



Centre for Climate
and Energy Analyses



POLAND NET-ZERO 2050

THE ROADMAP TOWARD ACHIEVEMENT OF THE EU CLIMATE POLICY GOALS IN POLAND BY 2050

#SUMMARY

LIFEClimateCAKEPL

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List of abbreviations

BECCS	Bioenergy with carbon capture and storage
CAKE	Centre for Climate and Energy Analyses
CAP	Common Agricultural Policy
CAP w EU ETS	Total annual quantity of allowances in the EU Emissions Trading Scheme (EU ETS)
CGE	Computable general equilibrium model
CCU	Carbon capture and utilisation
CCS	Carbon capture and storage
CO₂ eq.	Carbon dioxide equivalent
EGD, EU Green Deal	Communication from the European Union: The European Green Deal of 11 December 2019
EU	European Union
EU ETS	EU Emissions Trading Scheme
EUA	European Union Allowances allocated to the operators of stationary installations and used to account for emissions in the EU Emissions Trading Scheme (EU ETS), 1 EUA = 1 t CO ₂ eq.
GDP	Gross domestic product
GHG	Greenhouse gases
HDV	Heavy duty vehicle
KOBiZE	National Centre for Emissions Management
LDV	Light duty vehicle
MBK	Motorbike
Non-ETS	Sectors which are not covered by the EU Emissions Trading Scheme (EU ETS)

Main conclusions:

- ❖ Measures aimed at reduction of fossil fuels' use and intensification of energy generation from renewable sources are not sufficient to achieve climate neutrality targets by 2050 in the EU and Poland in particular. These measures will need to be supplemented with, among other, large scale adoption of BECCS, CCS, and CCU technologies, electrification of industry, adoption of hydrogen technologies, spread of electromobility and reduction of livestock production in agriculture.
- ❖ Transition to low-carbon (and eventually climate neutral) economy will require coordinated actions in a number of sectors. There is a need to design a strategy that could guide changes in specific sectors and to prepare financial frames that would also provide sufficient availability of capital for necessary investments. The EU decarbonisation targets are ambitious, but feasible only if low-carbon technological progress would be swift enough and if there would be an adequate access to financial resources.
- ❖ Most of emission reduction in Poland takes place in the energy sector, but the role of this sector in the overall decarbonisation effort will decrease over time. The sector will be responsible for 80% of total emission reduction by 2030 (relative to 2015) and 55% of the reduction by 2050. This implies that a large share of reduction potential in the energy sector will be utilised in the first transformation period, while the following transition will increasingly rely on costly GHG mitigation options in industry, transport and agriculture in the following period.
- ❖ Climate neutrality in 2050 will be achieved with relatively high marginal cost of emission abatement – above 400 EUR/tCO_{2 eq.} in the EU ETS and above 1,300 EUR/tCO_{2 eq.} in non-ETS sector in Poland.
- ❖ This transition requires introduction of necessary technological processes that could reduce emissions in sectors with limited abatement potentials (i.e. transport, agriculture and energy-intensive industry). This will require commitment of public and private investments. Entrepreneurs and policymakers will need to pay more attention to adoption of new technologies in these sectors.

ENERGY:

- ❖ Achieving deep emission reduction in the energy sector by 2050 will be associated with large capital costs, which – combined with increase in costs of operation – will lead to a significant increase in costs of electricity and district heat generation.
- ❖ The role of renewable energy sources in energy system will grow. Their development will be additionally stimulated by decreasing capital costs. However, growing capacity of wind and photovoltaic installations will require reserve capacity. Therefore, gas installations will remain an important element of energy system.
- ❖ Nuclear energy can significantly facilitate achieving ambitious reduction targets by providing stable energy supply at acceptable costs.

- ❖ Achieving ambitious reduction targets will be difficult without adoption of CCS technologies. Biomass installations with CCS (BECCS) will play a particularly important role due to their potential to achieve negative emission levels. Eventually, even gas installations will need to be equipped with CCS in order to meet increasingly stringent emission constraints.

TRANSPORT:

- ❖ In order to achieve climate neutrality by 2050, Poland should reduce CO₂ emission to 6.8 Mt CO₂ in passenger transport and to 6.4 Mt CO₂ in freight (60% reduction relative to 2005). Reduction in emissions will be achieved despite twofold increase in passenger activity and threefold increase in freight.
- ❖ Climate neutrality can be achieved through low-carbon transformation of the transport sector. In Poland it will embrace 21% of passenger travel in 2030 and ca. 75% in 2050 (excluding air travel).
- ❖ In 2030 21% of freight will use vehicles based on electricity or hydrogen. In 2050, this share will reach the level of ca. 65% of total freight.
- ❖ Low-carbon transition requires development of technologies for electric and hydrogen vehicles, which could lead to reduction in their prices. Cost of purchase will be reduced by 30-40% within the period of 2020-2050. The transition will require investments in infrastructure: charging stations, hydrogen fuelling stations, and electric road systems for lorries.
- ❖ Users of vehicles fuelled with oil will pay additional costs associated with combustion emissions. In case of passenger cars, this implies 30-40% increase in costs by 2050. In case of freight, the increase in costs will be twofold. It is important to implement an effective system of subsidies for zero-emission vehicles.
- ❖ By 2050 there will be a rapid increase in public transport (by ca. 150%) and rail transport (by 60%). Popularisation of these means of transport is associated with a drop in average costs per passenger-kilometre and tonne-kilometre.
- ❖ Demand for electricity for electrification of road transport will be on the level of ca. 5 TWh in 2030 and 50 TWh in 2050.
- ❖ Demand for hydrogen in transport will grow substantially after 2035 and could reach 40 kt in 2040 and almost 280 kt in 2050.

AGRICULTURE:

- ❖ Significant reduction in emissions cannot be achieved by reducing emission intensity only - it requires reducing the volume of production, particularly livestock.
- ❖ In response to reduction in supply of livestock, their prices will grow significantly. In case of cattle, price will increase fivefold between 2015 and 2050. In the same period, price of pork will increase twofold.
- ❖ Increase in prices of crops, with an exception of potatoes and beetroots, will be smaller than 20% in the period 2015-2020.

- ❖ In the scenario where farmers must pay price for emissions equal to other non-ETS sectors, introducing of ambitious emission reduction targets will lead to significant drop in farms' income, threatening their existence. Introducing emission limits would have smaller negative impact on income while achieving the same impact on emission reductions.
- ❖ Further reduction of emissions within farms could be achieved through afforestation of agricultural land, restoration of peatlands to their natural state, implementing activities that increase sequestration of organic carbon in the soil (e.g. cultivation of green manure crops or conversion of arable land to grassland). However, these activities must be adapted to local conditions.

Summary

- In this report, options of transition toward climate neutral economy in Poland in accordance with the climate policy goals set in the European Green Deal were analysed. An attempt to assess necessary transformations in all sectors of the economy was made, paying particular attention to three sectors: energy, transport and agriculture.
- In the analysis three basic scenarios for different EU climate policy targets were considered:
 - ▶ **Baseline scenario (BAU)** assuming 60% emission reduction by 2050 (relative to 1990), excluding the LULUCF sector.
 - ▶ **Reference scenario (REF)** assuming 80% reduction by 2050 (relative to 1990), excluding the LULUCF sector.
 - ▶ **Neutrality scenario (NEU)** assuming 90% reduction by 2050 (relative to 1990) and achievement of net-zero emission levels by inclusion of the LULUCF sector and using technologies to remove GHG emissions from the atmosphere (e.g. BECCS).
- The data in Table 1 presents main results of the analysis – a summary of transition pathways toward low-carbon economy in Poland. Energy sector and energy-intensive sectors included in the EU ETS will play the key role in the transformation. In addition, the report presents detailed information on the directions of development and the volumes of expected GHG emission reductions in transport and agriculture, which currently are accounted in the non-ETS sector.

Table 1. Transition pathways toward low-carbon economy in Poland – summary of results

		Poland 2030			Poland 2050		
		BAU	REF	NEU	BAU	REF	NEU
Emission reductions [%]	Total (vs. 1990)	42	42	53	60	80	90
	EU ETS (vs. 2005)	48	48	60	69	83	93
	non-ETS (vs. 2005)	7	7	18	31	62	73
Marginal emission abatement costs [EUR/tCO ₂ eq.]	EU ETS	40	40	100	100	200	400
	non-ETS	50	50	120	110	600	1300
GDP [billion USD'14] / [billion EUR'14]*		849 /638*	847 /637*	840 /632*	1218 /916*	1201 /903*	1151 /865*
Consumption of households [billion USD'14] / [billion EUR'14]*		485 /365*	485 /365*	478 /359*	720 /541*	714 /537*	700 /526*
Energy sector							
Emissions [Mt CO ₂]		87	87	54	16	-11	-20
Dynamics of average costs of electricity generation [1=100%]		1.45	1.45	1.82	1.58	1.58	1.57
Level of demand [TWh]	electricity	175	178	158	259	307	303
	district heat	69	69	63	59	54	52

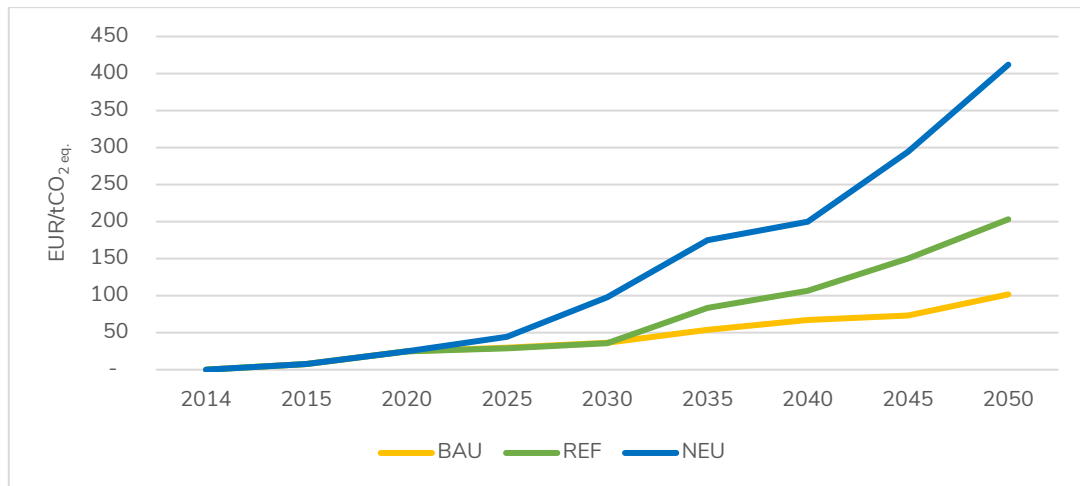
		Poland 2030			Poland 2050		
		BAU	REF	NEU	BAU	REF	NEU
	hydrogen from electrolysis	0	0	0	3.5	10	11
Transport sector							
Emissions [Mt CO ₂]		55	53	52	46	23	16
Electricity demand [TWh]	passenger transport	1.7	3.7	3.9	9.7	23.5	24.6
	freight transport	0.2	0.3	0.4	4.1	18.2	25.0
Number of electric passenger cars [million units]		1.0	2.3	2.4	5.2	13.4	14.0
Agriculture sector							
Emissions [Mt CO ₂ eq.]		26	26	22	20	10	8
Prices of agricultural products [2015 = 100%]		101.7	101.1	108.7	105.2	152.8	219.1
Changes in the structure of production [2015 = 100%]	crops	100.2	100.7	95.9	95.0	81.2	79.6
	livestock	94.0	94.9	85.9	88.2	57.4	39.9

Note: at the EUR/USD exchange rate of 1.33.

Source: CAKE/KOBiZE.

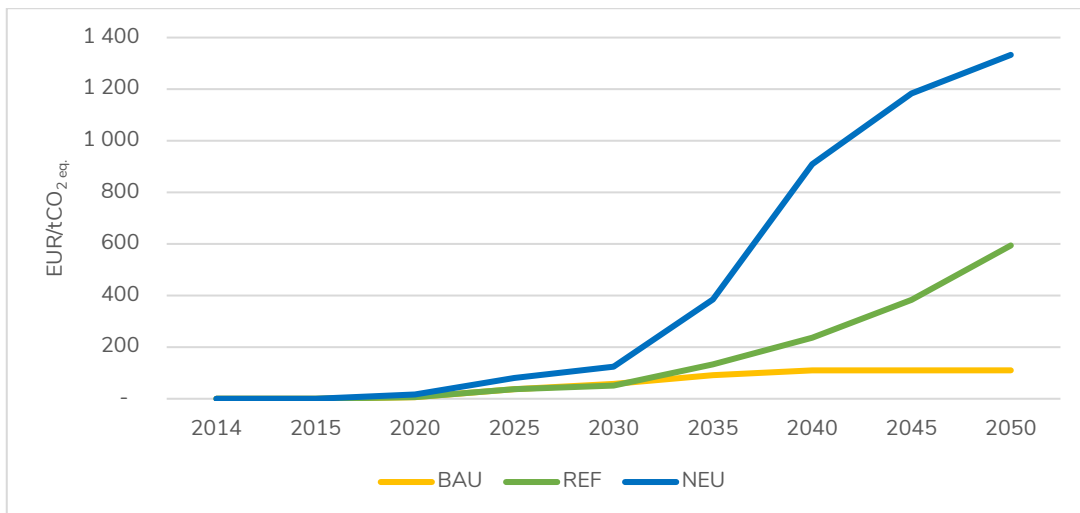
- The cost of emission reductions represents a price signal to sectors in both the EU ETS and non-ETS, making it cost-effective to implement various technologies contributing to the low-carbon economy transformation. The BAU, REF and NEU scenarios do not differ in the availability of technologies or their costs, so the choice of a specific solution depends only on the price impulse, and the latter – on the assumed reduction target. Visualisation (Fig. 1 and 2) shows the marginal costs of emission reductions in the EU ETS and non-ETS sectors in Poland in EUR/tCO₂ eq.. Simulations suggest that more ambitious climate scenarios (NEU) will be associated with an increase in marginal emission abatement costs, which in 2030 will reach ca. 100 EUR/tCO₂ eq. in the EU ETS and ca. 120 EUR/tCO₂ eq. in the non-ETS sectors in Poland.

Fig. 1. Marginal costs of emission reductions in the EU ETS sector in Poland [in EUR/tCO₂ eq.]



Source: CAKE/KOBiZE.

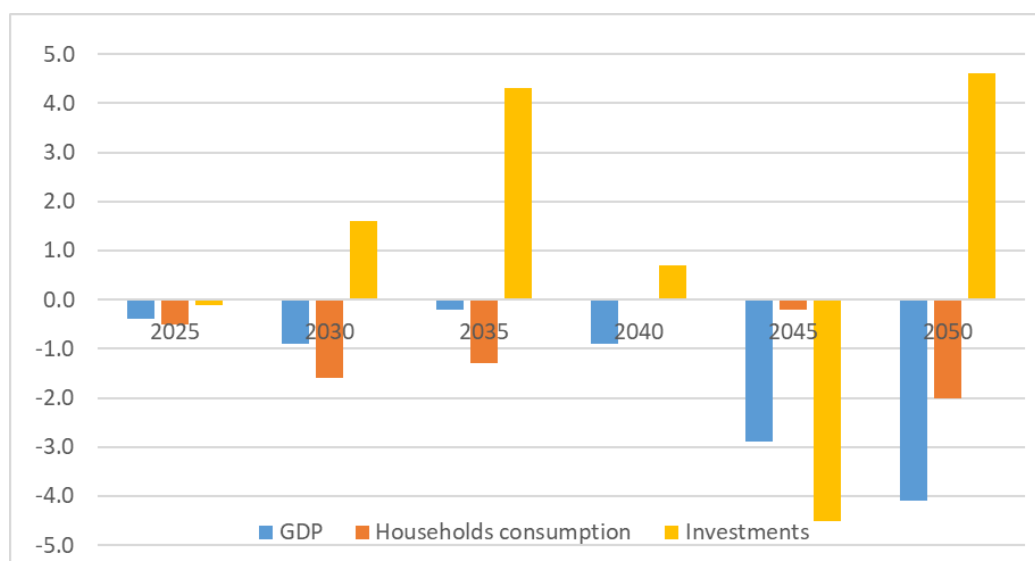
Fig. 2. Marginal costs of emission reductions in the non-ETS sector in Poland [in EUR/tCO₂ eq.]



Source: CAKE/KOBiZE.

5. Tightening of the GHG emission reduction target is associated with a significant increase in aggregate investments in Poland in 2030-2040, resulting from the need to purchase and implement low-emission technologies, especially in the energy sector. The need to finance investments also leads to a decline in consumption over the same period. In the years 2040-2050, a significant decrease in GDP can also be expected, which results, among other, from the need to use more capital-intensive production methods. Fig. 3 shows the differences in GDP, consumption and investments between the NEU and REF scenarios for Poland through 2020-2050.

Fig. 3. Differences in GDP, consumption and investments between the NEU and REF scenarios for Poland in 2020-2050 [in %]

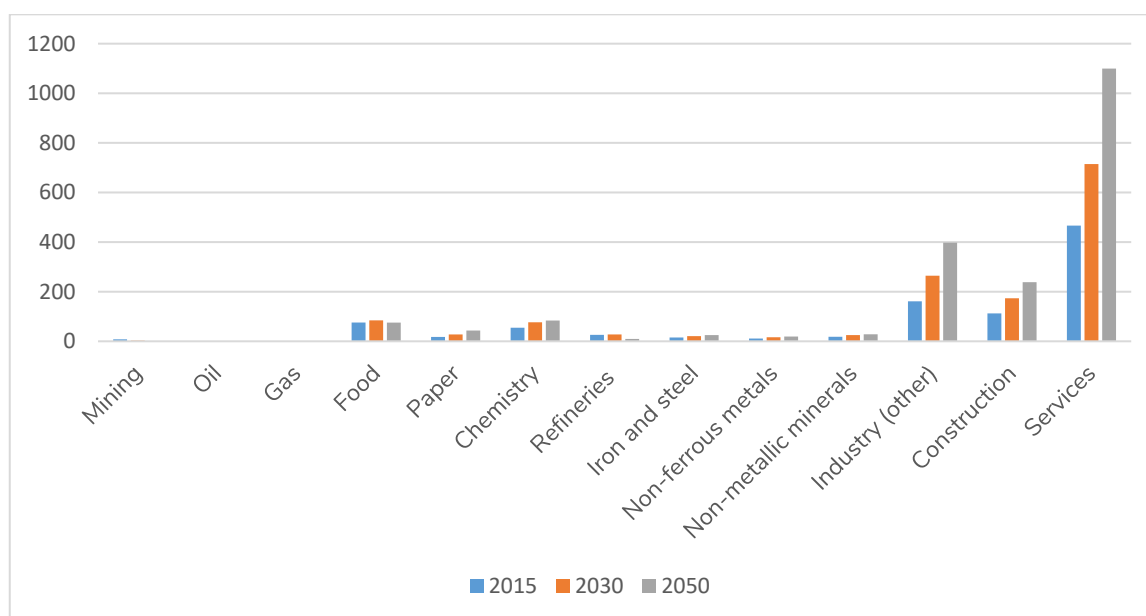


Source: CAKE/KOBiZE.

6. The costs of increasing climate ambitions are reflected through the differences of real household consumption between the scenarios. In the REF scenario, the cumulative consumption of households in the timeframe of 2021-2050 will decrease for Poland relative to BAU by 116 billion USD'14 (87 billion EUR'14). On the other hand, in the NEU scenario, the decrease in consumption relative to BAU is ca. 249 billion USD'14 (or 188 billion EUR'14) in the period of 2021-2050. Consumption drops will be caused, inter alia, by declines in competitiveness of the economy and increased investment needs (for instance, in the energy sector). Commercialisation of technologies that reduce emissions in hard-to-mitigate sectors will require commitment to public and private investments. Entrepreneurs and policymakers will need to pay more attention to adoption of new technologies in these sectors.
7. Industrial sector is a specific sector of the economy in the context of reducing emissions. Therefore, a large part of the reduction measures has already been carried out, and it is difficult to find one simple technology that would be the solution for all installations, as the energy-intensive sectors are highly diverse. Implementation of more ambitious emission reduction targets significantly changes the structure of industrial production. The largest drops in production relative to the BAU scenario occur in the mining and gas distribution sectors and in the energy-intensive industries, which have difficulty in reducing process emissions (e.g. chemical production, refining, iron and steel production, production of non-ferrous metals and non-metallic minerals, including cement). Declines in energy-intensive production in Poland in 2030 in the NEU scenario, compared to the BAU scenario, should reach somewhere between 5% and 10%, while in 2050 they could be at the level of 20-30%. Fig. 4 shows volumes of industrial production in Poland in 2015, 2030 and 2050 for the NEU

scenario (in billion USD'14). Most growth is visible in the low-emission sectors, such as services, as it grows over twofold in 2050 compared to 2015.

Fig. 4. Volumes of industrial production in Poland in 2015, 2030 and 2050 for the NEU scenario [in billion USD'14]

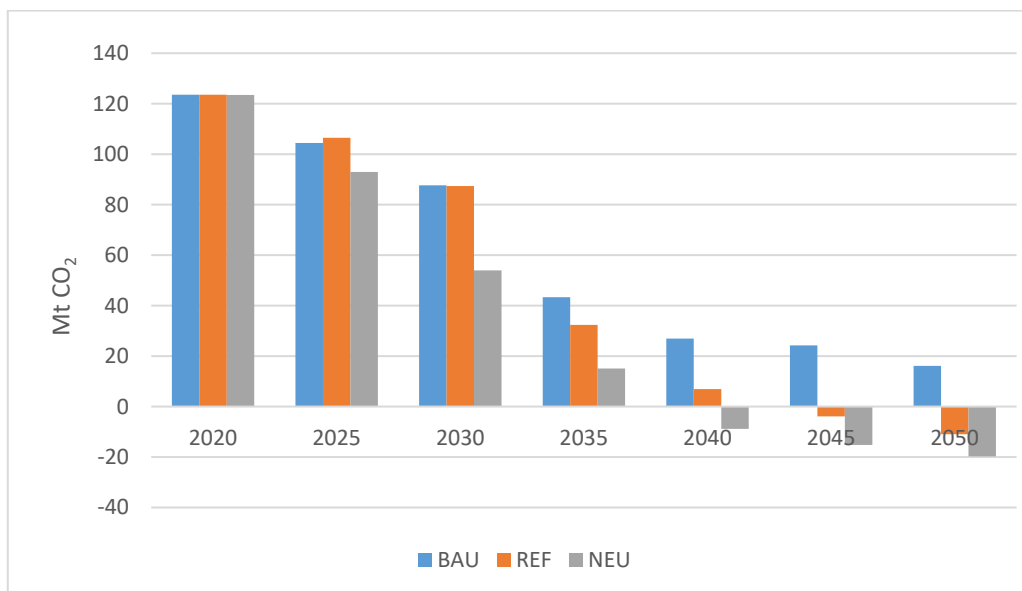


Source: CAKE/KOBiZE.

8. In both REF and NEU scenarios, simulations show a decline in coal demand, especially in the next 15 years. In the REF scenario, this demand drops by 70% in the period between 2020 and 2035 (from 2,168 PJ to 637 PJ) and by almost 89% in the period of 2020-2050 (to 254 PJ). In the NEU scenario, higher reduction targets and, consequently, higher emission allowance prices force even faster decarbonisation and decrease in demand for coal – by 77% in the period of 2020-2030 (to 493 PJ) and by 92% in the period of 2020-2050 (up to 171 PJ).
9. Energy sector is characterised with low costs of emission reduction relative to other sectors, therefore emission reduction will be the most significant in this sector (Fig. 5). However, overall we expect large capital costs in the sector due to the large scale of changes. This in turn will result in an increase in the costs of electricity generation. By 2050, the costs of electricity generation will increase by ca. 60% in all analysed scenarios. However, their dynamics differ over time - in the NEU scenario, the greatest increase in costs (even by about 80%) takes place until 2030. The reason is the tightening of the reduction target for 2030. In the following years, due to declining investment outlays in renewable energy sources and decreasing emissivity of energy production, the energy system becomes less sensitive to the costs of CO₂ emission allowances, and the average costs of electricity generation in the NEU scenario slightly decrease.

10. Transformation of the energy sector in Poland involves significant investment costs. In the NEU scenario, the total expenditure in the energy sector in the period 2021-2050 will be at the level of ca. 295 billion EUR. These expenditures are almost 60% higher than in the BAU scenario (ca. 185 billion EUR). It must be emphasised that the energy sector capital costs reported in this study include only investments in new generation units (including those that reserve capacity) and energy storage. They do not include expenditure related to the expansion and modernisation of the transmission and distribution network (both electricity and heating), or the modernisation of existing generation units. Thus, the full investment costs in the energy sector necessary for the implementation of the low-emission transformation are likely to be under-reported.

Fig. 5. CO₂ emissions in the energy sector of Poland for the BAU, REF and NEU scenarios [in Mt CO₂]

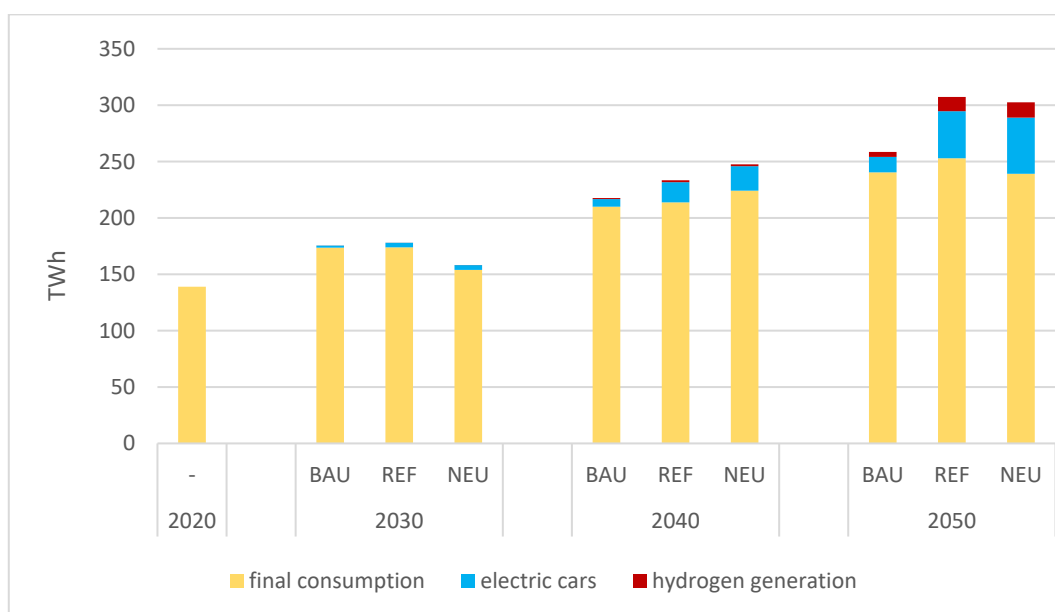


Source: CAKE/KOBiZE.

11. The energy demand projections are different in each scenario (Fig. 6). In NEU ambitious reduction targets lead to rapid increase of emission and energy prices. This creates an incentive for energy saving and investment in more efficient technologies. Also energy demand in energy intensive industry will decrease significantly. This effect will be most noticeable by 2030 in NEO scenario, as a result of tightened reduction target compared to other scenarios. This effect is even stronger, because by 2030 it will only be slightly mitigated by changes in the energy mix. High emission prices will directly affect electricity prices, since there will still be many emission intensive energy sources in the system. However, In the long term, greater share of renewables and other low emission energy units will ease the pace of electricity cost increases. Overall electricity demand will grow due to increased electricity consumption in transport, industry, house heating.

12. In order to achieve climate neutrality, Poland should reduce CO₂ emissions in transport by ca. 60% by 2050 relative to 2005 (Table 2). Additional reductions will be achieved by the development of electromobility (the number of electric cars in the NEU scenario in 2050 will equal 14 million units), an increase in the use of public transport will take place, and - in the case of freight transport - through electrification and use of hydrogen.

Fig. 6. Projections of net electricity demand in Poland - BAU, REF and NEU scenarios [in TWh]



Source: CAKE/KOBiZE.

Table 2. Changes in CO₂ emissions in the road transport sector of Poland in 2030 and 2050 by scenarios

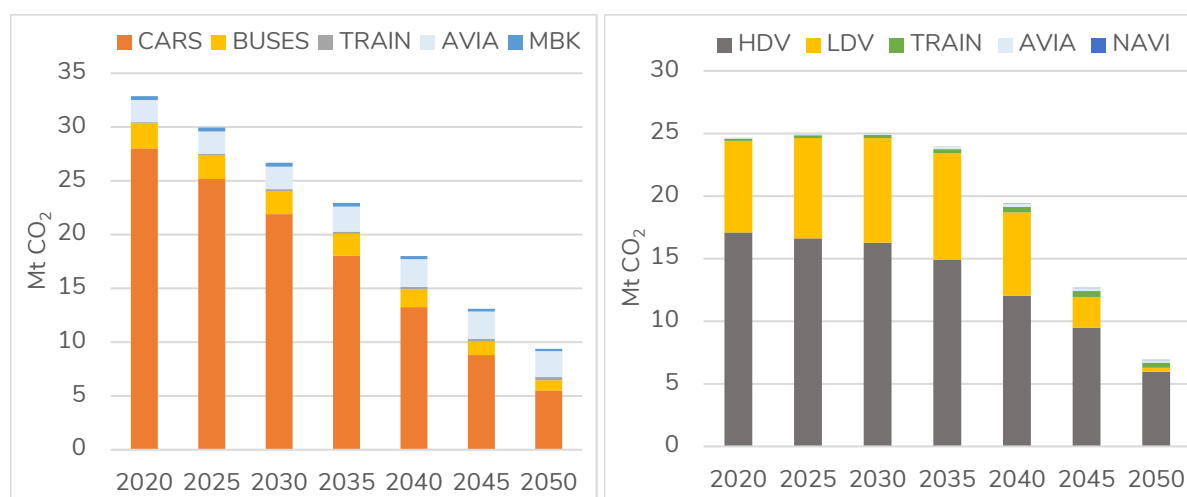
	2030			2050		
	BAU	REF	NEU	BAU	REF	NEU
Emission in the road transport [Mt CO ₂]	52.0	50.6	49.5	39.3	20.2	13.7
Changes of CO ₂ emission in the road transport relative to 2005	52%	48%	44%	15%	-41%	-60%

Source: CAKE/KOBiZE.

13. The impact of structural transformations on the emission changes will reach the reduction of ca. 41 Mt of CO₂, while due to the emission intensity changes the reduction will reach 17 Mt, thus balancing the increase of emissions caused by the growing need for transport services. In road passenger transport, due to the electrification of the passenger car fleet, emissions from their use would fall to 5.5 Mt CO₂ in 2050. Emissions from buses will decrease from ca. 2.5 Mt CO₂ in 2020 to around 1 Mt CO₂ in 2050 as a result of both electrification and road-to-rail passenger shift. In order to achieve climate neutrality in 2050, a major transformation

of freight transport is necessary. In the NEU scenario, light duty vehicles (LDV) are 100% electrified. Due to electrification and hydrogenation of heavy duty vehicles (HDV) emissions will be reduced threefold by 2050 to ca. 6 Mt CO₂.

Fig. 7. CO₂ emissions in passenger and freight transport in Poland by activity type (NEU scenario) [in Mt CO₂]



Source: CAKE/KOBiZE.

14. In the NEU scenario in 2050, the demand for electricity will be at the level of 50 TWh, which will constitute an increase over 20% from nearly 240 TWh (in the energy system). Total hydrogen demand in the transport sector will reach ca. 280 kt, of which 53 kt for passenger and 225 kt for freight transport (Table 3).

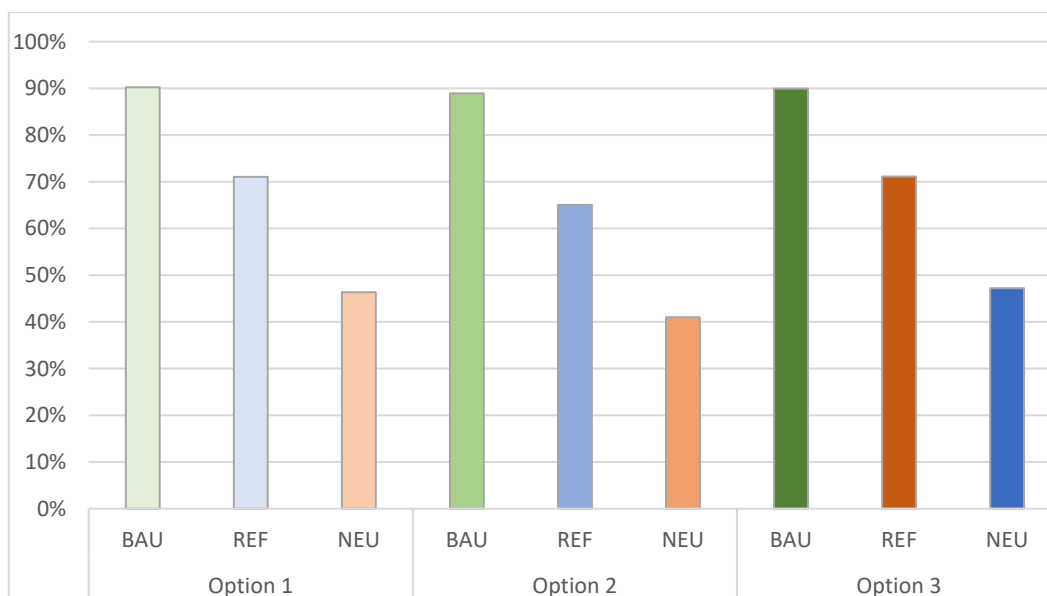
Table 3. Road transport demand for electricity and hydrogen in Poland in 2030 and 2050 by scenarios

		2030			2050		
		BAU	REF	NEU	BAU	REF	NEU
Electricity use [TWh]	passanger transport	1.7	3.7	3.9	9.7	23.5	24.6
	freight transport	0.2	0.3	0.4	4.1	18.2	25.0
Hydrogen use [kt]	passanger transport	0	0	0	19.4	51.7	52.7
	freight transport	0	0	0	77.6	227.4	225.2

Source: CAKE/KOBiZE.

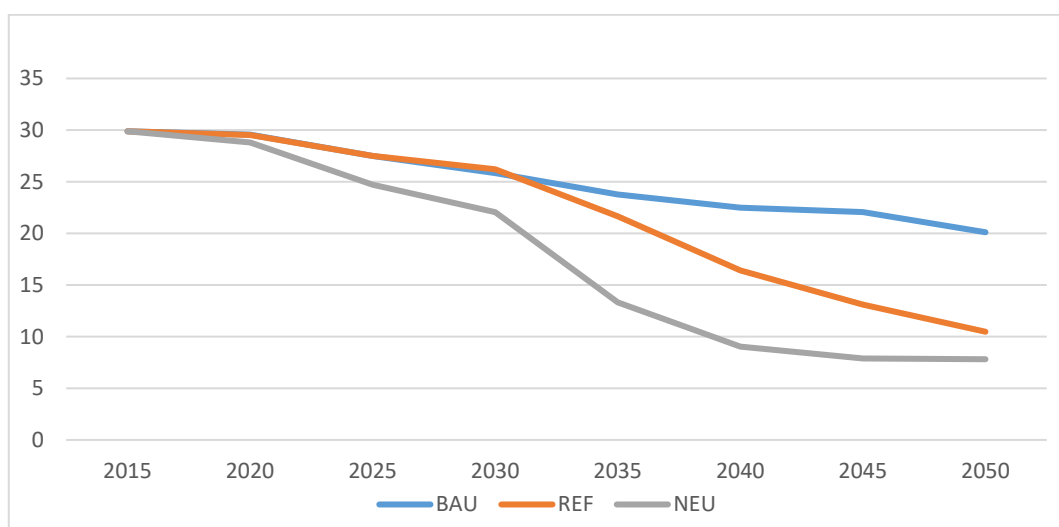
15. The size of hydrogen production and storage is primarily driven by demand in the transport and industrial sectors. For obvious reasons, hydrogen plays a more significant role in the neutrality scenario than in less ambitious scenarios. The use of hydrogen is particularly important for freight in 2050. If we assume that the reduction target in the non-ETS for Poland will be higher than that assumed in the NEU scenario, demand for hydrogen will increase even more. For this reason, hydrogen storage should become part of the infrastructure development in the transport sector. In the energy sector, the use of hydrogen as a storage facility, i.e. for the re-production of electricity, strongly depends on the configuration of the entire energy system. The key factor is the availability of surplus energy produced from RES in the low energy demand bands. The excess energy can be used to generate and store hydrogen. However, with the assumed scale of RES development and a large scale adoption of electric cars (partially fulfilling a function similar to energy storage), electricity surplus will probably not be sufficient to justify a wider deployment of hydrogen storage. If the deployment of intermittent RES was larger, the role of hydrogen would increase. However, a higher rate of RES development is unlikely both due to the scale of required investments and due to the requirement regarding development of the transmission and distribution network.
16. Potential changes in the agricultural sector have been analysed within three approaches: Option 1 – Emission payments (assuming implementation of GHG emission payments equal to those in other non-ETS sector, payable by farms); Option 2 – Emission limits (imposing an emission target for agricultural sector); and Option 3 – Subsidies (reduction of GHG emissions will be achieved through the implementation of a system compensating reduction efforts at farm level).
17. Implementation of “Option 1 – Emission payments” will lead to deep losses of farm production outputs (Fig. 8) and thus threaten the food security of the country. This is especially relevant in case of the REF and NEU scenarios. The “Option 2 – Emission limits” leads to reduction of GHG emissions with less drastic deterioration of the economic situation of farms. However, it may result in less optimal allocation of production from the point of view of emission efficiency. Utilisation of “Option 3 – Subsidies” is a costly measure in case of ambitious emission reduction scenarios. The level of subsidies expected to be offered to farmers for voluntarily giving up parts of their production to reduce GHG emissions to the level required in the NEU scenario would exceed the current level of subsidies within the CAP by several times. Feasibility of such option is thus uncertain in terms of available budgets.
18. Reduction of emissions in agriculture (Fig. 9) in the NEU scenario by 2050 may amount to as much as 65% compared to 2005 depending on the measures applied. The reduction of emissions causes both changes in the size of agricultural production and its structure. The greatest decrease in the volume of production is observed in livestock, in particular cattle.

Fig. 8. Agricultural production volumes in Poland in 2050 for the BAU, REF and NEU scenarios [in %, 2015=100%]



Source: CAKE/KOBiZE.

Fig. 9. GHG emissions from agriculture in Poland for the BAU, REF and NEU scenarios [in Mt CO₂ eq.]



Source: CAKE/KOBiZE.

19. Taking into account the results obtained, it seems that the most reasonable solution would be a hybrid model assuming simultaneous implementation of GHG emission limits and limited farm income support instruments, which combined would facilitate the transformation of farms towards lower GHG emissions while maintaining their economic viability. It is also recommended to deeply analyse options related to afforestation of agricultural land, restoration of peatlands to their natural state, and implementing activities that increase

sequestration of organic carbon in the soil (e.g. cultivation of green manure crops or conversion of arable land to grassland). Such activities will have positive effects on the reduction GHG emissions, while not having disruptive impact on agricultural production structure and volumes.

20. Overall, climate neutrality by 2050 requires moving away from coal-based fuels and adopting renewable energy sources. Additionally, it requires a large-scale adoption of BECCS, CCS and CCU technologies, increase in use of hydrogen, spread of electromobility and reduction of livestock production in the agricultural sector. Transition to low-carbon (and eventually climate neutral) economy will require coordinated actions in a number of sectors. There is a need to design a strategy that could guide changes in specific sectors and to prepare financial frames that would also provide sufficient availability of capital for necessary investments. The EU decarbonisation targets are ambitious, but feasible only if low-carbon technological progress would be swift enough and if there would be an adequate access to financial resources.