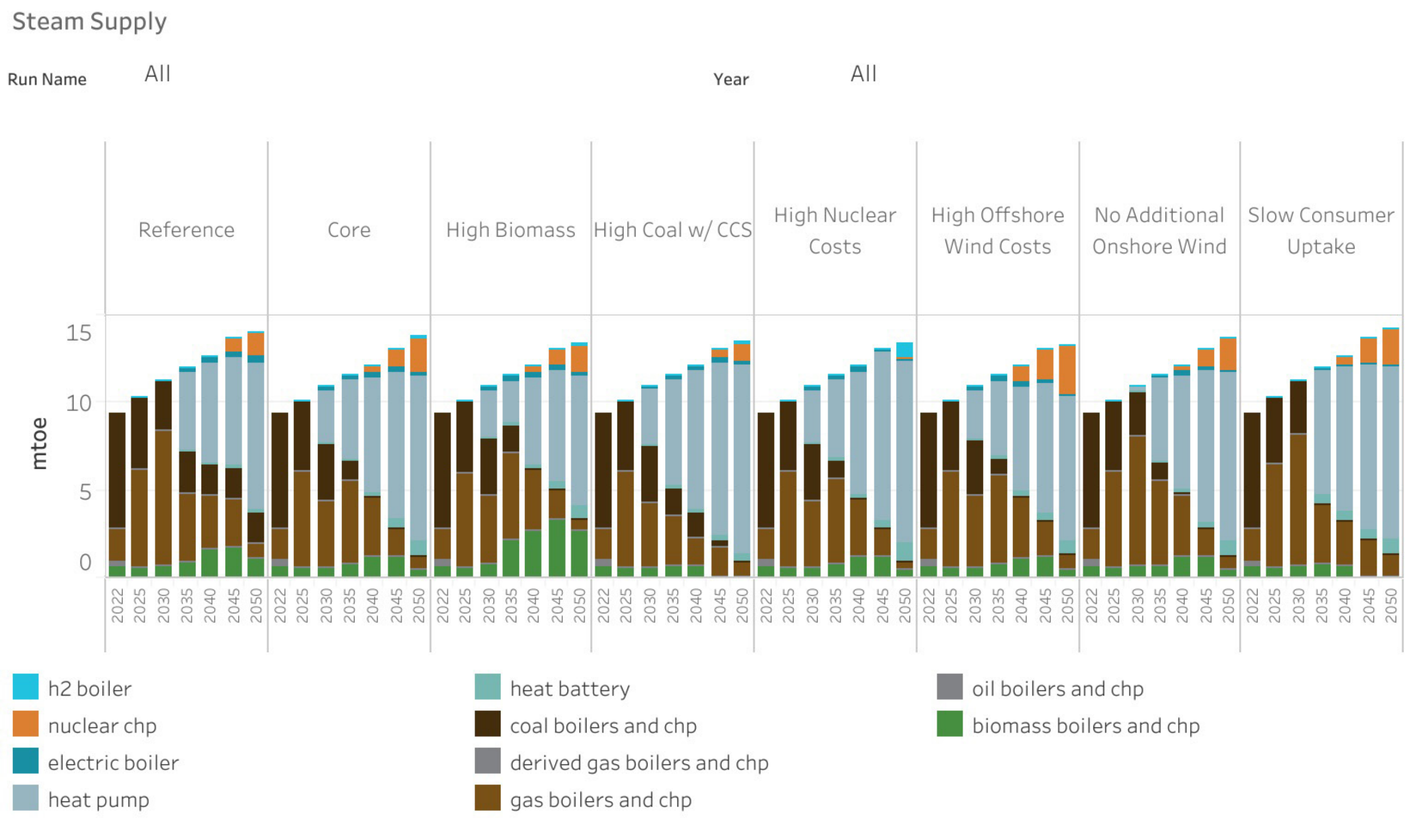
The full technical report can be found here. A full data Tableau with interactive results can be found at the end of this publication.

Achieving Clean Heat

Achieving a clean and decarbonised heating system for Poland requires two main strategies 1) replacing in-home coal and biomass boilers with heat pumps and 2) decarbonising steam supply for district heating and industry. Today, around 60% of residential buildings rely on coal or biomass boilers, 35% on district heating systems, and 5% on heat pumps. In our Core pathway, the percentage of homes with heat pumps needs to jump to 17% by 2030 and 45% by 2050. These heat pumps replace in-home coal and biomass boilers while district heating systems are preserved and decarbonised upstream. To achieve this goal, Poland requires a supply chain to install heat pumps in over 200,000 homes per year and more than quadruple electricity supply by 2050.

Below you can see how steam for district heating, as well as industry, is decarbonised. Currently, steam is principally produced through coal power plants and boilers. The coal phaseout for steam production is achieved primarily through the deployment of large heat pumps, with some gasification in the short-term. Beyond 2030, nuclear facilities also play an important role in providing steam, providing up to 14% of supply.

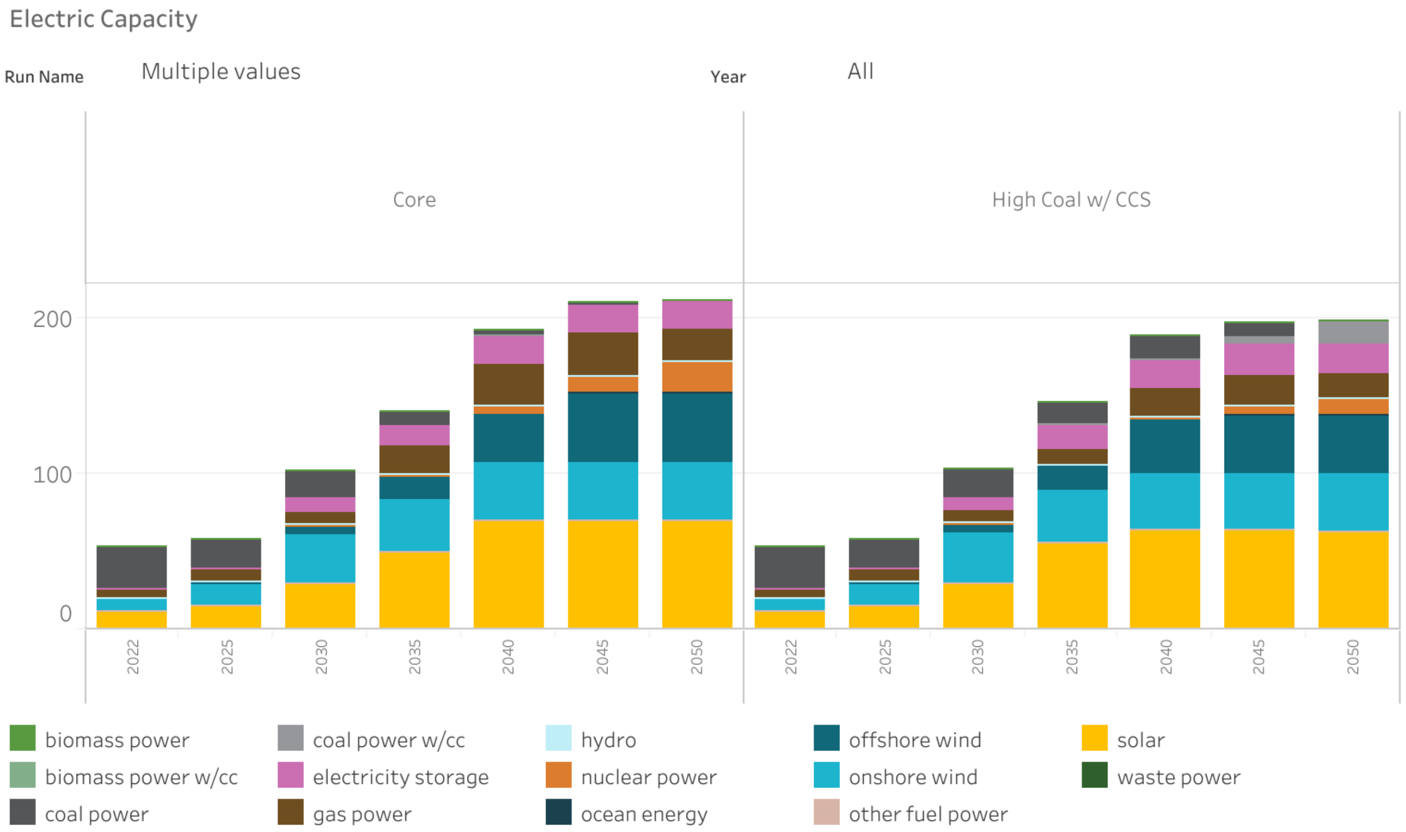
Figure 1: Steam production across all modelled pathways.



Future of Coal with Carbon Capture and Storage

Our pathway “High Coal w/ CCS” models what would happen if Poland were to keep coal in its energy economy system with up to 15 GW of coal capacity by 2050, equal to about 50% of the current fleet. We ran this pathway not to recommend preserving coal capacity, but to demonstrate the trade-offs in a strategy banking on carbon capture technology with coal or hoping to delay renewable deployment for future technology breakthroughs. As you can see in Figure 2, keeping coal creates a lower need for gas power compared to the Core pathway, but it does not negate the need for nuclear and renewables.

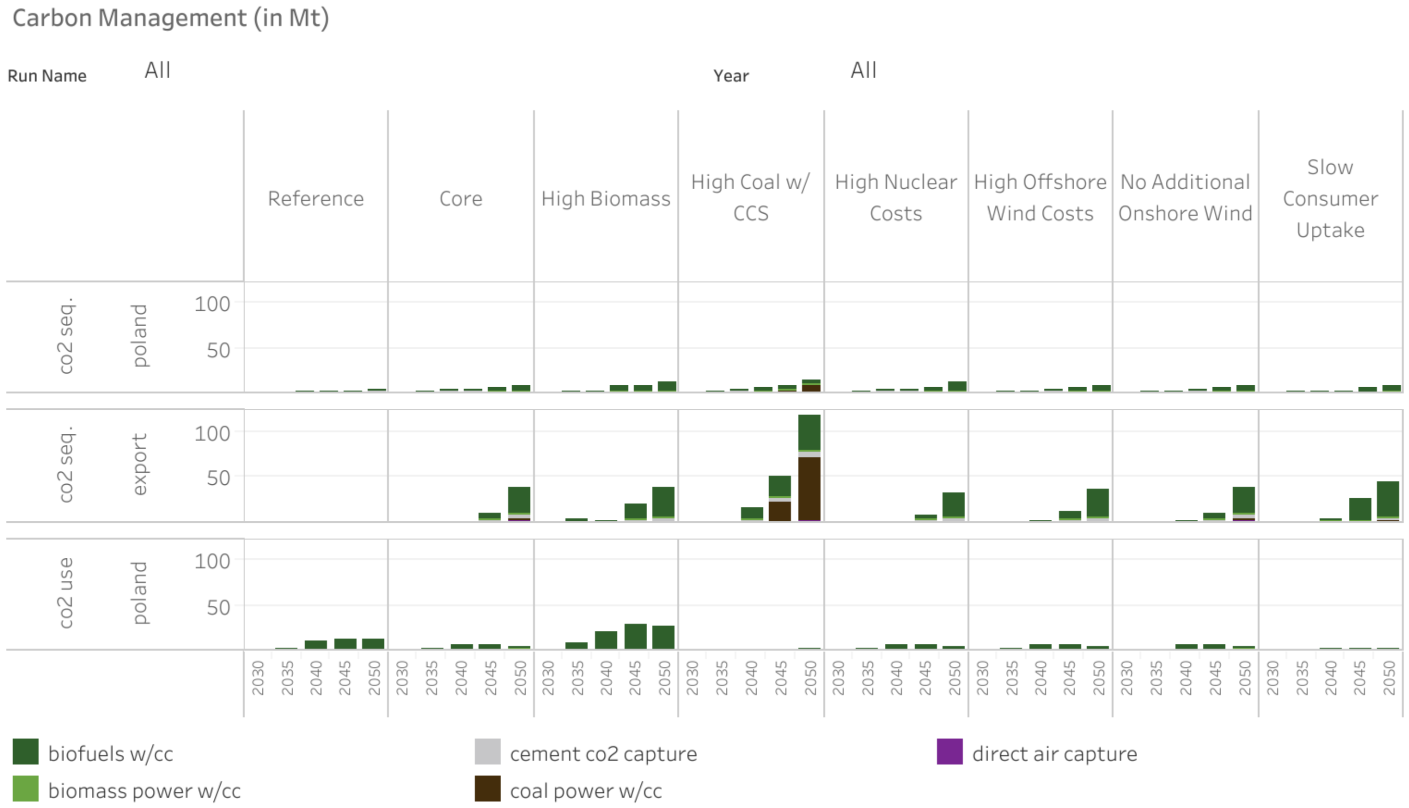
Figure 2: Electricity capacity in the "Core" versus the "High Coal w/ CCS" pathway



There are two potentially insurmountable challenges with the "High Coal w/ CCS" pathway: 1) costs and 2) carbon capture transport and storage infrastructure needs. A future bound to coal is the highest cost pathway and extremely expensive toward 2050 with at least 8.0 billion EUR more investments compared to our "Core" Pathway in the year of 2050 alone. It also requires over 100 megatons (Mt) of CO_2 exports annually on top of an annual 20 Mt domestic CO_2 sequestration and some domestic CO_2 utilisation (**Figure 3**). Achieving these scales of operations for both sequestration and export requires careful planning. Expanding CO_2 pipelines to Germany and other Central European countries as well as the Nordics is required in all pathways, but needs to be scaled up significantly in the case of keeping coal within the energy system.

Irrespective of the economics of CO_2 pipelines and deployment of carbon capture, utilisation, and storage (CCUS) technology, Poland will need to adhere to the European Union's Renewable Energy Directive (RED III) and account for ageing coal infrastructure that will need replacement regardless of climate targets.

Figure 3: Carbon capture sequestration in Poland, export, and utilisation.

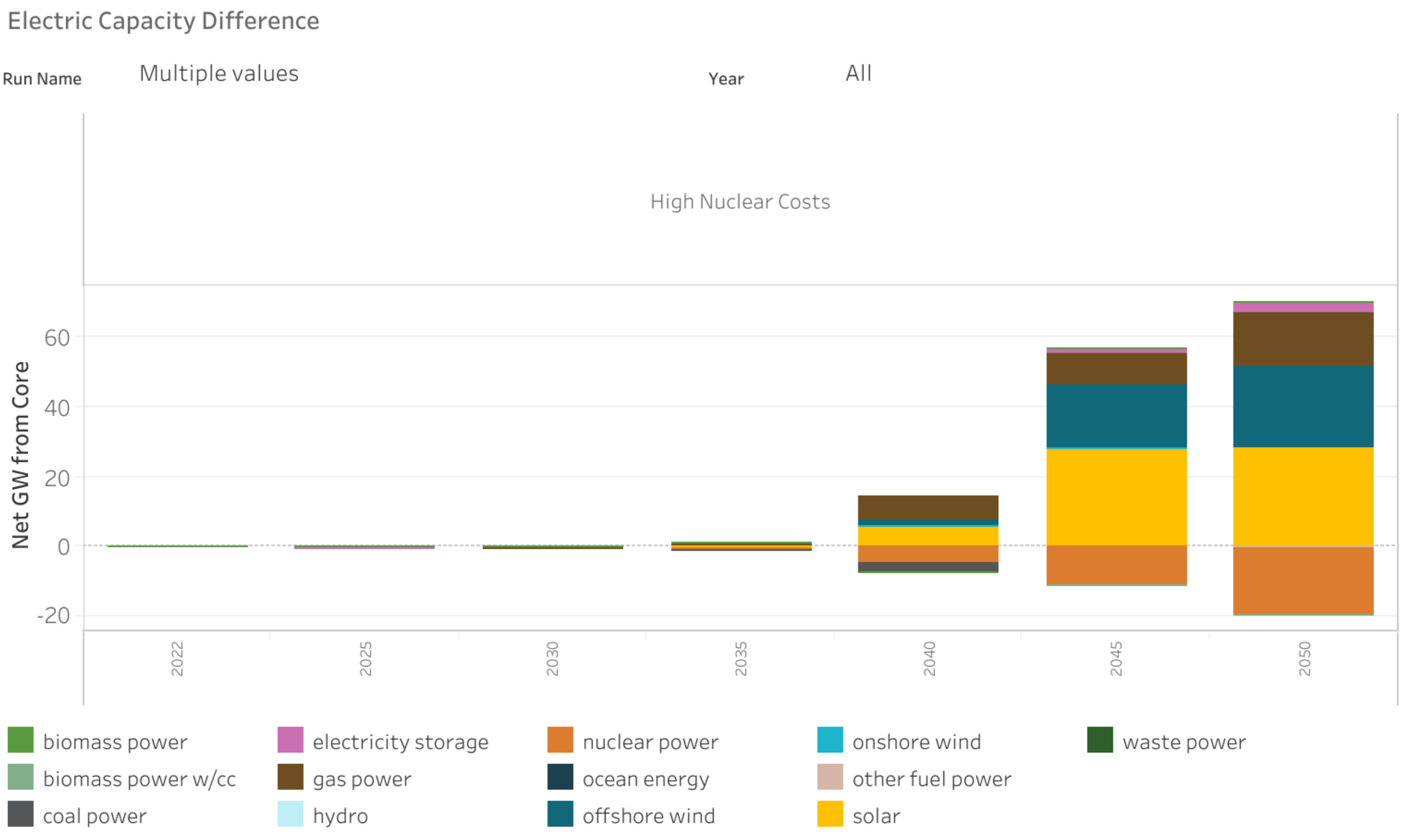


Role of Nuclear Energy

In all our model pathways nuclear energy plays a significant role in providing zero carbon electricity for the power sector as well as steam for industrial processes and district heating (see “Achieving Clean Heat”) and hydrogen production (see “Essential Hydrogen Interconnector”). We consider the potential of different sizes and types of reactors, including large light water reactors and advanced small modular reactors.

In the power sector, nuclear energy provides 19 GW of electric capacity by 2050 in our “Core” pathway. With less nuclear deployment due to cost constraints, represented with our “High Nuclear Costs” pathway, Poland would need to deploy more than three times the capacity of alternative clean energy resources. Figure 4 shows that replacing 19 GW of nuclear energy requires building more than 70 GW of alternative resources including majority solar, offshore wind, gas, and storage. The total electric capacity needs to be higher to provide the same electricity generation, including an increased gas peaker capacity and more electric storage to balance the grid.

Figure 4: Change in electricity capacity for the “High Nuclear Costs” pathways compared to “Core”



Offshore wind power becomes especially important in any pathway with limited nuclear energy deployment as solar and onshore wind power are using almost all available resources (see Figure 6). As you can see in Figure 5, the technologies have an inverse deployment relationship. High nuclear cost increases offshore wind demand and vice versa as shown by the “High Offshore Wind Costs” pathway. Considering cost and subsequent deployment uncertainties, a flexible framework that incentivizes the buildout of both nuclear and offshore wind is necessary.

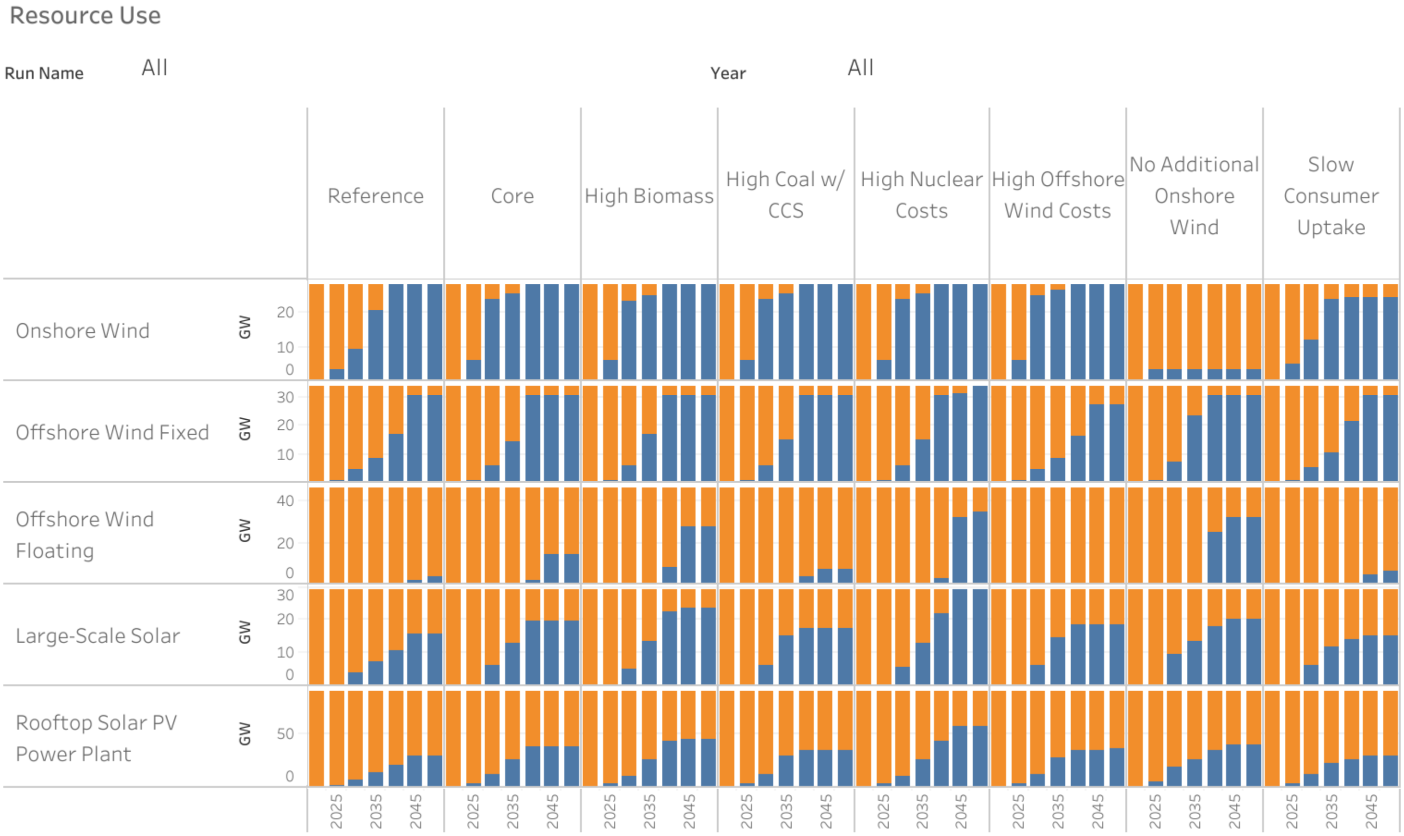
Figure 5: Electricity generation across all modelled scenarios.

Renewable Resource Availability

The EU requires Poland to reach 42.5% renewables in final energy consumption by 2030, a target that Poland can reach considering wind and solar resource potential. In our analysis, we consider the potential of renewable resources based on land use availability, resource quality, and relative economics compared to other clean energy resources. Reaching this target for final energy consumption will require Poland to ramp up its current power sector target of 50% renewables by 2030 and the electrification of the transportation sector (see “Electric Vehicles”). Our pathways suggest Poland should achieve 60-66% renewables in the power sector by 2030 even while total electricity generation increases by 50% compared to 2022.

Below you can see the Wind and Solar Resource Potential for Poland (orange) and how much of the renewable resources are used in each pathway over time (blue) to meet the renewable energy share. Onshore wind is a valuable resource that is maxed out in all pathways by 2040, except in a pathway where we explicitly prevent additional onshore wind builds. The vast majority of fixed offshore wind resources are used up over time as well and most pathways are also tapping into more expensive floating offshore wind resources. If nuclear power is prevented due to high cost or if onshore wind cannot be deployed, both fixed and floating offshore wind resources are facing maximum use. Solar is deployed across all pathways and large-scale deployment is maxed out if nuclear deployment is limited.

Figure 6: Wind and solar resource potential.



Essential Hydrogen Interconnector

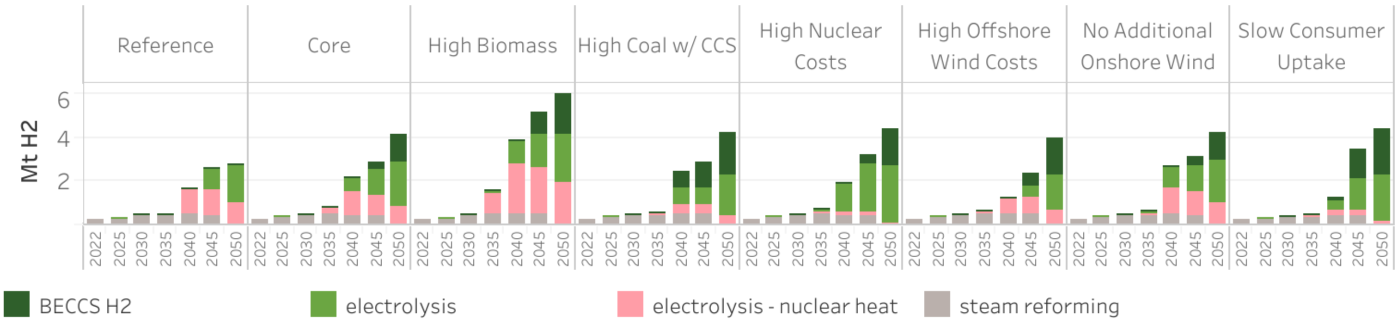
Poland is currently the third largest hydrogen producer (1.3 Mt H2/year[2]) and consumer (0.8 Mt H2/year[3]) in Europe and fifth largest producer in the world. Building on this workforce and experience, Poland can establish a clean hydrogen industry that fulfils domestic hydrogen demand (a key priority for energy security) and interconnects and exports hydrogen from the Baltics to Germany and other nations in need.

Figure 7 shows Poland's domestic hydrogen production. Across all pathways, Poland can leverage its hydrogen experience, future nuclear and offshore power, and biomass resources to become a large-scale hydrogen producer. The "High Biomass" pathway sees the most hydrogen product due to expanded BECCS hydrogen and nuclear heat electrolysis potential.

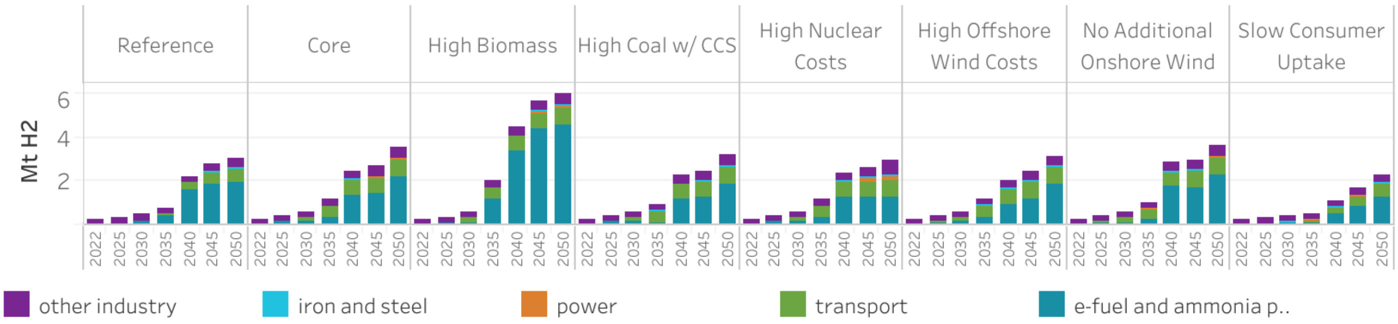
Poland's strategic location makes it an essential hydrogen interconnector for pipelines between the Baltics and Germany and other Central European countries. As shown in Figure 7, Poland can take hydrogen from the Baltics and domestic production, use it as a feedstock to produce e-fuels and ammonia, and export these alternative fuels. Fostering collaboration and strategic partnerships with neighbouring countries will create a cohesive regional hydrogen and alternative fuel network, leveraging an economic opportunity for Poland as a hydrogen interconnector.

Figure 7: Hydrogen supply and demand

Hydrogen Supply



Hydrogen Demand



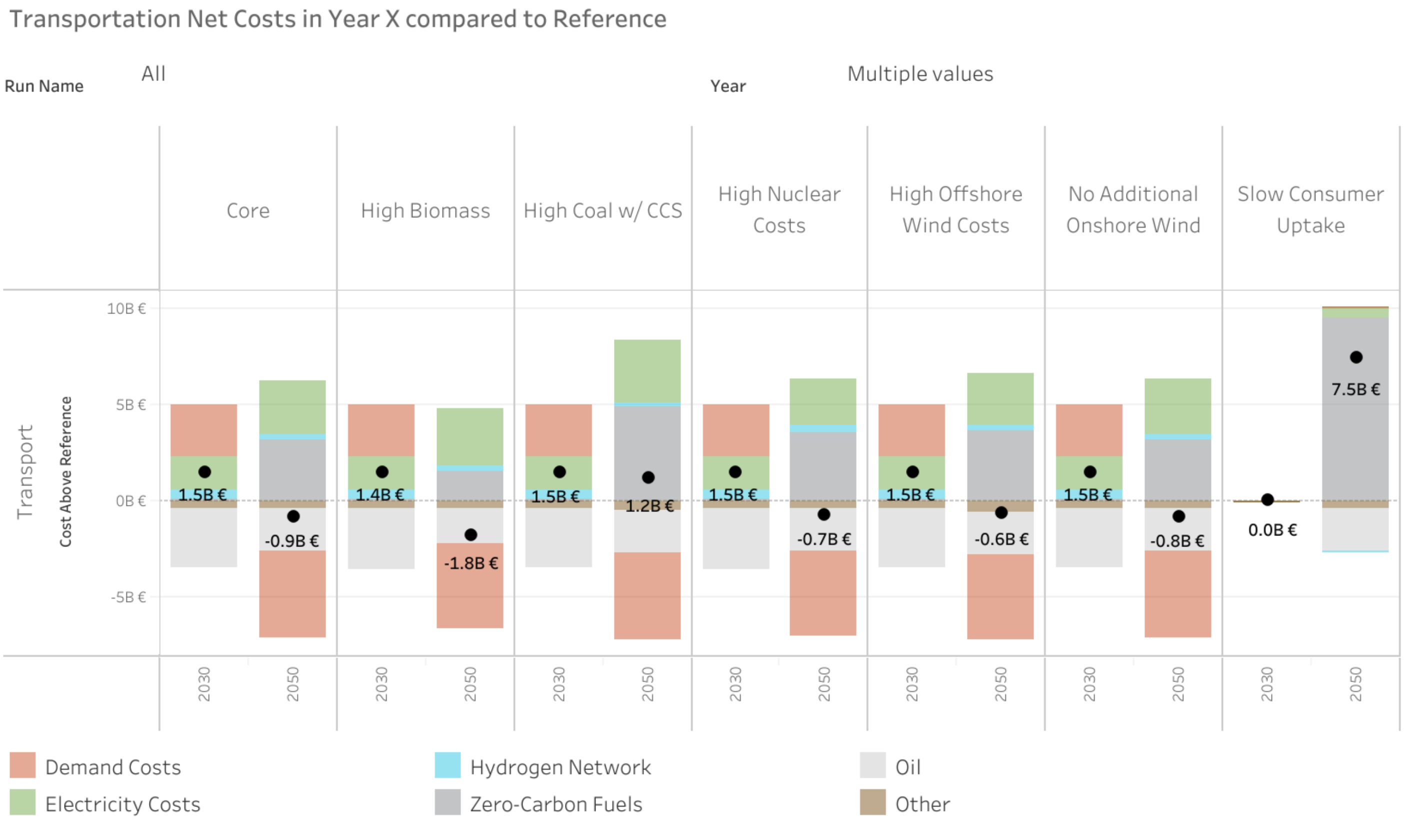
Electric Vehicles

Early and large-scale electrification, especially of the transportation sector, plays a vital role in the transition to a net-zero emissions economy. The difference between a short-term ("Core" pathway) and long-term electrification ("Slow Consumer Uptake" pathway) in transportation is a much higher price tag during a delayed transportation electrification.

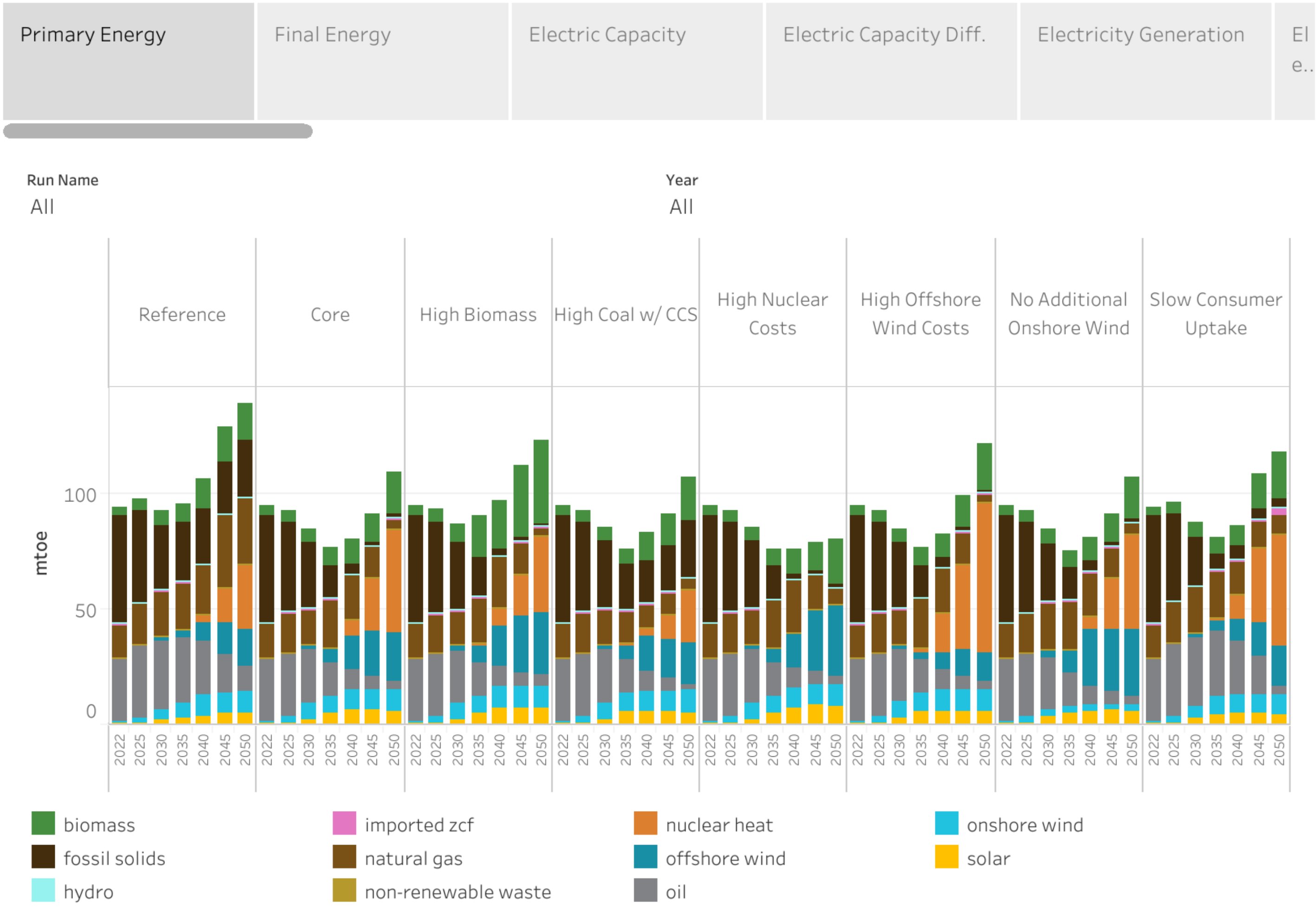
Below are the additional costs or savings by 2030 or 2050 compared to our Reference pathway that does not achieve net-zero emissions. On the one hand, slow electrification in transportation saves money in the near-term as no or little investments are made into electric vehicle infrastructure. On the other hand, slow electrification ends up costing significantly more money in the long-term because the system has little build-out of cost- and energy-efficient EV infrastructure and requires a higher dependency on expensive zero-emissions liquid fuels to achieve net-zero targets.

The electric vehicle deployment differences between the Core and Slow Consumer Uptake pathway are significant. In the most economic Core pathway, Poland will have 8.5 million passenger and 660,000 freight EVs by 2030. In the Slow Consumer Uptake pathway, only 1.9 million passenger and 220,000 freight EVs will be in Poland by 2030—a third to a quarter of the capacity of the Core pathway.

Figure 8: Transportation system costs across scenarios compared to Reference.



To explore all of our results from NZP see below the full data Tableau.



Endnotes

1. https://ourworldindata.org/energy/country/poland#how-much-of-the-country-s-energy-comes-from-renewables; Energy Institute - Statistical Review of World Energy (2023).

2. https://www.trade.gov.pl/en/news/polands-hydrogen-strategy-a-green-future/; Trade.gov.pl - January 2024.

3. https://observatory.clean-hydrogen.europa.eu/hydrogen-landscape/end-use/hydrogen-demand; European Hydrogen Observatory.