Centre for Climate
and Energy Analyses

POLAND NET-ZERO 2050

TRANSFORMATION OF THE POLISH AND EU ENERGY SECTOR UNTIL 2050

#Summary

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LIFEClimateCAKEPL

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Main conclusions:

- **The progressive decarbonisation of the Polish power sector in the 2050 perspective will lead to its complete remodeling.** The structure of power and electricity production will change completely. Wind and solar power plants will become the dominant technologies. In the scenarios assuming the implementation of the Fit for 55 package, it would be optimal to increase the share of renewable energy sources in electricity production even to approx. 50% already in 2030 and to 70% or more by 2050.
- **Not all industrial processes can be completely decarbonised. The power industry is one of the sectors of the economy where deep reduction or even obtaining negative emissions is possible.** In the neutrality scenarios in 2050, the EU-wide energy emissions balance is between -120 and -145 Mt CO_2. In the Polish energy sector alone, the negative balance is around -15 Mt CO_2 in 2050 (with differences between the scenarios at the level of 2-3 Mt CO_2).
- **The energy transformation will take place largely due to the ongoing electrification of various branches of the economy.** This is related to the increase in electricity demand in Poland from approx. 140 TWh in 2020 to 330-360 TWh in 2050 (depending on the scenario).
- In the basic scenario under consideration, assuming the implementation of the Fit for 55 package and the achievement of the net-zero target in 2050 (NEU scenario), the marginal cost of emission reduction increases to the level of approx. 145 EUR'2015 / tCO_2 in 2030 and approx. 575 EUR'2015 / tCO_2 in 2050.
- **Comparing to the entire EU, Poland will face one of the most difficult transformations. The process will be a significant challenge due to a large share of fossil fuel sources,** especially coal, in the current energy mix. Poland will need to equalize its emission intensity with EU average. This implies reducing emission intensity from approx. 0.65 tCO_2/MWh (which is 2.5-fold higher than current EU average) to close to zero.
- **The results of all scenarios also show that the fastest increase in electricity generation costs should be expected in the next decade. In the scenarios assuming the implementation of the Fit for 55 package, due to the tightening of the 2030 target, this may mean an over 2-fold increase in production costs already in the period 2020-2030.** The largest increase in costs takes place in the scenario assuming high fuel prices and limitations in the availability of natural gas - in the light of the current crisis, this scenario also seems very likely.
- The implementation of the ambitious goals of the climate policy means a slowdown in the growth of household consumption in 2020-2030 by about 0.3 p.p. On the other hand, in the following decades, the growth in consumption in the NEU and BASE scenarios is similar, and the difference in the level of consumption between the two scenarios remains constant.

Summary

1. In this study we analyse possible directions of the transformation of electricity and district heat generation sectors in Poland and in the EU. We consider scenarios that are important from the point of view of challenges lying ahead, taking into consideration risks associated with fuel market turbulences in the current geopolitical situation:
   - **The reference scenario (BASE)** that assumes 60% reduction of emissions in 2050 vs. 1990, excluding Land Use, Land Use Change and Forestry (LULUCF) sector.
   - **The neutrality scenario (NEU)** that assumes 90% reduction of emissions by 2050 vs. 1990 and net-zero emissions from all sectors, including LULUCF by the same date.
   - **The neutrality scenario with high fuel prices (NEU_HPRICE)** that assumes the same GHG reduction targets and technological potential as the NEU scenario, but assumes higher prices of fossil fuels
   - **The neutrality scenario with lower potential of offshore wind installations (NEU_LWIND)** that assumes the same GHG reduction targets but lower potential of sites suitable for the construction of offshore wind installations.
2. Changes in the power sector will have a significant influence on all sectors of the economy, including transport, heating and industry. Meanwhile, the decarbonisation process in this sectors will impact the functioning of the power system by generating additional demand for electricity, which will require increase in production.

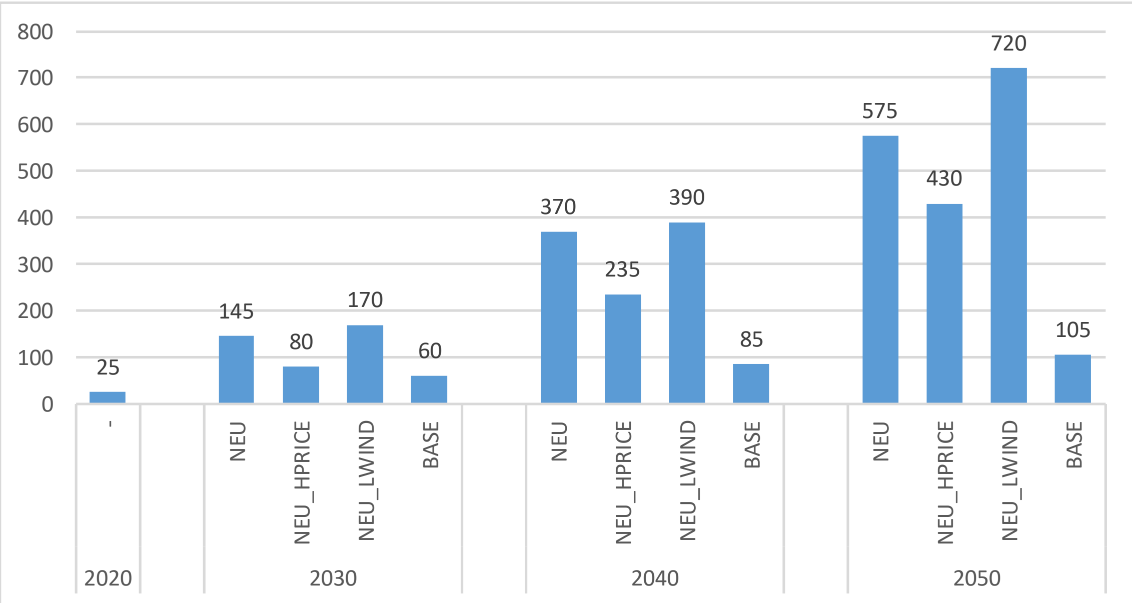
Table 1. Overview of the main modeling results for the energy sector.

		Poland 2030				Poland 2050			
		BASE	NEU	NEU_HRICE	NEU_LWIND	BASE	NEU	NEU_HRICE	NEU_LWIND
Emission reduction target [%] vs. 1990 for the EU		42	53	53	53	60	90	90	90
Marginal abatement costs in EU ETS [EUR'2015/t$CO_{2\ eq.}$]		60	145	80	170	105	575	430	720
PKB [bln EUR'2015]*		642	634	634	632	935	861	852	845
Household consumption [bln EUR'2015]*		368	355	350	354	535	523	518	518
Energy sector									
Emissions [Mt CO_2]		93	64	71	60	16	-17	-16	-14
Average costs of electricity generation [EUR'2015/MWh]		94	127	135	138	93	95	108	96
Demand level [TWh]	electricity	200	190	195	185	345	360	345	330
	district heat	84	77	77	76	77	67	64	73
	hydrogen from electrolysis	0	0	0	0	17	31	31	22

** The assumed exchange rate is 1.33 USD for 1 EUR.*
Source: CAKE/KOBiZE.

3. The realization of ambitious targets of climate policy and decarbonization of the economy leads to a deep reconstruction of Polish power sector. Modernization of the sector will be incentivised by a fast growing prices of emission allowances for the sector. In the NEU scenario that assumes realization of Fit for 55 package and net-zero targets by 2050, price of allowances for the power sector (which in the model is equal to the marginal costs of emission abatement) grows to the level of approx. 145 EUR'2015/tCO_2 in 2030 and approx. 575 EUR'2015/tCO_2 in 2050. Also in the other scenarios (NEU_HPRICE and NEU_LWIND) the projections suggest that realization of net-zero target is associated with high prices of emission allowances. Only in the BASE scenario that assumes much less ambitious reduction targets, prices of allowances do not grow significantly and reach approx. 105 EUR'2015/tCO_2 in 2050.

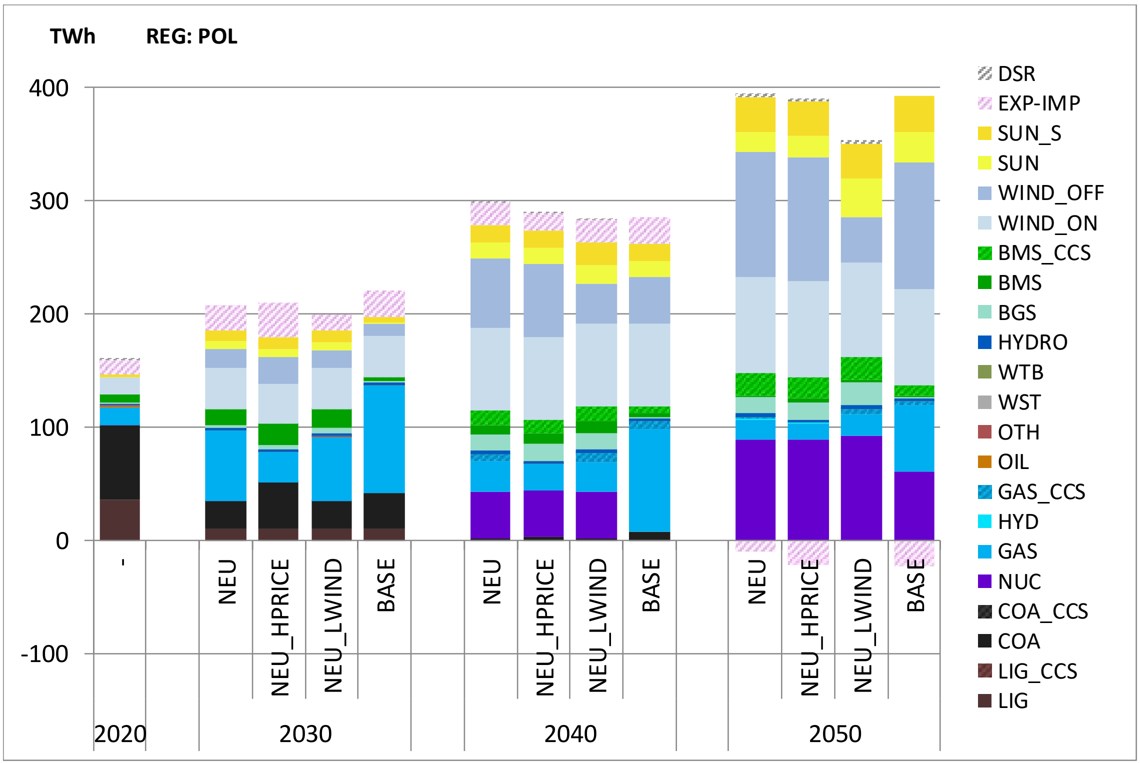
Figure 1. Marginal costs of emission reduction in the EU ETS sector - NEU, NEU_HPRICE, NEU_LWIND and BASE scenarios [EUR'2015 / tCO_2].



Source: CAKE/KOBiZE.

4. In all scenarios, in the perspective of 2050, renewable energy sources (RES) become a dominant technology. Among them, onshore wind, offshore wind and photovoltaics play the most important role. In the scenarios that assume the realization of Fit for 55 package, the modelling results suggest that the share of RES should increase to approx. 50% in 2030 and 70% in 2050 in order to minimize energy system costs. At the same time, one must note that the realization of these scenarios would require large investment effort and acceleration of the modernization. Among the considered scenarios only the BASE scenario is characterized with slower pace of RES deployment in the coming decade (30% RES share in 2030). This is intuitive given that this scenario assumes no need to meet the targets of the Fit for 55 package. Yet, even in this scenario, RES deployment accelerates in the long-run, leading to more than 65% share in electricity production in 2050, which is slightly less than the share projected in the neutrality scenarios. This shows that even with low prices of emission, RES technologies will be competitive in 2040s.

Figure 2. Electricity generation in Poland in 2020-2050 for the NEU, NEU_HPRICE, NEU_LWIND and BASE [TWh] scenarios.



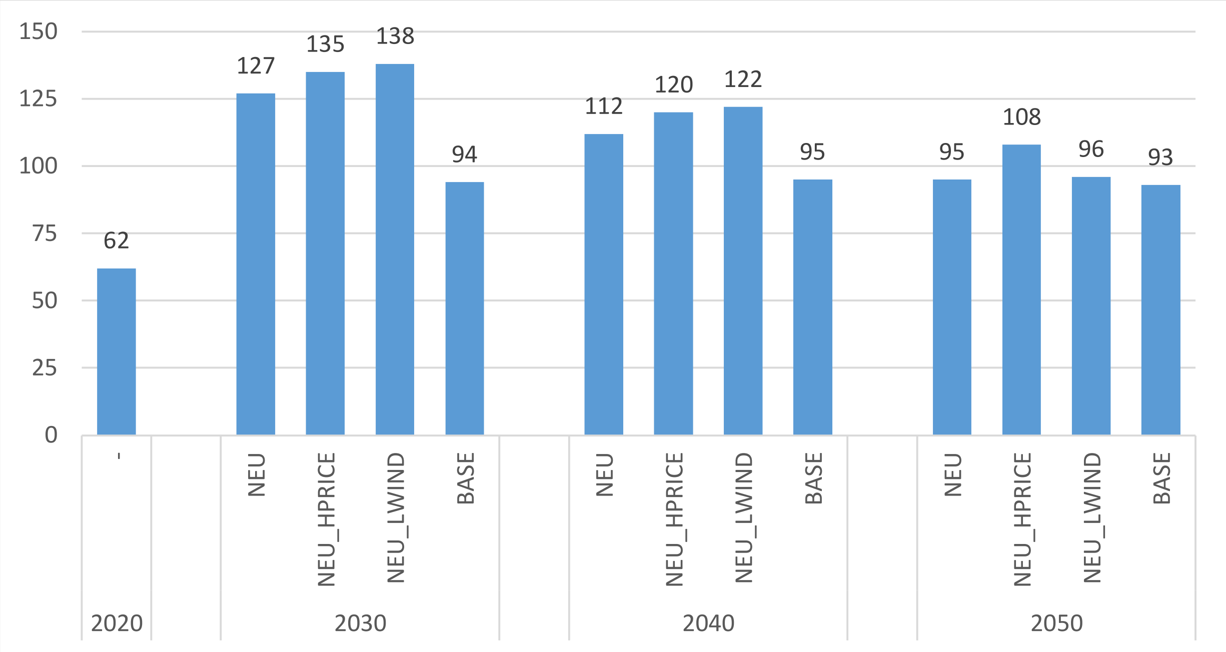
Source: CAKE/KOBiZE.

Legend:

DSR	Demand side response
EXP-IMP	Import-export balance
SUN_S	Small photovoltaic (PV) power plants (PP)
SUN	Large PV PP
WIND_OFF	Offshore wind farms
WIND_ON	Onshore wind farms
BMS_CCS	Biomass PP and combined heat and power (CHP) with carbon capture and storage (CCS)
BMS	Biomass PP and CHP
BGS	Biomass PP and CHP
HYDRO	Hydro PP
WTB	Renewable waste fuel CHP
WST	Non-Renewable waste fuel CHP
OTH	Other fuel PP and CHP
OIL	Oil PP
GAS_CCS	Gas PP and CHP with CCS
HYD	Gas PP and CHP (hydrogen use)
GAS	Gas PP and CHP
NUC	Nuclear PP
COA_CCS	Hard Coal PP and CHP with CCS
COA	Hard Coal PP and CHP
LIG_CCS	Lignite PP with CCS
LIG	Lignite PP

5. Changes in the generation structure are not limited to the deployment of intermittent RES - nuclear energy will play a major role too. Nuclear technology is one of the few sources that provide dispatchable energy supply with no GHG emissions at moderate costs. Moreover, nuclear power plants can deliver large supply of electricity at the base load complimenting intermittent RES production that, when available in excess quantities, can be utilized to produce hydrogen. Such mix allows to stabilize price of electricity and increase the availability of green hydrogen.
6. We expect a significant role played by Bioenergy with Carbon Capture and Storage (BECCS), which provides a possibility to generate net-negative emissions, and hence allows to reduce abatement pressure in sectors in which marginal abatement costs are particularly high.
7. Energy sector which is saturated with intermittent RES installations will require energy storage capacity and systems allowing for dynamic demand responses. In the periods of excess RES energy production, electrolyzers will allow to produce hydrogen, which can be used in the other industries. Hydrogen can play the role of a long-term storage facility.
8. Electric vehicles will put an additional demand pressure for the power sector, however they can also play a positive role in smoothing the load curve. To make this possible, it is necessary to deploy smart systems for charging and management of car batteries storage capacity. This is necessary to prevent cumulating load and to utilize the periods of excess electricity production.
9. Achieving ambitious CO_2 reduction goals in Poland in the entire economy will be associated with a significant increase in the electricity generation cost. In the scenarios that assume introduction of Fit for 55 package this involves doubling the costs in the period 2020-2030, due to more restrictive reduction targets. In this period substantial increase in price of emissions will translate directly into an increase in the costs of generation because coal sources will still have a significant share in the electricity production. Technical constraints for the construction of new capacity, availability of finance and other constraints implies that the reconstruction of the power sector is and will be a time-consuming process. However, this investment effort will lead to falling costs of generation after 2035. Unfortunately, this means that the largest burden of the transformation lays not in a distant future, but rather in the coming decade.

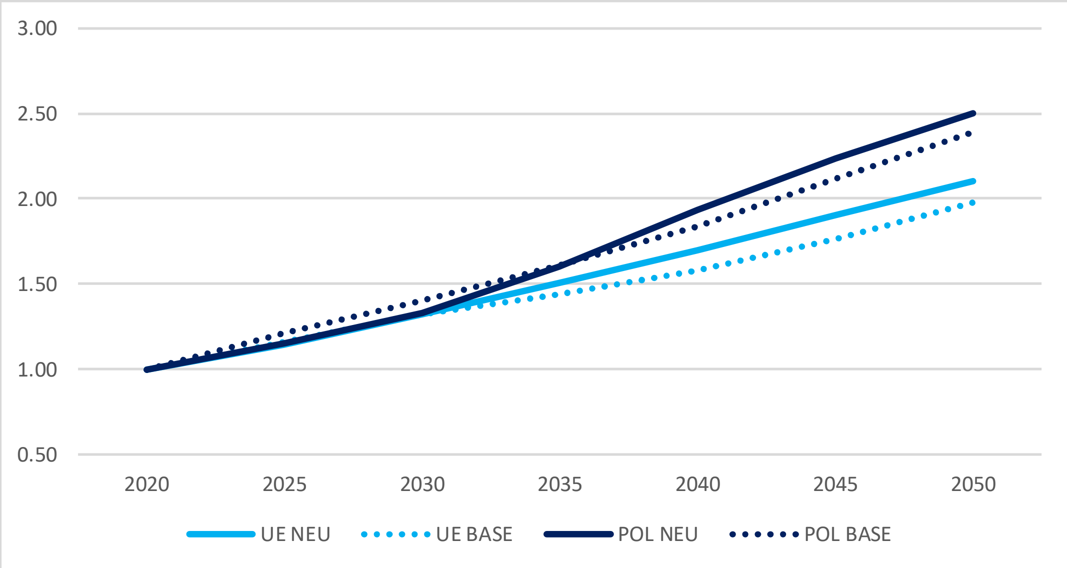
Figure 3. Average costs of electricity generation in Poland in 2020-2050 for the NEU, NEU_HPRICE, NEU_LWIND and BASE scenarios [EUR'2015 / MWh].



Source: CAKE/KOBiZE.

10. Energy transformation to a large extend will take place through advancement in electrification of various sectors of the economy. The share of electricity in final energy consumption in Poland will grow from 20% in 2020 to 40% in 2050 in the BASE scenario and to 60% in the NEU scenario. This involves a significant increase in demand for electricity from the level of 140 TWh in 2020 to 330-360 TWh in 2050, depending on the scenario. In the analysed period, average annual growth of demand in Poland is 3.1% in the NEU scenario and 2.9% in the BASE scenario. In EU, the growth rates are 2.5% in NEU and 2.4% in BASE scenario. Higher growth rate of demand in Poland comparing to the growth rate in EU can be explained with lower electricity consumption per inhabitant at the beginning of the period.

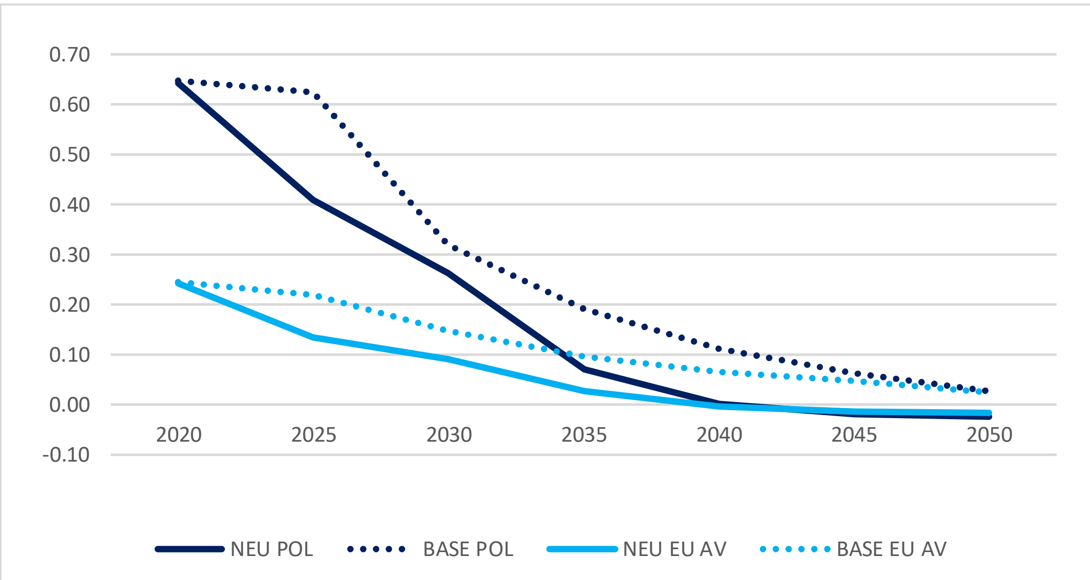
Figure 4. The dynamics of growth in electricity demand in the EU and in Poland - the NEU and BASE scenarios.



Source: CAKE/KOBiZE.

11. Comparing to the entire EU, Poland will face one of the most difficult transformations. The process will be a significant challenge due to a large share of fossil fuel sources, especially coal, in the current energy mix. In Poland and in the EU, NEU scenario implies drop of emissions from the power sector by half by 2030 comparing to 2020, emissions close to zero around 2040 and net-negative emissions (using BECCS technology) after that date. Taking into account the common reduction target in the neutrality scenarios and the interlinkages between electricity markets, Poland will need to equalize its emission intensity with EU average. This implies reducing emission intensity from approx. 0.65 tCO_2/MWh (which is 2.5-fold higher than current EU average) to close to zero.

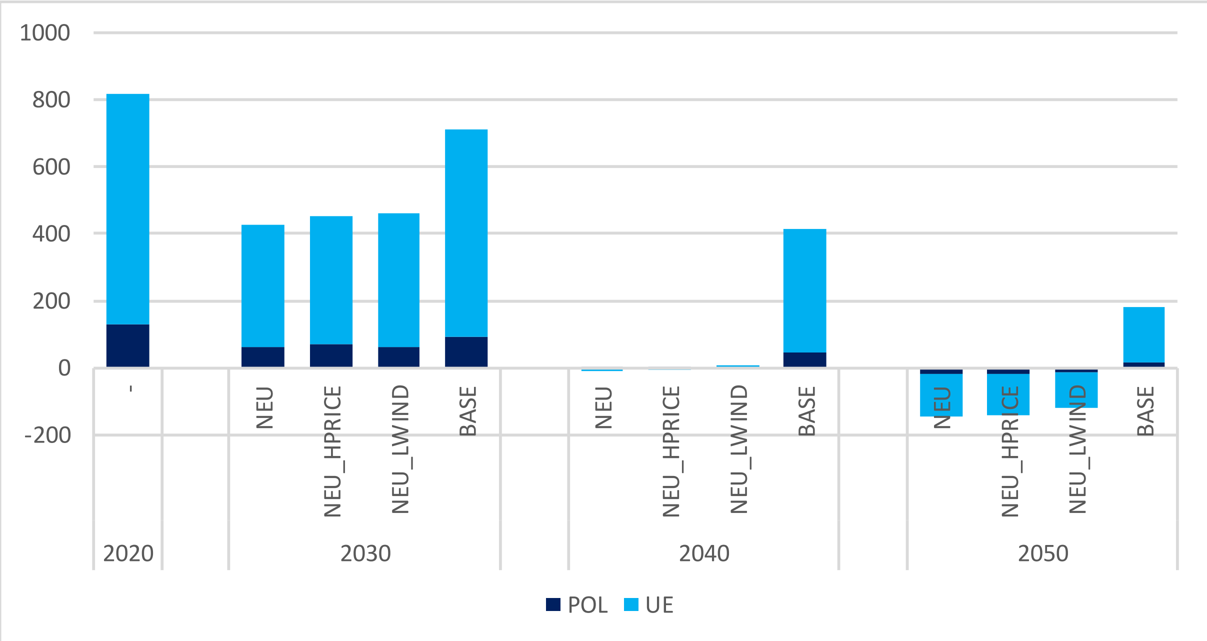
Figure 5. Average emission factors of electricity generation in the EU and in Poland - NEU and BASE scenarios [tCO_2 / MWh].



Source: CAKE/KOBiZE.

12. Achieving ambitious reduction targets that involve net-zero emission in the entire economy is challenged by the fact that not all industrial processes can be completely decarbonized. As a result it is necessary to obtain maximum emission reduction or even negative emissions in all sectors where emission abatement is possible at reasonable cost. Simulation results suggest that the power sector is one of those sectors of the economy where deep reduction and negative emissions are feasible. Achieving net-zero at the EU scale, requires not only improvement in energy efficiency but also development of wide range of technologies allowing for emission abatement – including RES, BECCS and nuclear technologies. In the neutrality scenarios emissions in the energy sector in the entire EU reaches the level between -120 and -145 Mt CO_2 in 2050. In Polish energy sector emissions should reach the level of approx. -15 Mt CO_2 w 2050 r. (with differences across scenarios a the level of 2-3 Mt CO_2).

Figure 6. CO_2 emissions in the electricity and district heat generation sector in the EU and Poland - NEU, NEU_HPRICE, NEU_LWIND and BASE [Mt CO_2] scenarios.

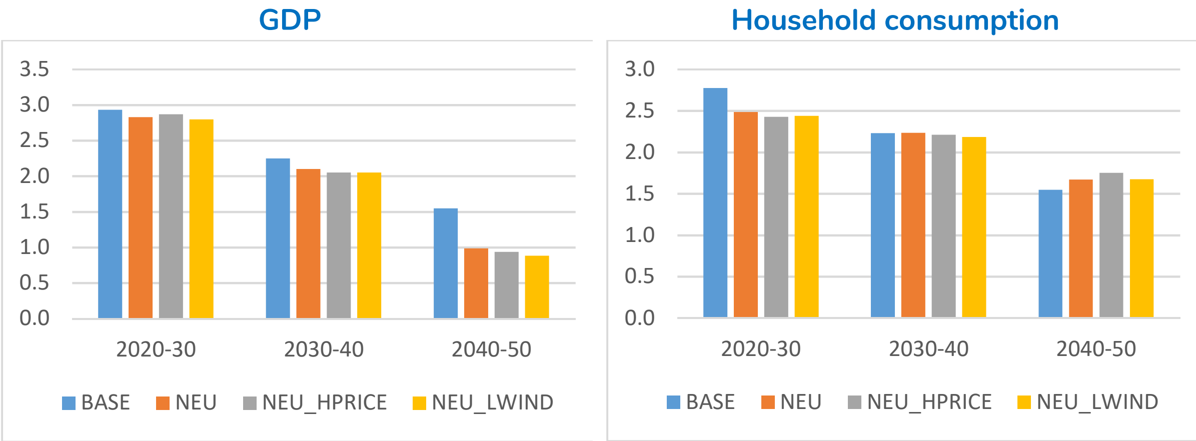


Source: CAKE/KOBiZE.

13. The transformation of the district heating sector in Poland will be difficult due to technical and financial constraints of companies. Scalable technological options that are able to deliver stable supplies of heat with no emissions include biomass, biogas and heat pumps. In the long-run, hydrogen might be used too, however it seems that the potential of this solution is limited due to high costs of this technology. Taking into account both, potential and costs of individual technologies it seems that the decarbonisation of heating sector will be mostly achieved with the deployment of heat pumps, both individual and in centralized heating systems.

14. Achieving ambitious mitigation targets will involve small deceleration of growth of households consumption in 2020s. In this period, the growth rate will be smaller by 0.3p.p in the NEU scenario comparing to the BASE scenario. In the next decades, the growth of consumption in NEU and BASE scenarios is similar and the difference in consumption between these two scenarios will stay roughly constant.
15. In the NEU_HPRICE and NEU_LWIND scenarios, the growth of consumption in 2020s will be smaller by 0.1 p.p. comparing to the growth in the NEU scenario. In the following decades, the differences in the growth rates between scenarios are negligible.

Figure 7. GDP and household consumption in Poland, average annual growth rates in %



Source: CAKE/KOBiZE.