

ENERGY AND CLIMATE POLICY (ECP) SCENARIO

Impact assessment of policies and measures

Annex 2 to the ***National Energy and Climate Plan for 2021-2030***

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Introduction

This document is the second analytical annex to the National Energy and Climate Plan for 2021-2030 (NECP).

It presents an **Energy and Climate Policy (ECP) Scenario** containing an analysis (assessment) of the impacts of policies and measures, demonstrating how and with what effect the objectives will be achieved in the five dimensions of the Energy Union, including the 'climate and energy targets'.

The document contains comparisons to the Reference Scenario (REF), i.e. an analysis of the impacts of the PaMs (policies and measures) that existed until the end of 2017 (business as usual) – Annex 1 to the NECP. Both documents present a multi-faceted analysis of the impacts of implementation by 2030, with an outlook for 2040.

The document also implements the conclusions drawn from comments submitted during the public consultation process between 15 January and 18 February 2019, as well as the conclusions of the European Commission recommendations of 18 June 2019 to the NECP, which had been received by all EU Member States.

The structure of the document reflects the five dimensions of the Energy Union – energy security, the internal energy market, energy efficiency, decarbonisation, and research, innovation and competitiveness.

The content and the scope of information presented correspond to the guidelines set out in Regulation (EU) 2018/1999 of the European Parliament and of the Council of 11 December 2018 on the Governance of the Energy Union and Climate Action, amending Regulations (EC) No 663/2009 and (EC) No 715/2009 of the European Parliament and of the Council, Directives 94/22/EC, 98/70/EC, 2009/31/EC, 2009/73/EC, 2010/31/EU, 2012/27/EU and 2013/30/EU of the European Parliament and of the Council, Council Directives 2009/119/EC and (EU) 2015/652 and repealing Regulation (EU) No 525/2013 of the European Parliament and of the Council.

In line with the guidelines, statistical data is presented for the years 2005, 2010 and 2015, while the forecasts span five-year periods to 2030, with an outlook for 2040. In accordance with the Commission Recommendation, the document presents the trajectory of the share of renewable energy in gross inland final energy consumption and for the power, heating and cooling and transport sectors by year for the 2021-2030 timespan. Some trajectories for the decarbonisation and energy efficiency are also broken down by year.

Statistical data from the EUROSTAT database for historical periods has been modified in line with the update made by the EUROSTAT on 24 April 2019. Therefore, the statistical data provided for 2005, 2010 and 2015 differ from the data presented in the REF scenario.

5. IMPACT ASSESSMENT OF POLICIES AND MEASURES

5.1. Impacts of planned policies and measures on the energy system and GHG emissions and removals

This document presents the results of analyses and forecasts aimed at determining the future situation of the fuel and energy sector for conditions determined by economic and environmental requirements and resource constraints, taking into account the planned PaMs described in the previous section. The analysis covers all sectors of the national economy, as well as the currently used and prospective energy carriers across the supply chain. The results of forecasts are compared for the two scenarios: the Energy and Climate Policy (ECP) and REF. The purpose of the comparisons is to assess the impact of the parameters that underlie the differences between these scenarios and to identify the interactions between existing and planned policies and measures within the five dimensions of the Energy Union.

The calculation methods used are based on methodologies commonly used worldwide for preparing sectoral analyses and forecasts that take into account economic developments and that can be used for drafting and analysing scenarios and variants for the development of the energy sector to the extent that allows analysing:

- the impacts of changes in the energy sector on the country's economy,
- changes in the electricity production mix as a result of changes in external factors and regulations (global energy trends, international fuel prices, prices of ETS emission allowances, changes in technology costs, macroeconomic indicators, cost of raising capital for investments), as well as changes in internal factors and legislation,
- the share of energy produced from renewable energy sources in gross final consumption and by sector (heating and cooling, electricity, transport), broken down into individual RES technologies, taking into account the technical and economic potential, availability of resources, capital expenditure and operating costs, existing and planned support schemes, and solutions designed to improve the flexibility of the system,
- changes in the volume of carbon dioxide emissions across the economy and in individual sectors (taking into account the potential for recovery), the situation in the heating and cooling sector, in particular as regards the development of cogeneration and renewable sources,
- movement in electricity prices on the wholesale and retail markets as a result of developments in the electricity sector and external factors,
- changes in final energy demand under the influence of independent variables (including GDP growth and value added in sectors, changes in the manufacture of energy-intensive products),
- potential primary and final energy savings by sector of the economy, as well as developments on the natural gas market,
- changes in the use of fuel, including for electricity and heating generation purposes,
- developments on the liquid fuels market, taking into account trends in the transport sector, including the growing importance of electromobility.

The following basic models are used for analysing the fuel and energy economy:

1. The STEAM_PL (Set of Tools for Energy Demand Analysis and Modelling) simulation model for forecasting final energy demand
2. The MESSAGE (Model for Energy Supply Strategy Alternatives and their General Environmental Impacts) electricity and heating sector optimisation model
3. The computable general equilibrium (CGE) model for analysing the impacts on the economy and employment
4. Models for analysing pollution volumes and assessing health impacts.

5.1.1. General parameters and variables

5.1.1.1. Population

Estimates regarding the size of Poland's resident population are made on the basis of the 2011 census, while the calculations for the following years are based on official records of births, deaths and long-term internal and international migration (the migration estimates do not include undocumented and illegal migrations)¹.

¹ Residents (resident population), Central Statistical Office, access:

<http://stat.gov.pl/obszary-tematyczne/ludnosc/ludnosc/rezydenci-ludnosc-rezydujaca,19,1.html>

Table 1. Resident population [million]

	2005	2010	2015	2020	2025	2030	2035	2040
Total	38.1	38.1	38.0	38.1	37.9	37.5	37.1	36.5
Urban	23.4	23.1	22.9	22.6	22.3	21.8	21.2	20.7
Rural	14.7	14.9	15.1	15.4	15.6	15.7	15.8	15.8

Source: Prognoza ludności rezydującej Polski na lata 2015-2050 (Projected Polish resident population in 2015-2050). Central Statistical Office, Warsaw, January 2016.

As is shown by the demographic projection presented, the resident population is expected to fall over the timespan from the current 38.0 million to 36.5 million. This decline has mostly effect on the urban population, with a simultaneous, gradual increase in the number of rural residents, which is mainly associated with the growing urban-rural migration, mostly to suburban municipalities centred around large cities, a trend that has been observed since 2000.

5.1.1.2. GDP

The macroeconomic scenario that underlies the projection of energy demand in Poland until 2040 is based on GDP growth forecasts published by the Ministry of Finance (MF)² in May 2017³. The projected GDP growth for Poland in absolute terms used in the model calculations is presented in Table 2, while the projections of average annual increases is shown in Table 3.

Table 2. Gross domestic product [EUR'2016 million]

	2005	2010	2015	2020	2025	2030	2035	2040
GDP	317 010	400 114	462 370	551 249	649 661	748 029	843 849	938 089

Source: Eurostat, MF

Table 3. 2016-2040 GDP forecast (average annual growth)

	2016-2020	2021-2025	2026-2030	2031-2035	2036-2040	2016-2040
GDP	103.6	103.3	102.9	102.4	102.1	102.9

Source: MF, ARE S.A.

As the projections demonstrate, the average annual 2016-2040 GDP growth rate in Poland is 2.9%. The rate is higher than assumed in the PRIMES⁴ baseline scenario by approx. 0.7 percentage points. The reindustrialisation of the economy announced in the government's 'Strategy for Responsible Development' and the projected increase in the affluence of society are expected to be the main drivers of future economic growth⁵.

5.1.1.3. Sectoral gross value added

² Guidelines on the use of uniform macroeconomic indicators for assessing the financial impacts of draft legislation. May 2017 Update (*Wytyczne dotyczące stosowania jednolitych wskaźników makroekonomicznych będących podstawą oszacowania skutków finansowych projektowanych ustaw. Aktualizacja - maj 2017 r.*), Ministry of Finance, Warsaw 2017, <https://www.gov.pl/web/finanse/wytyczne-sytuacja-makroekonomiczna>

³ More recent MF projections are currently available, including those from May 2019, but the projections used in the forecast and the latest MF estimates on Poland's macroeconomic development only differ for the first five-year period. In order to ensure comparability with the REF scenario, the calculations are based on an unchanged path of economic growth. Furthermore, the energy demand projections are adjusted against the latest statistical data regarding the fuel and energy economy. In most cases, the adjustments produce an increase in energy demand, which is closely associated with the growth of GDP in the first five-year forecast period as anticipated by the latest MF projections.

⁴ *Poland: Reference Scenario. Detailed Analytical Results*. Primes Ver. 4 Energy Model. E3MLab, National Technical University of Athens.

⁵ Strategy for Responsible development (with an outlook for 2030), as adopted by Resolution of the Council of Ministers of 14 February 2017, Warsaw 2017.

The structure of gross value added is estimated on the basis of the anticipated GDP growth path and macroeconomic assumptions derived from the PRIMES model (Reference Scenario)¹⁰.

Table 4. Sectoral gross value added [EUR'2016 million]

	2005	2010	2015	2020	2025	2030	2035	2040
Gross value added	278 683	351 994	402 825	475 640	555 687	636 721	714 785	790 674
Industry	61 282	86 857	103 904	119 117	137 327	156 588	171 983	185 218
Agriculture	10 298	10 267	9 537	9 735	9 937	10 143	10 351	10 564
Transport	18 277	18 613	25 905	31 207	33 929	36 469	38 943	41 184
Construction	22 971	29 885	35 389	35 166	38 852	42 636	44 560	46 727
Services	165 855	206 373	228 090	280 416	335 641	390 886	448 947	506 982

Source: Eurostat, Ministry of Finance, PRIMES Ref2016, ARE S.A.

In accordance with the projection of gross value added growth, services will be the fastest growing sector of the economy, with its value added bound to double in 2015-2040. Added value also increases considerably in industry, although its share in the breakdown will gradually decline (Figure 1).

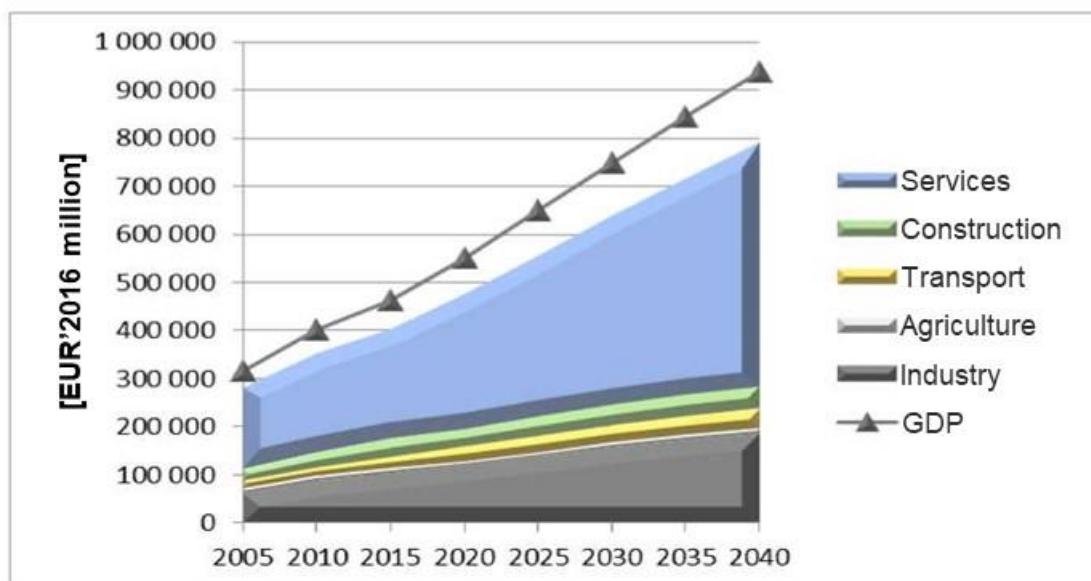


Figure 1 GDP and breakdown of gross added value in Poland

5.1.1.4. Number and size of households

The projections of the number of households and the average number of people per household used in the model calculations (tables 5 and 6, respectively) stem from Poland's projected size of population. The individual estimates are based on an analysis of the historical trend and comparisons with corresponding projections of the Central Statistical Office (GUS). The analyses foresee a gradual improvement of the housing conditions in Poland, as manifested by a decrease in the number of persons per household. In 2015, the average household consisted of 2.7 persons, with this figure set to improve to approx. 2.3 in 2030 and 2.2 in 2040.

Table 5. Number of households

	2005	2010	2015	2020	2025	2030	2035	2040
Total	12 776	13 471	13 962	14 742	15 443	16 044	16 530	16 922
Urban	8 580	9 088	9 398	9 875	10 301	10 646	10 905	11 102
Rural	4 196	4 383	4 564	4 867	5 142	5 398	5 625	5 820

Source: GUS, ARE S.A.

Table 6. Number of members per household

	2005	2010	2015	2020	2025	2030	2035	2040
Total	3.0	2.8	2.7	2.6	2.5	2.3	2.2	2.2
Urban	2.7	2.5	2.4	2.3	2.2	2.0	1.9	1.9
Rural	3.5	3.4	3.3	3.2	3.0	2.9	2.8	2.7

Source: GUS, ARE S.A.

5.1.1.5. Disposable income of households

In accordance with the Eurostat methodology, which has been implemented into Polish statistics, household's available income is the sum of annual gross cash incomes of all household members minus tax on income, property taxes, social and health insurance contributions, inter-household cash transfers paid, and settlements with the Tax Office (cash that households can allocate for consumption, investments or savings). This indicator can be used for assessing the real purchasing power of households. For the purposes of this document, use is made of statistical data on the level of average monthly disposable income per capita presented in a GUS publication⁶. The forecast for this indicator (table below) is based on the projected growth of GDP in Poland and the average size of household.

Table 7. Projected disposable household income [EUR'2016]

	2005	2010	2015	2020	2025	2030	2035	2040
Country total	8 640	11 111	10 731	12 700	14 383	16 019	17 607	19 493

Source: GUS, ARE S.A.

According to the presented projection, disposable income of households almost doubles in the period 2016-2040, which reflects the improvement in the financial situation of society.

5.1.1.6. Passenger transport performance

The demand for transport performance is the primary driver of the demand for fuels and energy, as well as of emissions in the transport sector.

In accordance with the methodology adopted in this document, the forecast demand for passenger transport presented in this section are not assumptions, but stem from calculations made using the energy model (STEAM_PL). The demand in this model is calculated as follows:

$$\begin{aligned} & \text{Transport performance for the mode of transport concerned [tkm]} \\ & = \text{weight of transported loads [tonne]}^* \text{ average transport distance of 1 tonne of load [km]} \end{aligned}$$

Subsequently, the total demand for transport is calculated as the sum of transport activity performed by all types of passenger transport.

The model forecasts such categories as the number of vehicles of a given type, the average annual mileage, and the average number of passengers using a given type of vehicles.

The resultant values of total demand for transport are confronted with the results of an econometric model relying on identified relationships between the level of economic activity measured by GDP per capita and the level of transport activity (top-down approach).

The transport performance values for different modes of transport for the ECP scenario differ from those obtained in respect of the REF scenario since they include the additional measures aimed at reducing energy consumption and emissions from the transport sector envisaged by the National Plan. In summative terms, they are similar (the slight differences stem from the assumption that some actions to be taken in the ECP scenario will reduce mobility, e.g. introduction of clean transport zones), but the way of satisfying the demand for

⁶ 2016 Household Budgets, GUS, Warsaw 2017.

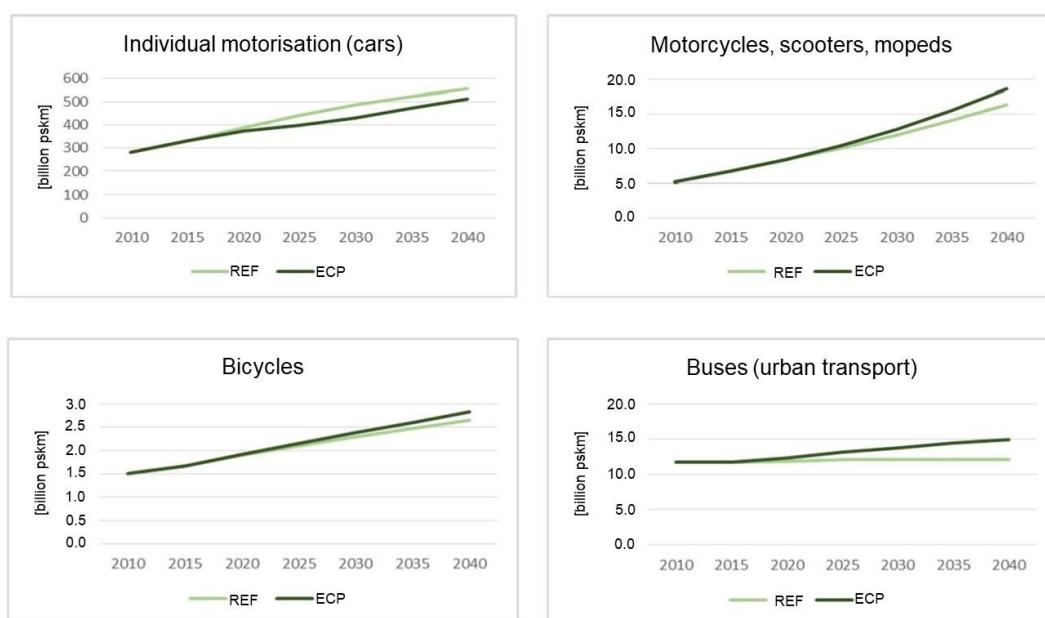
passenger transport activity is completely different, oriented more to the low-carbon modes, e.g. most of the burden of transport performance is transferred to public transport, which is characterised by lower specific emission factors.

In synthetic terms, the demand for passenger transport performance in the ECP scenario increases in 2015–2040 from 408 billion pskm to 664 billion pskm, i.e. by about 63%. By mode of transport, the greatest share in the demand is represented by individual road transport, which increases from 332 billion pskm in 2015 to 515 billion pskm in 2040. However, the ECP scenario demonstrates a clear slowdown in the growth of demand for transport handled by individual motor vehicles (passenger cars). A comparison of the two scenarios points to a shift from individual motorised transport to public transport (passenger rail, bus, tram, and metro transport) and to low-emission individual means of transport (motorcycles, mopeds, scooters and bicycles).

Table 8. Passenger transport performance [billion pskm] – ECP scenario

	2005	2010	2015	2020	2025	2030	2035	2040
Passenger cars (individual)	No data	281.0	332.5	375	400	432	473	515
Motorcycles (individual)	No data	5.1	6.7	8	10	13	15	19
Scooters, mopeds, bicycles	No data	1.5	1.7	2	2	2	3	23
Buses (urban transport)	No data	11.7	11.7	12	13	14	14	15
Buses (extra-urban)	21.6	21.5	21.5	22	23	24	26	27
Railways (public)	18.2	17.9	17.4	19	26	40	43	45
Aeroplanes	8.5	8.3	13.5	17	21	24	28	31
Inland waterway vessels	No data	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Rail vehicles (trams, trolleybuses, metro)	No data	3.2	3.5	4	5	7	8	10
Total	No data	350	408	460	501	556	610	664

Source: Primes Ver. 4 Energy Model. National Technical University of Athens, 2013-01-07, “Transport - wyniki działalności” – GUS. Warsaw, 2011, 2012, 2013, 2014, 2015, “Sustainable Transport Development Strategy 2030”. Warsaw, 2019 and ARE S.A. estimates.



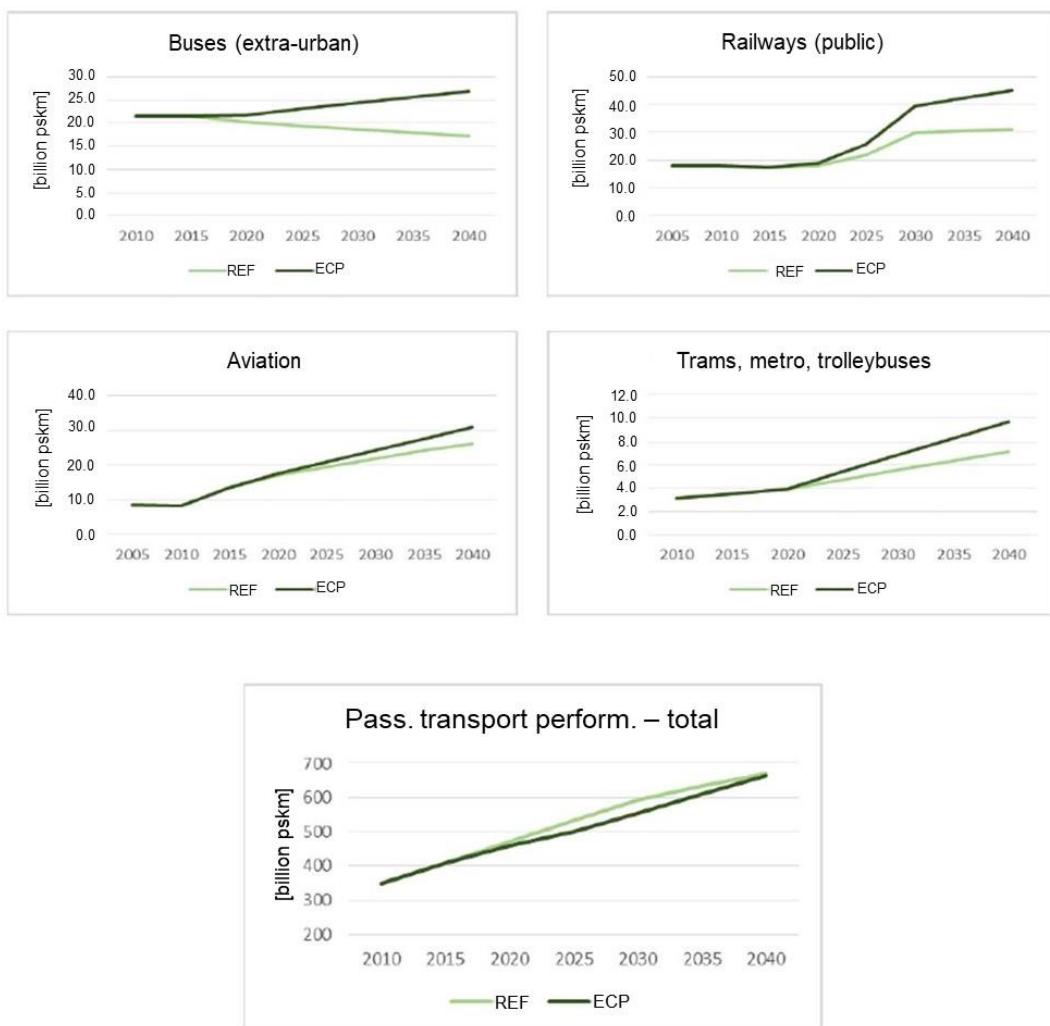


Figure 2. Comparison of projected demand for passenger transport – ECP vs REF

5.1.1.7. Freight transport performance

In addition to economic growth as measured by a number of macroeconomic indicators, the demand for freight transport is driven by such factors as changes in the transport intensity of business operations (which tend to decrease with the increase in the share of highly processed goods and services), the volume of Polish foreign trade, the modal shift, and the developments on international transport markets. The projections of the demand for freight transport used in the energy forecasts result from a model based on the following algorithm:

$$\begin{aligned} & \text{Transport performance for the mode of transport concerned [tkm]} \\ & = \text{weight of transported loads [tonne]}^* \text{ average transport distance of 1 tonne of load [km]} \end{aligned}$$

The forecast assumes an increase in demand for freight transported by Polish carriers from 1 824 million t in 2015 to 2 398 million t in 2030, and then to 2 437 million t in 2040 (based on the result obtained in an econometric model where the nationwide GDP growth rate is adopted as the explanatory variable). The forecasts of the average distance over which loads will be transported by individual means of transport are based on a historical trend analysis. The tables below summarise the projections of freight transport performance generated by the bottom-up model used for the purposes of this document, for the REF and ECP scenarios, respectively.

As is shown by the results presented, the demand for freight transport increases from 506 billion tkm in 2015 to 682 billion tkm in 2030 and to 732 billion tkm in 2040. By modes, the largest portion of the demand is that of road transport, the share of which reaches approx. 54% in 2015 to drop gradually to 43% in 2040. The greatest differences between the scenarios occur in rail and road transport. The graphs below illustrate the differences in the projected demand for freight transport.

Table 9. Freight transport performance [billion tkm] – ECP scenario

	2005	2010	2015	2020	2025	2030	2035	2040
Rail transport	50.0	48.9	50.7	72	90	109	126	141
Road transport	119.7	214.2	273.1	296	311	322	321	315
Pipeline transport	25.4	24.2	21.8	24	27	28	29	29
Inland waterway transport	1.3	1.0	0.8	1.4	1.6	1.9	2.2	2.4
Shipping	No data	112	158	180	200	220	235	245
Air transport	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2
Total	No data	400	506	573	629	682	713	732

Source: ARE S.A., *Primes Ver. 4 Energy Model*. National Technical University of Athens, 2013-01-07, "Transport - wyniki działalności" – GUS. Warsaw, 2011, 2012, 2013, 2014, 2015, "Sustainable Transport Development Strategy 2030". Warsaw, 2019 and ARE S.A. estimates.

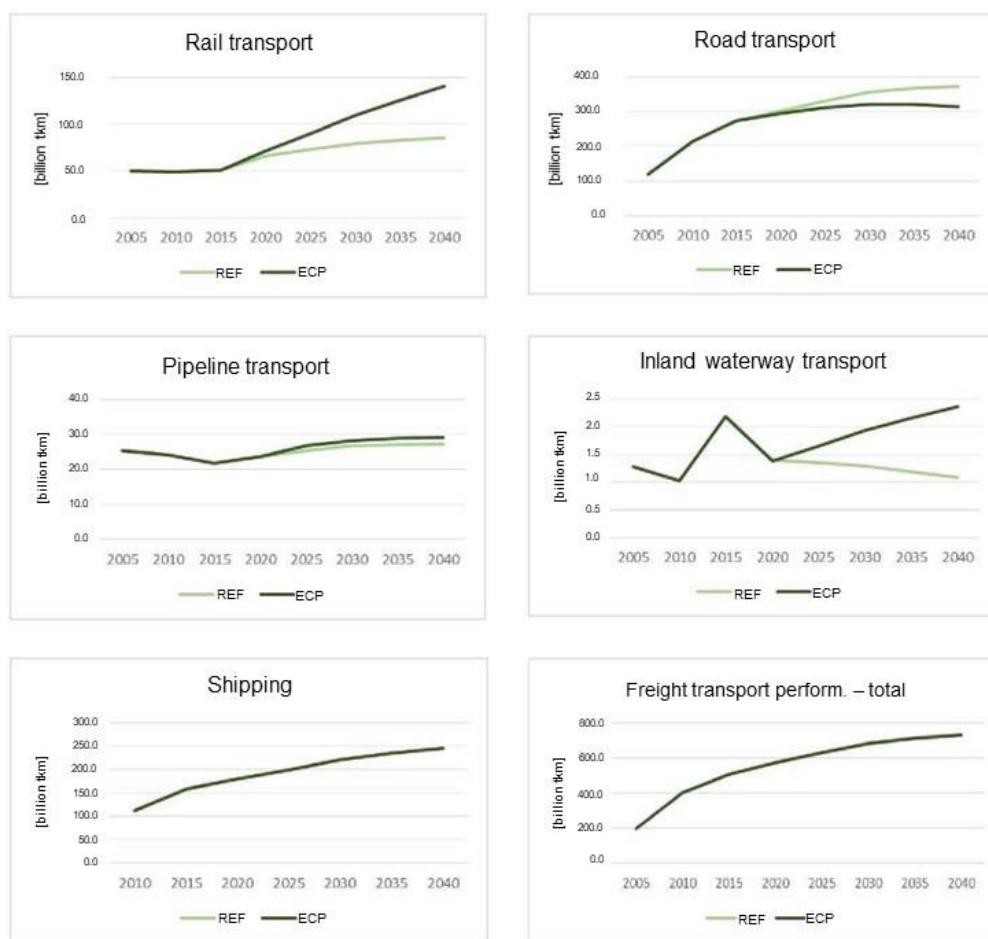


Figure 3. Comparison of projected demand for freight transport – ECP vs REF

5.1.1.8. International fuel import prices

The projections of the prices of fuels imported into the European Union used in the model calculations (see the

table and figure below) come from the projection of the International Energy Agency (IEA)⁷ – World Energy Outlook 2017, New Policies Scenario. These projections are used as the basis for determining trends in fuel price projections on the domestic market.

The hard coal and natural gas price projections for the Polish energy sector are based on the assumption that fuel prices in Poland are correlated with those on global markets.

The cost of coal for individual baseload power plants used in the model is differentiated on the basis of statistical data, taking into account, *inter alia*, differences in the cost of transport.

Table 10. Prices of fuels imported into the EU [EUR'2016/GJ (NCV)]

	2005	2010	2015	2020	2025	2030	2035	2040
Crude oil	7.73	9.94	6.83	8.0	10.7	12.1	13.3	14.3
Natural gas	5.17	6.28	6.64	5.5	6.9	7.6	8.0	8.4
Coal	2.18	2.66	1.97	2.2	2.6	2.7	2.7	2.7

Source: ARE S.A. on the basis of the World Bank, IMF, European Commission, and IEA's New Policies Scenario 2017

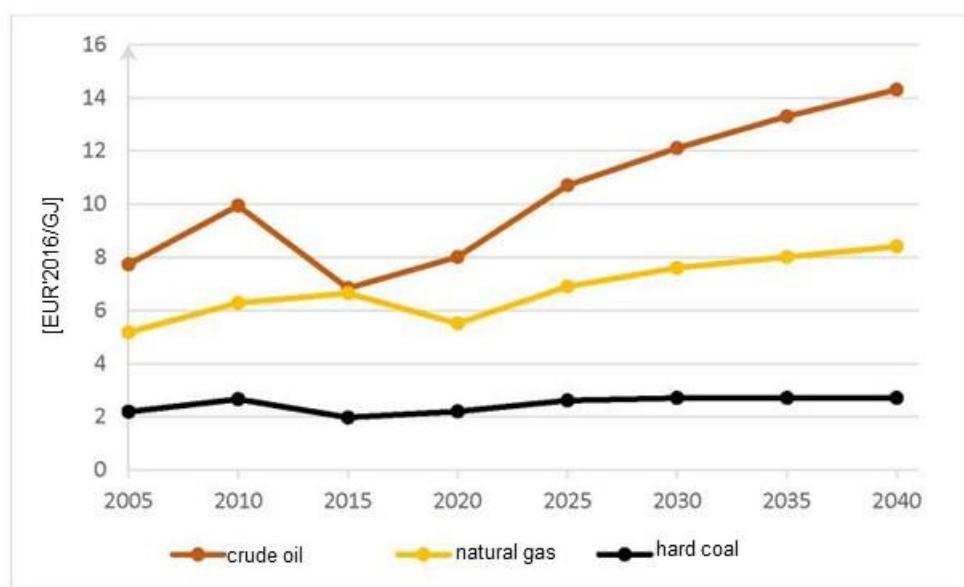


Figure 4. Prices of fuels imported into the EU

5.1.1.9. Prices of EU ETS CO₂ emission allowances

In order to maintain consistency, the projected prices of EU ETS CO₂ allowances (EUA) are also based on the IEA's World Energy Outlook 2017 (New Policies Scenario)¹⁵. The Outlook foresees a substantial increase in EUA prices over the time horizon under study. The prices of CO₂ emission allowances applied in the analysis are presented in Table 11. Over the timespan, a linear increase in the cost of CO₂ emission allowances is assumed.

Table 11. EUA prices [EUR'2016/tCO₂]

	2005	2010	2015	2020	2025	2030	2035	2040
Price of 1 allowance	0	12	8	17	21	30	35	40

Source: ARE S.A. on the basis of IEA, EC, Thomson Reuters, KfW Bankengruppe

⁷ World Energy Outlook 2017, International Energy Agency, Paris 2017.

It is assumed that the price of CO₂ emission allowances will gradually increase to EUR'2016 40/t CO₂ in 2040, working towards the EU's goal of cutting GHG emissions by 40% in 2030 and the ambitious long-term goal of reducing GHG emissions by 80-95% in 2050 compared to the 1990 level⁸. The price of CO₂ emission allowances will be driven, *inter alia*, by the Market Stability Reserve (MSR). Until 2030, the assumed prices of allowances align with the recommendations of the European Commission on the use of indicators for the purposes of preparing national plans⁹. In 2030-2040, the increase in the prices of CO₂ emission allowances assumed by the IEA is slightly slower than in the EC's Reference Scenario.

It should be noted that the projections presented have a long-term nature and do not take into account the fluctuations that will certainly occur in the future, but only set a certain trend. There will be periods when market prices will be both above and below the trajectory, but prices averaged over longer periods should align with it.

The European Commission has not questioned the CO₂ emission allowance price increase path assumed in the forecasts for the REF and ECP scenarios. In addition, despite the substantial increase in prices of CO₂ emission allowances in 2018, the EC has not presented updated, i.e. higher, EUA price forecasts to be used in analytical work for national plans. Therefore, the price projections adopted are considered to be suitable for analytical needs.

5.1.1.10. Exchange rates

The exchange rates are adopted in correspondence to the recommendations of the European Commission regarding the preparation of the NECP. They assume stabilisation of the USD/EUR exchange rate at 1.2 and that for PLN/EUR at 4.25. The 2005-2015 historical figures come from the NBP data.

Table 12. Exchange rates

	2005	2010	2015	2020	2025	2030	2035	2040
USD/EUR	1.245	1.328	1.120	1.16	1.20	1.20	1.20	1.20
PLN/EUR	4.023	3.995	4.184	4.25	4.25	4.25	4.25	4.25

Source: NBP, European Commission recommendations. Number of heating and cooling degree-days

Assumptions underlying the number of heating and cooling degree-days

The assumptions regarding the number of degree-days over the forecast period are adopted on the basis of the Commission's recommendations regarding the preparation of the NECP. The 2005-2015 historical data originate from Eurostat statistical databases. The projections assume a gradual rise in average annual temperatures in Poland's climate zone, which has a significant impact on the forecast demand for heat in the heating period and for cold in the summer.

Table 13. Number of heating degree-days (HDD)

	2005	2010	2015	2020	2025	2030	2035	2040
HDD	3 547	3 881	3 113	3 442	3 430	3 418	3 408	3 399

Source: Eurostat, European Commission recommendations

Table 14. Number of cooling degree-days (CDD)

	2005	2010	2015	2020	2025	2030	2035	2040
CDD	216	197	220	223	226	229	231	233

Source: Eurostat, European Commission recommendations

¹⁵ Ibidem.

⁸ European Commission, Energy Roadmap 2050 (COM(2011) 885 final of 15 December 2011.

⁹ European Commission: EU Reference Scenario 2016. Energy, transport and GHG emissions trends to 2050, July 2016.

5.1.1.11. Assumptions regarding the technical and economic parameters of energy technologies

The parameters of new generating units presented in Table 15 are based on the latest publications of reputable research centres available at the time when this document was being prepared. The analyses in the model assume that the electricity and heat generation technologies that are currently available in commercial offers will exclusively be available. Carbon capture and storage (CCS) technologies are also included in the list. As regards renewable energy technologies, use is also made of the costs estimated in the Regulatory Impact Assessment for Regulation of the Minister of Energy on the reference price of renewable electricity¹⁰ and the results of previous auctions. Some values are updated in correspondence to the assumptions indicated in section 4.1.12 in Annex 1, i.e. in the REF scenario.

Explanatory note to the table below:

CHP – cogeneration, combined heat and power generation;
 PC – condensing power plants with pulverised coal boilers
 PL – condensing power plants with pulverised lignite boilers
 CCS – sequestration (carbon capture and storage)
 GTCC – gas turbine combined cycle power plants
 IGCC – integrated gasification combined cycle power plants
 FBC – fluidised bed combustion power plants
 PWR – pressurised water reactor
 MV – medium voltage
 EHV – extra highest voltage
 HV – high voltage

Source of data presented below: ARE S.A. based on:

World Energy Outlook, International Energy Agency, Paris 2016;
WEIO 2014-Power Generation Investment Assumptions, International Energy Agency, Paris 2014;
The Power to Change: Solar and Wind Cost Reduction Potential to 2025", International Renewable Energy Agency, Bonn 2016; Energy and Environmental Economics – "Recommendations for WECC's 10- and 20-Year Studies", San Francisco 2014;
World Energy Perspective Cost of Energy Technologies, World Energy Council, Project Partner: Bloomberg New Energy Finance, 2013;
Lazard's Levelized Cost of Energy Analysis - Version 9.0, Lazard, New York 2015;
Scenarios for the Dutch electricity supply system, Frontier Economics, London 2015;
Energy Technology Reference Indicator projections for 2010-2050, European Commission JRC Institute for Energy and Transport, Brussels 2014;
Projected Cost of Generating Electricity 2015 Edition, International Energy Agency, Nuclear Energy Agency, Organization for Economic Co-operation and Deployment, Paris, 2015;
Cost and Performance Characteristics of New Generating Technologies, Annual Energy Outlook 2016, U.S. Energy Information Administration, Washington 2016.

Table 15. Technical and economic parameters of production and transmission technologies (EUR'2016 constant prices)

fuel/ technology	commissioning time	capital expenditures	costs		Net electrical/total efficiency	Full load hours equivalent	Technical life time
			fixed	variable			
		EUR thousand/MW _{net}	EUR thousand/MW _{net}	EUR/MW h _{net}	%	h/annum	years
CHP							
1.1 Lignite – PL	2016-2040	1800	48	3.4	44	7000	40
1.2 Lignite – PL+CCS	2030-2040	3250	72	8.6*	38	7000	40

¹⁰ Regulatory Impact Assessment for Regulation of the Minister of Energy on the reference price of electricity produced from renewable energy sources in 2017 and the time periods applicable to producers that won auctions in 2017. Warsaw, 24 March 2017.

1.3 Lignite – FBC	2020-2040	2050	50	3.4	40	7000	40
2.1 Coal – PC	2016-2040	1650	44	3.2	46	7000	40
2.2 Coal – IGCC	2025-2040	2250	58	5.0	48	7000	40
2.3 Coal – IGCC+CCS	2030-2040	3250	78	7.2*	40	7000	40
2.4 Coal – CHP	2016-2040	2250	48	3.2	30/80	7000	40
2.5 Coal – CHP+CCS	2030-2040	3500	76	10*	22/75	7000	40
3.1 Natural gas – GTCC	2016-2040	750	18	1.8	58↑62	7000	30
3.2 Natural gas – GTCC+CCS	2030-2040	1350	38	4.0*	50↑52	7000	30
3.3 Natural gas – GTCC+CHP	2016-2040	1050	32	1.8	50↑75	6000	30
3.4 Natural gas – TG	2025-2040	500	16	1.4	40	1500	30
3.5 Gas Micro CHP	2016-2040	2350	97	-	20/90	3500	25
4.1 Generation III nuclear power plant – PWR	2030-2040	4500	85	0.8	36	7500	60
Renewable energy sources							
5.1 Onshore wind	2016-2020	1350	50	-	-	2300↑2400	25
5.1 Onshore wind	2021-2040	1350↓1250	50	-	-	2400↑2600	25
5.2 Offshore wind	2020-2030	2450↓2250	90	-	-	3500↑3750	25
5.2 Offshore wind	2031-2040	2250↓2100	90	-	-	3750	25
5.3 Large hydropower	2020-2040	2500	35	-	-	2000	60
5.4 Large hydropower	2016-2040	3000	75	-	-	3500	60
5.5 Geothermal	2020-2040	7000↓5500	160	-	0.12	7500	30
5.6 Photovoltaics	2016-2020	1100↓800	16	-	-	750↑850	25
5.6 Photovoltaics	2021-2040	800↓600	16	-	-	850↑1000	25
5.7 Roof photovoltaics	2016-2020	1250↓1100	20	-	-	750↑850	25
5.7 Roof photovoltaics	2021-2040	1100↓700	20	-	-	850↑950	25
5.8 Agricultural biogas	2016-2040	3250↓2750	220	-	40/80	5250	25
5.9 Wastewater treatment plant biogas	2016-2040	3500	135	-	40/65	4400	25
5.10 Landfill biogas	2016-2040	1800	80	-	40/45	4000	25
5.11 Solid biomass	2016-2040	2500	100	-	35	6000	30
5.12 Solid biomass – CHP	20161-2040	2950↓2750	120	-	25/80	5500	30
5.13 Municipal waste incineration plant – CHP	2021-2040	10000	150	-	16/60	6000	25
Heat plants							
6.1 Coal-fired heat boiler	2016-2040	350	1	1.4	0.9	2500	30
6.2 Natural gas-fired heat boiler	2016-2040	150	1	0.4	0.96	2500	30
6.3 Heating oil-fired boiler	2016-2040	200	1	0.5	0.95	2500	30
6.4 Biomass-fired heat boiler	2016-2040	500	1	1.4	0.9	2500	30
Connection to/strengthening power grid							
7.1 Baseload power plants	2016-2040	250					
7.2 Onshore wind	2016-2040	350					
7.3 Offshore wind	2016-2040	850					

7.4 Other power plants and CHP plants	2016-2040	50 - 250
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* Including carbon transportation and storage

Table 16 presents the technical and economic parameters of central heating (CH) and warm service water (WSW) technologies used by households and small service enterprises adopted for the calculations in the model. The data comes from a range of different sources, including official websites of manufacturers and distributors of the individual devices in Poland.

Table 16. Technical and economic parameters of CO and WSW technologies

	purchase cost [EUR'2016/kW]	cost of additional installations to be purchased [EUR'2016/kW]	description of additional installations	efficiency [%]
electric boilers or heaters – installed permanently	24	none	N/A	100
electric boilers or heaters – movable	12	none	N/A	100
electric underfloor heating	143	48	control devices and automatic controls	100
electric water heater (boiler, flow-through heater)	17	none	N/A	100
central heating natural gas-fired boiler	48	179	water heaters + connection	90-97
natural gas water heater (boiler, flow-through water heater)	18	60	connection	90
natural gas-fired combi boiler (CH+WSW)	72	179	water heaters + connection	90-97
LPG central heating boiler	48	239	water heaters + tank	90-97
LPG water heater	18	2	cylinder	90
LPG combi boiler (CH+WSW)	72	239	water heaters + tank	90-97
CH fuel oil-fired boiler	48	131	water heaters + tank	90-95
fuel oil-fired combi boiler (CH+WSW)	72	131	water heaters + tank	90-95
CH solid fuel-fired boiler	48	119	water heaters	60-80
solid fuel-fired water heater	18	48	solid fuel-fired boiler	60-80
solid fuel-fired combi boiler (CO+WSW)	66	119	water heaters	60-80
solid fuel space heaters	24	none	N/A	40-80
open solid fuel fireplace	24	72	mantel	40-80
solid fuel fireplace with a closed insert	24	72	mantel	50-80
solid fuel fireplace with a water jacket	96	191	mantel + radiators	60-80
solid fuel cooker	24	none	N/A	30-80
dual-purpose district heating substation	70	none	substation+connection	70
heat pump	717	119	water heaters	3.5-5.4*

* For heat pumps, the coefficient of performance (COP) is given instead of the efficiency

Source: ARE S.A. based on data collected from producers and distributors of devices

Owing to the complexity of production processes in industry and the high diversity of industrial technologies and solutions, the industry sector is treated in a simplified manner in the energy model. The model defines five main purposes of energy use: boiler heat, process steam, electric drives, space heating and lighting. The results are given in the table.

Table 17. Technical and economic parameters of industrial technologies

technology	fuel	purpose	purchase cost [EUR'2016/kW]	O&M costs [EUR'2016/GJ]	technical life time	CO ₂ emission factor [kg/GJ]
industrial furnaces/boilers for process heat production	blast furnace gas	furnace heat	1200-3030	0.30	25	260
industrial furnaces/boilers for process heat production	coke oven gas	furnace heat	1611-4066	0.40	25	44
industrial furnaces/boilers for process heat production	coke	furnace heat	500-1262	0.12	25	107
industrial furnaces/boilers for process heat production	electricity	furnace heat	1200-3029	0.30	25	0
industrial furnaces/boilers for process heat production	coal	furnace heat	1611-4066	0.40	25	94
industrial furnaces/boilers for process heat production	heavy fuel oil	furnace heat	1611-4066	0.40	25	77
industrial furnaces/boilers for process heat production	light fuel oil	furnace heat	1611-4066	0.40	25	77
industrial furnaces/boilers for process heat production	LPG	furnace heat	1200-3030	0.30	25	63
industrial furnaces/boilers for process heat production	natural gas	furnace heat	1200-3030	0.30	25	56
electric motors	electricity	electrical propulsion	400-1100	0.18	10	0

Source: ARE S.A. on the basis of on input data for the MARKAL¹¹ model and European Commission guidelines on the preparation of the NECP

Table 18 presents the technical and economic parameters of road transport vehicles.

Table 18. Technical and economic parameters of technologies used in transport and agriculture

	New vehicle purchase cost [EUR'2016/vehicle]	Specific fuel/energy consumption [l/100km] 2015→2040
Cars (petrol<1399 cm ³)	8 200	5.4 → 3.6

¹¹ UK MARKAL Model Documentation, Kannan R., Strachan N., Pye S., Anandarajah G., Balta-Ozkan N. 2007, access: www.ucl.ac.uk/energy-models/models/uk-markal.

Cars (petrol 1400-1900 cm ³)	10 600	6.6 → 4.3
Cars (petrol >1900 cm ³)	12 900	8.5 → 5.5
Cars (Diesel <1399 cm ³)	11 800	4.6 → 3.0
Cars (Diesel 1400-1900 cm ³)	15 300	5.9 → 3.8
Cars (Diesel >1900 cm ³)	17 600	6.9 → 4.5
Cars (LPG <1399 cm ³)	8 900	6.4 → 4.3
Cars (LPG 1400-1900 cm ³)	11 300	8.1 → 7.0
Cars (LPG >1900 cm ³)	13 600	10.7 → 7.1
Cars (hybrid)	17 400 → 12 000	3.8 → 2.8
	[EUR'2016/vehicle]	[m3/100km]
Cars (CNG)	16 500	7.1 → 6.5
HGVs up to 3.5t (CNG)	31 000	11.9 → 10.5
	[EUR'2016/vehicle]	[kWh/100km]
Cars (electric)	20 000 → 14 000	23.0 → 21.0
HGVs up to 3.5 t (electric)	70 000 → 50 000	33.0 → 28.0
	[EUR'2016/vehicle]	I/100km
HGVs up to 3.5t (petrol)	24 000	12.0 → 8.5
HGVs up to 3.5t (Diesel)	31 000	9.6 → 7.0
HGVs up to 3.5t (LPG)	29 000	12.1 → 10.6
HGVs up to 3.5t (CNG)	31 000	11.9 → 8.7
HGVs above 3.5t (Diesel)	94 000	45.0 → 34.0
	[EUR'2016/vehicle]	[toe/annum]
Agricultural tractors	40 000	1.15 → 1.02
Forage harvesters	135 000	4.5 → 3.96
Combine harvester-threshers	63 500	1.42 → 1.25

Source: ARE S.A. on the basis of EC recommendations, data obtained from producers and industry organisations (e.g. ITS, SAMAR). In agriculture: Pawlak Jan, Instytut Budownictwa Mechanizacji i Elektryfikacji Rolnictwa – „Nakłady inwestycyjne i koszty energii w rolnictwie polskim”. Warsaw, 2007.

5.1.2. ‘Decarbonisation’ dimension

5.1.2.1. Greenhouse gas emissions and removals

The 2040 projections of GHG emissions and recovery for the Energy and Climate Policy (ECP) scenario are based on the following data sources:

1. Activity forecasts for the ECP scenario (consumption of fuels), which are presented further below;
2. Draft Fourth Biannual Report for UNFCCC (BR4) (Projekt Czwartego raportu dwuletniego dla UNFCCC), Instytut Ochrony Środowiska - Państwowy Instytut Badawczy, KOBiZE, 2019;
3. National Inventory Report 2019. Greenhouse Gas Inventory for 1988-2017 (Krajowy raport inwentaryzacyjny 2019. Inwentaryzacja gazów cieplarnianych dla lat 1988-2017), prepared by the National Centre for Emissions Management (KOBiZE), Institute of Environmental Protection – National Research Institute, for the purposes of the United Nations Framework Convention on Climate Change and the Kyoto Protocol;
4. CRF tables with data on greenhouse gas emissions (2019), prepared by the National Centre for Emissions Management (KOBiZE), Institute of Environmental Protection – National Research Institute, in connection with the above reporting obligation.

5.1.2.1.1. Forecasts of greenhouse gas emissions and removals with projected changes in sectors

Below are the synthetic results of the 2020-2040 greenhouse gas emissions forecast in Poland, as part of the planned policies and measures, by the sectors included in the methodology (classification) of the Intergovernmental Panel on Climate Change (IPCC), in relation to 2005-2015 emissions (Table 19 and Figure 5).

Table 19. GHG emission projections for the ECP scenario by sectors

Source category	GHG emissions [ktCO ₂ eq]							
	2005	2010	2015	2020	2025	2030	2035	2040
Total excluding LULUCF	403 424.42	411 668.71	390 444.60	384 247.14	363 471.01	336 252.75	295 011.52	271 109.81
Total including LULUCF	356 817.09	381 648.18	359 888.13	352 469.47	336 133.38	314 559.82	277 268.88	257 088.53
1. Energy	331 239.12	340 898.85	318 446.48	314 996.08	294 590.13	267 891.48	227 183.91	203 763.73
2. Industrial processes and product use	25 467.77	25 000.46	28 508.35	24 419.97	24 039.81	23 605.13	23 106.20	22 792.66
3. Agriculture	29 656.05	29 727.52	29 612.74	31 751.72	32 452.22	32 880.91	33 169.74	33 249.44
4. Land Use, Land-Use Change and Forestry (LULUCF)	-46 607.33	-30 020.54	-30 556.47	-31 777.68	-27 337.63	-21 692.93	-17 742.64	-14 021.28
5. Waste	17 061.48	16 041.89	13 877.03	13 079.37	12 388.85	11 875.23	11 551.66	11 303.98

Source: ATMOTERM S.A. own data on the basis of KOBiZE data for 2005-2015 and for 2020-2040 regarding greenhouse gas emissions for the following sectors: 2. Industrial processes and product use, 3. Agriculture, 4. Land Use, Land-Use Change and Forestry (LULUCF) and 5. Waste

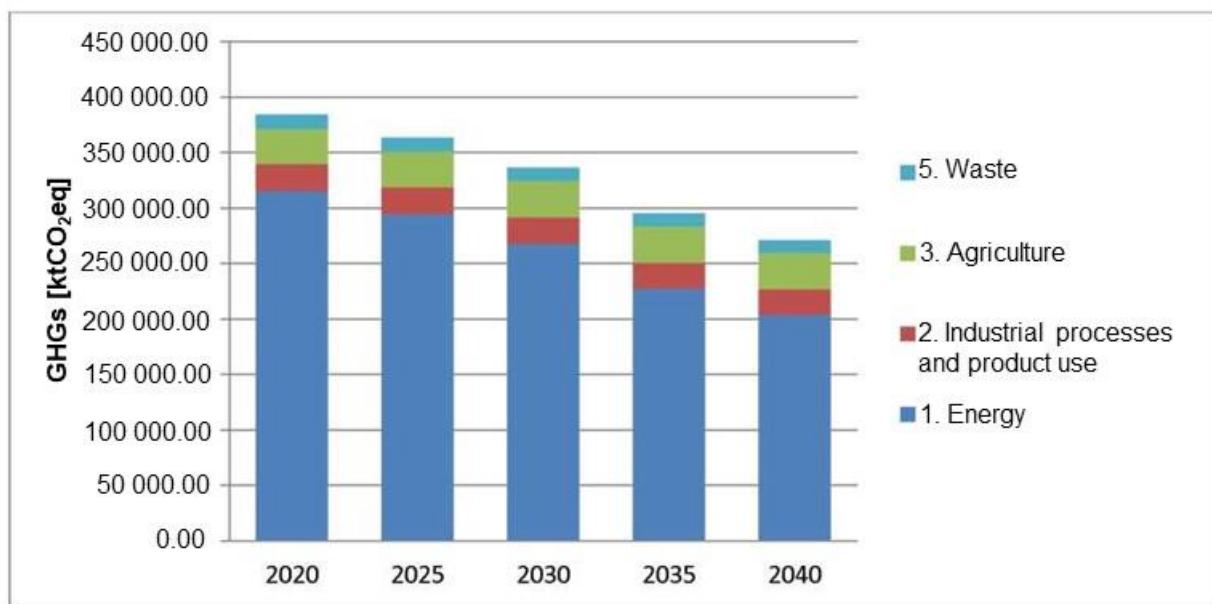


Figure 5. GHG emission projections for the ECP scenario by sectors, excluding LULUCF

As is shown by the data presented above, a steady decline in greenhouse gas emissions is expected over the forecast period, particularly noticeable in 2035 and 2040. Consequently, **in 2040 emissions reach the level of approx. 271 million tonnes of CO₂eq (including LULUCF)**, which means a downward movement of approx. 33% in the period 2005-2040. The reduction of CO₂eq emissions in the entire economy relative to 1990 is 29% for 2030 and 43% for 2040, respectively.

In 2040, the largest emission volumes will continue to come from the energy sector, notably the combustion of fuels, but emissions in this sector will gradually decrease (Table 19).

The anticipated emission evolution of emissions as broken down by the ETS and non-ETS (ESD) sectors are shown in Table 20 and Figure 6.

Table 20. GHG emission projections by ETS and non-ETS for the ECP scenario

Emission	Greenhouse gas emissions [kt CO ₂ eq.]							
	2005	2010	2015	2020	2025	2030	2035	2040
Total excluding LULUCF	403	411	390	384	363	336	295	271
	424.4	668.7	444.6	247.1	471.0	252.8	011.5	109.8
EU ETS	223	199	198	188	181	169	137	121
	440.9	726.9	696.5	921.1	772.1	525.1	797.5	846.5
Non-ETS (ESD)	179	211	191	195	181	166	157	149
	983.5	941.8	748.1	326.1	698.9	727.7	214.0	263.3

Source: ATMOTERM's own data

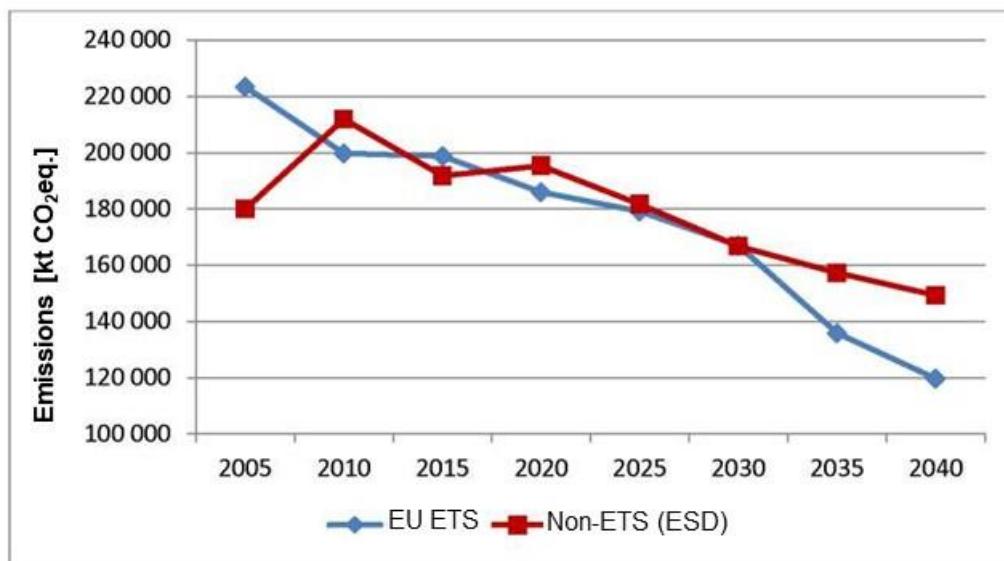


Figure 6. GHG emission projections by ETS and non-ETS sectors for the ECP scenario

Greenhouse gas emissions are expected to fall in both ETS and non-ETS. An increase is only anticipated for non-ETS emissions over the years 2015-2020 as a result of growing activity in transport. The ETS is expected to see a 25% HGH emission reduction in 2005-2030.

Given the 2030 non-ETS reduction target for Poland set at -7% compared to the level calculated for 2005 (using a KOBIZE methodology consistent with methods defined by the European Commission):

- on the basis of information on total greenhouse gas emissions (excluding LULUCF) in 2005 (in accordance with the 2019 inventory);
- with account taken of adjustments stemming from the second and third ETS phases;

it can be concluded that the results of the forecasts indicate attainment of the reduction target with the PaMs foreseen in the ECP scenario. It is estimated that with the actions foreseen in the ECP scenario, a reduction of at least 7% is feasible in non-ETS sectors.

The forecast shares of individual greenhouse gas emissions for the ECP scenario is presented in Tables 21-23 and Figure 7 below.

The largest CO₂ emissions will be produced by the energy sector, with a projected steady decline towards 2040. Emissions from industrial processes and product use rank second and are bound to increase slightly. In accordance with the methodology used (IPCC), the energy sector includes emissions generated by the combustion of fuels in all sectors and fugitive emissions from fuels.

Table 21. Projected CO₂ emissions by sector for the ECP scenario

Source category	CO ₂ emissions [kt]							
	2005	2010	2015	2020	2025	2030	2035	2040
Total excluding LULUCF	322 545.79	333 457.41	312 320.56	311 227.40	292 568.10	268 601.18	230 561.04	208 893.98
Total including LULUCF	271 331.36	298 727.57	280 636.39	277 532.70	263 260.92	244 996.85	210 897.79	193 078.08
1. Energy	304 748.07	315 601.31	292 619.07	290 147.24	271 155.63	246 879.43	208 592.08	186 661.77
A. Fuel combustion	301 576.50	312 796.48	288 368.88	285 598.27	266 993.84	242 923.81	204 975.28	183 415.11
1. Energy industries	177 290.03	172 262.80	162 622.03	146 578.98	142 112.87	132 233.28	101 830.10	87 259.45

2. Manufacturing industries and construction	33 790.32	29 455.75	27 738.32	25 437.57	22 234.82	19 355.89	17 432.54	15 639.33
3. Transport	35 613.78	48 659.65	47 367.83	62 849.34	60 362.78	56 327.76	54 598.87	52 365.71
4. Other sectors	54 882.37	62 418.29	50 640.71	50 732.37	42 283.37	35 006.87	31 113.77	28 150.62
B. Fugitive emissions from fuels	3 171.57	2 804.83	4 250.19	4 548.97	4 161.80	3 955.62	3 616.79	3 246.65
1. Solid fuels	2 019.08	1 747.97	2 221.01	2 521.42	2 133.60	1 926.90	1 587.64	1 217.12
2. Crude oil and natural gas	1 152.49	1 056.85	2 029.18	2 027.55	2 028.20	2 028.72	2 029.16	2 029.53
2. Industrial processes and product use	16 091.78	16 642.81	18 484.19	19 327.17	19 622.99	19 909.94	20 129.36	20 344.52
A. Mineral products	8 355.79	9 849.54	10 088.59	10 873.13	11 124.74	11 349.32	11 531.04	11 700.97
B. Chemical industry	4 886.78	4 335.42	5 141.13	5 303.40	5 375.28	5 446.71	5 503.64	5 560.75
C Metal production	2 216.99	1 784.33	2 576.81	2 442.32	2 414.66	2 405.60	2 386.37	2 374.48
D. Non-energy products from fuels and solvent use	632.22	673.53	677.66	708.31	708.31	708.31	708.31	708.31
3. Agriculture	1 291.94	790.01	736.36	1 013.16	1 041.93	1 064.27	1 092.06	1 140.15
G. Liming	944.90	391.55	373.84	448.91	489.45	527.19	569.70	631.60
H. Urea application	347.04	398.46	362.52	564.25	552.48	537.08	522.36	508.55
4. Land Use, Land-Use Change and Forestry (LULUCF)	-51 214.43	-34 729.84	-31 684.16	-33 694.70	-29 307.18	-23 604.33	-19 663.26	-15 815.90
5. Waste	414.00	423.27	480.95	739.83	747.54	747.54	747.54	747.54
C. Ashing and open burning of waste	414.00	423.27	480.95	739.83	747.54	747.54	747.54	747.54
CO₂ emissions from biomass	19803.98	30442.05	34962.70	41 228.70	42 222.21	45 167.75	47 522.40	50 028.71

Source: ATMOTERM's own data

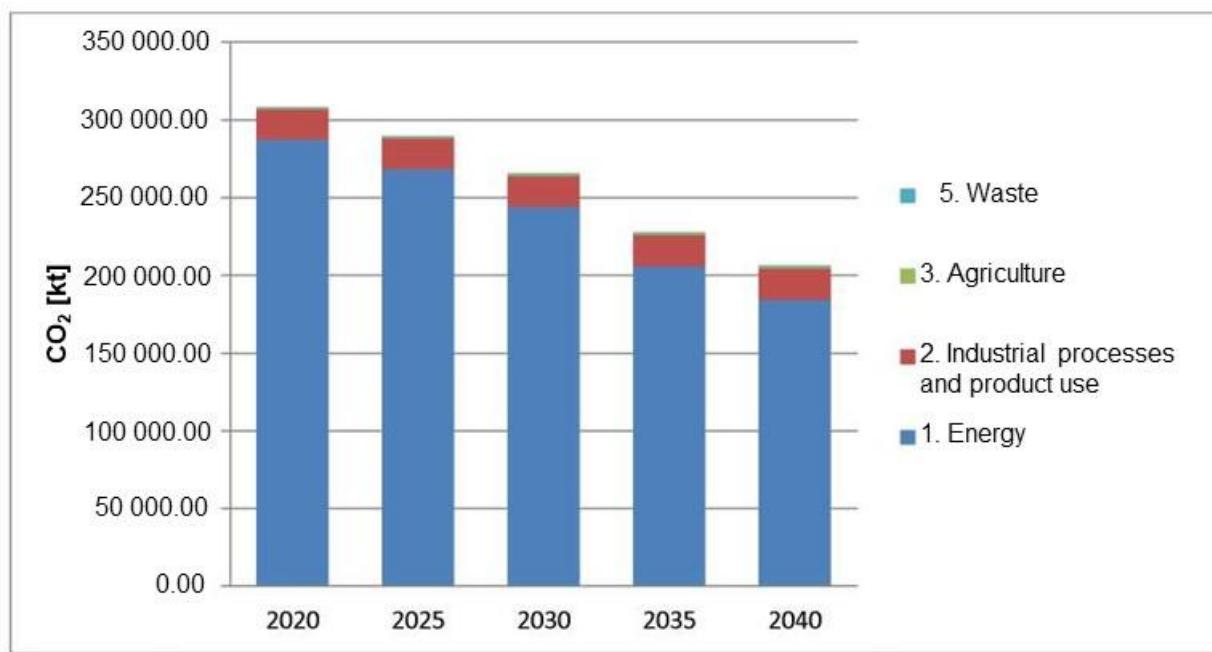


Figure 7. CO₂ emissions by sectors for the ECP scenario, excluding LULUCF

The projected N₂O emissions are presented in the table below. The largest emissions of nitrous oxide are produced by agriculture, followed by the energy and waste sectors, on a much smaller scale though. In the agricultural sector, a steady increase in emissions is expected until 2040.

Table 22. Projected N₂O emissions by sectors for the ECP scenario

Source category	N ₂ O emissions [kt]							
	2005	2010	2015	2020	2025	2030	2035	2040
Total excluding LULUCF	75.90	66.35	63.86	67.70	68.54	69.31	69.71	69.30
Total including LULUCF	91.25	82.05	67.53	74.04	75.05	75.62	76.05	75.22
1. Energy	8.80	8.46	8.05	6.34	6.21	6.00	5.41	5.07
A. Fuel combustion	8.80	8.46	8.05	6.34	6.21	5.99	5.41	5.07
1. Energy industries	2.61	2.68	2.60	2.45	2.47	2.47	2.00	1.75
2. Manufacturing industries and construction	0.48	0.50	0.60	0.60	0.63	0.66	0.65	0.66
3. Transport	1.57	1.97	1.83	2.17	2.08	1.91	1.83	1.74
4. Other sectors	4.13	3.31	3.02	1.11	1.03	0.95	0.93	0.92
B. Fugitive emissions from fuels	0.0016	0.0015	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018
2. Crude oil and natural gas	0.0016	0.0015	0.0018	0.0018	0.0018	0.0018	0.0018	0.0018
2. Industrial processes and product use	15.29	4.15	2.96	3.04	3.05	3.07	3.08	3.09
B. Chemical industry	14.87	3.71	2.51	2.60	2.61	2.62	2.64	2.65
G. Production and use of other products	0.43	0.44	0.44	0.44	0.44	0.44	0.44	0.44
3. Agriculture	49.18	50.92	49.68	55.07	56.02	57.02	58.03	58.00
B. Livestock manure	7.57	7.26	6.97	7.74	7.98	8.26	8.54	8.69
D. Agricultural soils	41.58	43.63	42.67	47.29	47.99	48.72	49.45	49.27

Source category	N ₂ O emissions [kt]
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	2005	2010	2015	2020	2025	2030	2035	2040
F. Incineration of plant waste	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.04
4. Land Use, Land-Use Change and Forestry (LULUCF)	15.35	15.70	3.67	6.34	6.51	6.31	6.35	5.92
5. Waste	2.63	2.82	3.17	3.25	3.26	3.23	3.18	3.13
B. Biological neutralisation of solid waste	0.13	0.19	0.44	0.46	0.50	0.50	0.50	0.50
C. Ashing and open burning of waste	0.06	0.09	0.18	0.25	0.25	0.25	0.25	0.25
D. Sewage management	2.43	2.54	2.55	2.53	2.51	2.47	2.43	2.37

Source: ATMOTERM's own data

The projected CH₄ emission trends are presented in the table below. The highest CH₄ emissions come from the energy and agriculture sectors, and smaller from waste. Emissions are expected to decline in the energy and waste sectors, while agriculture is bound to see a steady slight growth.

Table 23. Projected CH₄ emissions by sectors for the ECP scenario

Source category	CH ₄ emissions [kt]							
	2005	2010	2015	2020	2025	2030	2035	2040
Total excluding LULUCF	2 139.59	2 055.20	2 000.64	1 949.35	1 881.88	1 771.79	1 667.90	1 604.75
Total including LULUCF	2 140.93	2 056.47	2 002.00	1 950.48	1 883.07	1 772.97	1 669.08	1 605.93
1. Energy	954.77	911.02	937.14	918.39	863.37	769.00	679.15	623.63
A. Fuel combustion	141.08	172.69	145.89	144.40	124.22	108.60	100.99	96.30
1. Energy industries	2.51	3.92	4.70	5.25	6.01	7.23	7.09	6.90
2. Manufacturing industries and construction	3.37	3.52	4.27	4.44	4.68	4.89	4.88	4.95
3. Transport	6.87	6.24	4.58	5.13	5.18	5.21	5.56	5.71
4. Other sectors	128.33	159.01	132.34	129.58	108.36	91.27	83.46	78.73
B. Fugitive emissions from fuels	813.69	738.33	791.25	773.99	739.15	660.40	578.16	527.33
1. Solid fuels	719.82	651.44	690.01	663.39	626.98	546.63	461.25	408.41
2. Crude oil and natural gas	93.87	86.89	101.24	110.59	112.17	113.77	116.91	118.92
2. Industrial processes and product use	1.89	2.50	2.62	2.97	3.04	3.10	3.15	3.20
B. Chemical industry	1.39	2.03	2.02	2.40	2.47	2.53	2.58	2.63
C Metal production	0.50	0.46	0.60	0.57	0.57	0.57	0.57	0.57
3. Agriculture	548.33	550.50	562.87	573.15	588.70	593.03	591.34	592.96
A. Enteric fermentation	471.12	479.57	496.78	499.76	496.21	491.88	488.27	489.71
B. Livestock manure	76.43	70.08	65.14	72.41	91.47	100.11	101.99	102.13
F. Incineration of plant waste	0.77	0.85	0.95	0.99	1.01	1.04	1.07	1.11
4. Land Use, Land-Use Change and Forestry (LULUCF)	1.34	1.27	1.36	1.13	1.18	1.18	1.18	1.18
5. Waste	634.60	591.18	498.00	454.84	426.77	406.65	394.25	384.96
A. Landfill of solid waste	474.16	444.05	387.76	354.89	328.87	310.84	298.13	288.85
B. Biological neutralisation of solid waste	2.15	3.13	7.34	7.73	8.34	8.34	8.34	8.34
C. Ashing and open	0.00000	0.00000	0.00000	0.00009	0.00009	0.00009	0.00009	0.00009

burning of waste	5	2	6						
D. Sewage management	158.30	143.99	102.90	92.21	89.56	87.47	87.78	87.77	

Source: ATMOTERM's own data

5.1.2.1.2. Comparison of projected GHG emissions and removals until 2040 with the PaMs planned under the ECP to projections with existing PaMs – ECP vs. REF.

The results of the comparison of projections of GHG emissions and removals until 2040 for the ECP scenario to projections for the REF scenario are presented in Table 24.

Table 24. Comparison of projections of GHG emissions and removals for the ECP scenario to projections for the REF scenario by main source categories

Source category	GHG emissions [ktCO ₂ eq]									
	REF scenario					ECP scenario				
	2020	2025	2030	2035	2040	2020	2025	2030	2035	2040
Total excluding LULUCF	397 810.5	403 635.2	404 739.6	370 476.2	333 869.8	384 247.1	363 471.0	336 252.8	295 011.5	271 109.8
Total including LULUCF	366 032.8	376 297.6	383 046.7	352 733.6	319 848.5	352 469.5	336 133.4	314 559.8	277 268.9	257 088.5
1. Energy	328 559.4	334 754.3	336 041.7	301 769.4	265 070.7	314 996.1	294 590.1	267 891.5	227 183.9	203 763.7
2. Industrial processes and product use	24 420.0	24 039.8	23 941.8	23 985.4	24 245.6	24 420.0	24 039.8	23 605.1	23 106.2	22 792.7
3. Agriculture	31 751.7	32 452.2	32 880.9	33 169.7	33 249.4	31 751.7	32 452.2	32 880.9	33 169.7	33 249.4
4. Land Use, Land-Use Change and Forestry (LULUCF)	-31 777.7	-27 337.6	-21 692.9	-17 742.6	-14 021.3	-31 777.7	-27 337.6	-21 692.9	-17 742.6	-14 021.3
5. Waste	13 079.4	12 388.9	11 875.2	11 551.7	11 304.0	13 079.4	12 388.9	11 875.2	11 551.7	11 304.0

Source: ATMOTERM's own data

The total greenhouse gas emissions for all forecast years for the REF scenario are clearly higher than those calculated for the ECP scenario. Difference in emissions between the scenarios. The measures to be delivered under the ECP scenario produce a reduction in emissions (with LULUCF) relative to the REF scenario of about 18% in 2030 to about 20% in 2040.

The largest reduction of CO₂ emissions between the ECP and REF scenarios will take place in the fuel combustion sector, in particular in the energy industries. Considerable differences can also be observed for other sectors, including housing and services, as well as transport. It is worth noting that the ECP scenario involves an increase in CO₂ emissions from biomass.

A comparison of projected emissions by the ETS and non-ETS (ESD) sectors for the ECP and REF scenarios is presented in Table 25 and in Figure 8.

Table 25. GHG emission projections for the ECP and REF scenarios by ETS and non-ETS

Source category	GHG emissions [ktCO ₂ eq]									
	REF scenario					ECP scenario				
	2020	2025	2030	2035	2040	2020	2025	2030	2035	2040
Total excluding LULUCF	397 810.50	403 635.22	404 739.60	370 476.24	333 869.76	384 247.14	363 471.01	336 252.75	295 011.52	271 109.81
Total including	199	203	204	176	144	188	181	169	137	121

LULUCF	685.72	891.44	972.43	238.34	822.99	921.07	772.09	525.07	797.50	846.55
EU ETS	198 124.79	199 743.78	199 767.17	194 237.89	189 046.77	195 326.07	181 698.92	166 727.68	157 214.02	149 263.27
Non-ETS (ESD)	397 810.50	403 635.22	404 739.60	370 476.24	333 869.76	384 247.14	363 471.01	336 252.75	295 011.52	271 109.81

Source: ATMOTERM's own data

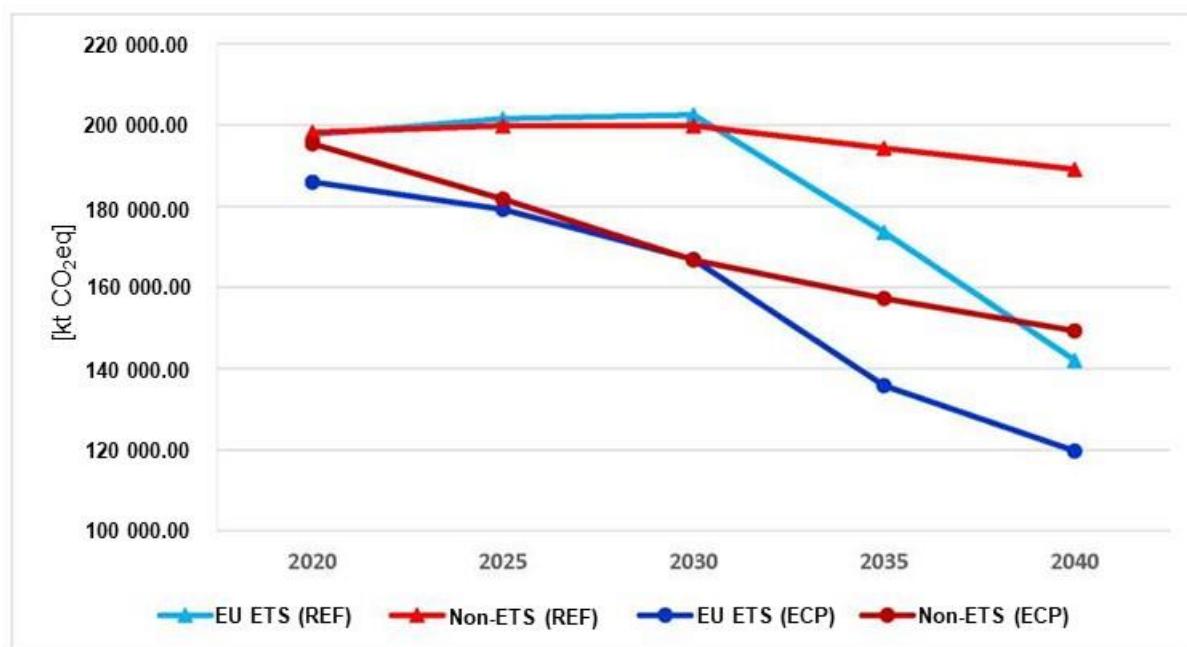


Figure 8. GHG emissions by sectors for the ECP and REF scenarios, excluding LULUCF

Until 2030, a slight initial increase in ETS greenhouse gas emissions is forecast for the REF scenario to be followed by a sharp decline. For non-ETS, the decline in emissions after 2030 is mild. In the ECP scenario, both ETS and non-ETS show a gradual downward trend, which is particularly noticeable for the ETS.

However, given the 2030 GHG emission reduction target for Poland (in the non-ETS sector) of -7% relative to 2005, it can be seen that it cannot be met in the REF scenario (the projected 2030 emissions will be higher by approx. 11% compared to the 2005 baseline), while for the ECP scenario the target will be achieved (the projected 2030 emissions will be lower by approx. 7.4% compared to 2005).

The differences in greenhouse gas emission projections for the ECP and REF scenarios (tables above) reveal the greatest changes for the following sectors:

- energy industries (notably electricity and heat production);
- manufacturing industries and construction;
- other sectors (housing, institutions/trade, services, agriculture – stationary sources);
- transport (in particular road transport).

For the above sectors, projections of 2020-2040 pollutant emissions are prepared for both scenarios (REF and ECP), following which the absolute difference in emissions between the scenarios is determined. The following pollutants are included: NOx, NMVOC (non-methane volatile organic compounds), SOx, NH3, PM2.5 and PM10. The forecast of air pollutant emissions in 2020-2040 for the REF and ECP scenarios is based on the relationship between the GHG and air pollutant emissions inventoried in the base year (2015) and in the preceding years (in accordance with KOBIZE reports to the European Commission).

The two tables below summarise pollutant emissions for the projection years and both scenarios, and the differences between the results. Depending on the type of pollution, the greatest reductions in emissions between the REF and ECP scenarios are expected for:

- NO_x – in road transport;
- NMVOC – in other sectors (in particular housing and services);
- SO_x – in other sectors, manufacturing industries and construction, as well as in electricity and heat production;
- NH₃ – in road transport;
- PM_{2,5} and PM₁₀ – in manufacturing industries and construction.

Table 26. Projected pollutant emissions from selected sectors

Year	REF scenario – emission [kt]						ECP scenario – emission [kt]					
	NO _x (as NO ₂)	NMVOC	SO _x (as SO ₂)	NH3	PM2.5	PM10	NO _x (as NO ₂)	NMVOC	SO _x (as SO ₂)	NH3	PM2.5	PM10
1A1a. Electricity and heat production												
2020	153.83	3.95	164.18	0.00	10.18	17.19	151.72	3.77	158.71	0.00	9.98	16.85
2025	134.60	4.08	136.82	0.00	8.91	15.05	126.33	3.65	132.17	0.00	8.31	14.04
2030	135.81	4.11	138.05	0.00	8.99	15.18	116.83	3.37	122.22	0.00	7.69	12.98
2035	110.14	3.34	111.95	0.00	7.29	12.31	87.88	2.54	91.93	0.00	5.78	9.76
2040	81.84	2.48	83.19	0.00	5.42	9.15	73.94	2.13	77.36	0.00	4.87	8.21
1A2. Manufacturing industries and construction												
2020	55.64	37.39	110.26	0.00	27.58	27.58	49.11	33.00	97.32	0.00	24.34	24.34
2025	54.03	36.31	107.08	0.00	26.79	26.79	43.02	28.91	85.26	0.00	21.33	21.33
2030	52.32	35.16	103.69	0.00	25.94	25.94	37.55	25.24	74.42	0.00	18.62	18.62
2035	50.60	34.01	100.27	0.00	25.08	25.08	33.88	22.77	67.14	0.00	16.79	16.79
2040	48.91	32.87	96.93	0.00	24.25	24.25	30.46	20.47	60.37	0.00	15.10	15.10
1A4. Other sectors (housing, institutions/trade, services, agriculture – stationary sources)												
2020	92.09	112.17	168.04	0.48	67.25	112.70	89.49	109.00	163.29	0.47	65.35	109.52
2025	90.69	110.46	165.47	0.48	66.22	110.98	74.65	90.93	136.21	0.39	54.51	91.36
2030	88.80	108.16	162.02	0.47	64.84	108.67	61.92	75.42	112.98	0.33	45.21	75.78
2035	86.50	105.36	157.83	0.46	63.16	105.86	55.17	67.20	100.66	0.29	40.28	67.51
2040	83.91	102.20	153.10	0.44	61.27	102.69	50.09	61.01	91.39	0.26	36.58	61.30
1A3b. Road transport												
2020	289.62	84.41	0.00	5.77	13.29	15.98	257.86	75.15	0.00	5.13	11.83	14.23
2025	305.70	89.10	0.00	6.09	14.03	16.87	249.89	72.83	0.00	4.97	11.47	13.79
2030	314.65	91.71	0.00	6.26	14.44	17.36	237.06	69.09	0.00	4.72	10.88	13.08
2035	311.85	90.89	0.00	6.21	14.31	17.21	227.41	66.28	0.00	4.53	10.44	12.55
2040	307.49	89.62	0.00	6.12	14.11	16.97	216.37	63.06	0.00	4.31	9.93	11.94

Source: ATMOTERM's own data

Table 27. Differences in projected emissions from selected sectors for the ECP and REF scenarios

Year	REF-ECP – changes in emissions [kt]					
	NO _x (as NO ₂)	NMVOC	SO _x (as SO ₂)	NH ₃	PM2.5	PM10
1A1a. Electricity and heat production						
2020	2.12	0.18	5.47	0.00	0.20	0.34
2025	8.27	0.43	4.65	0.00	0.60	1.01
2030	18.98	0.74	15.83	0.00	1.30	2.20
2035	22.26	0.80	20.02	0.00	1.51	2.55
2040	7.89	0.34	5.83	0.00	0.55	0.93
1A2. Manufacturing industries and construction						
2020	6.53	4.39	12.94	0.00	3.24	3.24
2025	11.01	7.40	21.82	0.00	5.46	5.46
2030	14.77	9.93	29.27	0.00	7.32	7.32
2035	16.72	11.24	33.13	0.00	8.29	8.29
2040	18.45	12.40	36.56	0.00	9.15	9.15
1A4. Other sectors (housing, institutions/trade, services, agriculture – stationary sources)						
2020	2.60	3.17	4.75	0.01	1.90	3.18
2025	16.04	19.53	29.26	0.08	11.71	19.63
2030	26.88	32.74	49.04	0.14	19.63	32.89
2035	31.33	38.16	57.17	0.16	22.88	38.34
2040	33.82	41.19	61.71	0.18	24.70	41.39
1A3b. Road transport						
2020	31.76	9.26	0.00	0.63	1.46	1.75
2025	55.80	16.26	0.00	1.11	2.56	3.08
2030	77.60	22.62	0.00	1.54	3.56	4.28
2035	84.43	24.61	0.00	1.68	3.88	4.66
2040	91.12	26.56	0.00	1.81	4.18	5.03

Source: ATMOTERM's own data

5.1.2.2. Renewable energy

5.1.2.2.1. Projected consumption of renewable energy

Tables 28-32 present national and sectoral forecasts for RES share, for the scenario with PaMs (ECP). The shares are compared with those obtained for the REF scenario.

As is shown by the projection results, the **2030 share of renewable energy in the final gross demand will amount to 23%**. Attaining that share will require the commitment of considerable funds and undertaking a series of robust actions across the relevant sectors, namely the electricity, heating and transport industries. As can be seen in the calculation results, by 2020, the share of RES in gross final energy consumption may reach a level consistent with the 15% target for Poland foreseen by the RES Directive¹². Achieving this will be supported by obtaining large volumes of renewable energy through auctions, as well as by stimulating the potential for co-firing biomass and coal in existing installations and enhancing the use of biofuels in transport. However, it is expected that the technological development and economic maturity of individual sources will boost the share of RES after 2020.

In the years 2021-2030, activities for the development of the domestic renewable energy potential will gain momentum. Importantly, additional volumes of renewable electricity will be provided by offshore wind farms, and large photovoltaic, biomass, and biogas installations. The gradual increase in renewable heat production and the growing amounts of biocomponents and use of electricity in transport will play a particular role, too. The model calculations take into account the growing importance of biomass in CHP and heating plants expected as a result of making district heating systems more efficient. Biomass-fired boilers are expected to be a technology that will easily replace the capacity of coal-fired boilers in existing heating plants. On the one hand, the much wider use of biomass in heat production than to date (also e.g. in the municipal and domestic sector) is necessary to attain the required increase in the share of RES in heating by at least 1.1 pp on average per annum by 2030, and on the other, to secure a specific contribution towards the targeted 23% share of renewable energy in gross final energy consumption. By 2030, the consumption of biomass for heat production in heating plants must grow almost 10 times, to 346 ktoe (in 2015, 36 ktoe of chemical energy contained in solid biomass was consumed at all Polish heating plants, while in 2016 and 2017 this was 58 and 66 ktoe respectively). Considering the limited biomass resources, this is likely to require deploying mechanisms incentivising plants with the highest production efficiency, mainly cogeneration units and heating boiler plants, to use this raw material.

The results obtained imply the need to ensure a substantial increase in the **share of renewable energy in electricity generation**. In 2015-2030, the **share of renewable energy in the power sector is set to grow from 13.4% in 2015 to 31.8% in 2030**. The sector is the one where renewable energy development can be controlled by the volumes of energy made available for auction by the Ministry of Energy. **Achieving the above RES results in the energy sector will not be possible without ensuring a substantial share of offshore wind energy. By 2030, offshore power plants with a capacity of nearly 4 GW should have been built.**

By far the highest volumes of RES are consumed by heating, which is shown both by historic data and by forecasts. As is demonstrated by the projections for the ECP scenario, the **share of renewable energy in the heating and cooling sector increases from 14.5% in 2015 to 28.4% in 2030**, which means an increase of 13.9 pp in 2015-2030 and by 11 pp in 2020-2030 (the average annual increase is therefore 1.1 pp, which is consistent with the one recommended in the RED II Directive). The completed analysis, which takes into account the optimisation of the entire national fuel and energy system and resource-related conditions (availability of primary energy carriers), shows that the pace of renewable energy development in Polish heating proposed by the RED II Directive is only achievable if sufficient financial resources are available for thorough modernisation of existing units of heating plants, 97% of which are currently based on coal. Biomass will become the main renewable energy carrier used in Polish district heating. The domestic resources of biomass and its cost, as well as the introduction of criteria for sustainable biomass production with a view to enhancing the economic and environmental effects of its use are the factors that constrain its utilisation. In the municipal and domestic sector, given the planned anti-smog measures, the increase in the use of biomass for heating purposes is not significant though noticeable. However, a much more widespread use of biomass in combined heat and power

¹² Eurostat renewable energy statistics on the progress made by other Member States towards their RES share targets in 2016 are available under the following link, access: [https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Renewable energy statistics/pl](https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Renewable%20energy%20statistics/pl)

plants is anticipated.

The production of electricity and heat by distributed sources will also add significantly to the increase in the share of RES in Polish energy consumption. The projections for RES development in buildings are presented in the next subsection.

In the transport sector, the RES share is expected to have reached 14% in 2030. This target is primarily pursued through the use of biocomponents in liquid fuels and increased use of electricity (especially in road transport), as well as through the development of biofuels from waste (mainly second-generation biofuels), the amount of which depends on the limit on the content of first-generation biofuels of up to 7%. The above forecasts indicate that a 10% share of renewable energy in transport will be achieved in 2020, but this requires a substantially increased share of biofuels used in transport in 2020, including high amounts of imported second-generation biofuels. Attaining the 2020 target in the transport sector will be very challenging since 2016 and 2017 saw a high increase in the official consumption of diesel and petrol following a decline in illegal trade in these fuels, which drives up the amount of biofuels required to reach the same percentage share. As regards the prospects for the development of renewable energy in transport in 2040, the results of the analysis demonstrate that a 22% share of RES is feasible, although this will require far-reaching growth of the market for alternative fuels, including electromobility. Electricity consumed in road transport greatly increases the share of renewable energy because of the associated use of a multiplier, which means that the energy consumed in this way is counted against the share at a level that is several times higher. Second-generation biofuels in road transport will also contribute to the target to a greater extent¹³.

The figure below presents the use of renewable energy by energy subsectors and the share of renewable energy in final energy consumption. The following tables show detailed forecasts for the use of RES by source.

¹³ The calculations for the period until 2020 use the multipliers set out in Directive 2009/28/EU, as amended by Directive 2015/1513, i.e.

- second-generation biofuels – conversion factor of 2;
- RES electricity in road transport – conversion factor of 5;
- RES electricity in rail transport – conversion factor of 2.5;

On the other hand, the multipliers used in calculations as from 2021 are consistent with Directive 2018/2001 of 11 December 2018 on the promotion of the use of energy from renewable sources:

- second-generation biofuels – conversion factor of 2;
- RES electricity in road transport – conversion factor of 4;
- RES electricity in rail transport – conversion factor of 1.5.

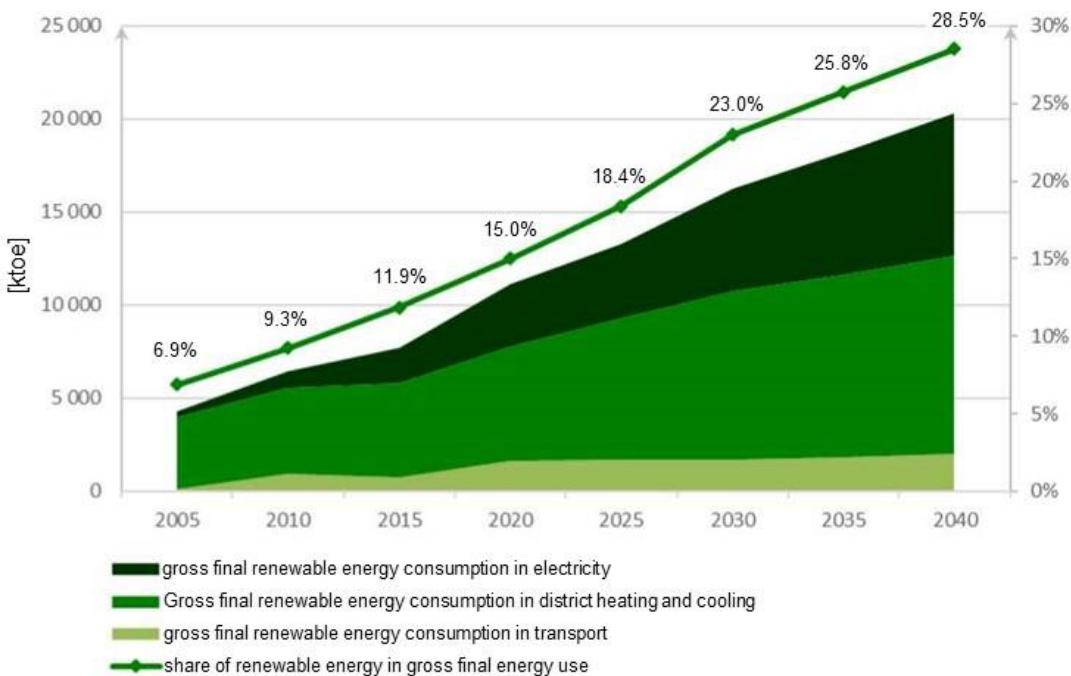


Figure 9. Gross final renewable energy consumption in the three subsectors [ktoe] and the share of RES in gross final energy consumption [%]

Table 28. Projected total and sectoral gross final renewable energy consumption [ktoe] and the share of RES consumption – total and by sector [%] – ECP scenario

[ktoe]	2005	2010	2015	2020	2025	2030	2035	2040
gross final energy consumption (RES-OS denominator)	61573.8	69156.4	64596.0	73512	71508	69345	68906	68836
gross final renewable energy consumption	4245.4	6399.3	7664.4	11 027	13 143	15 937	17 761	19 637
consumption of RES in electricity	331.7	890.3	1894.3	3369	4004	5493	6581	7715
consumption of RES in district heating and cooling	3867.6	4641.6	5116.7	6163	7604	9027	9812	10601
consumption of RES in transport	95.2	916.2	721.2	1613	1677	1708	1856	2024
[%]	2005	2010	2015	2020	2025	2030	2035	2040
share of RES in gross final energy consumption	6.9%	9.3%	11.9%	15.0%	18.4%	23.0%	25.8%	28.5%
share of RES in the electricity sector	3.1%	7.0%	13.4%	22.1%	24.8%	31.8%	36.0%	39.7%
share of RES in district heating and cooling	10.2%	11.7%	14.5%	17.4%	22.7%	28.4%	31.5%	34.4%
share of renewable energy in transport (with multipliers)	1.6%	6.6%	6.4%	10.0%	11.2%	14.0%	17.7%	22.0%

Source: Own study by ARE S.A., Eurostat

The table below also shows the expected increases in renewable energy use between 2020 and 2030, with the checkpoints marked.

Table 29. Projected gross final renewable energy consumption [ktoe] and share of renewable energy consumption [%] (trajectory) in 2020-2030, with checkpoints marked – ECP scenario

[ktoe]	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
gross final energy consumption (RES-	73512	73260	72890	72464	71993	71508	71051	70561	70151	69704	69345

(OS denominator)											
gross final renewable energy consumption	11027	11423	11939	12241	12497	13143	13758	14232	14742	15350	15937
consumption of RES in electricity	3369	3397	3506	3553	3659	4004	4281	4571	4892	5229	5493
consumption of RES in district heating and cooling	6163	6516	6909	7147	7278	7604	7966	8175	8387	8682	9027
consumption of RES in transport	1613	1583	1620	1649	1685	1677	1673	1682	1688	1696	1708
share of RES in gross final energy consumption [%]	15.0%	15.6%	16.4%	16.9%	17.4%	18.4%	19.4%	20.2%	21.0%	22.0%	23.0%
share of RES in the electricity sector	22.1%	22.1%	22.6%	22.6%	23.0%	24.8%	26.1%	27.5%	29.0%	30.6%	31.8%
share of RES in district heating and cooling	17.4%	18.6%	19.9%	20.8%	21.5%	22.7%	24.1%	25.0%	25.9%	27.1%	28.4%
share of RES in transport (with multipliers)	10.0%	9.3%	9.8%	10.2%	10.8%	11.2%	11.6%	12.2%	12.7%	13.3%	14.0%

*Table 30. Projected gross final renewable energy production in the **electricity sector** by technology [ktoe] and the shares of RES from individual technologies [%] – ECP scenario*

renewable energy production by technology [ktoe]	2005	2010	2015	2020	2025	2030	2035	2040
gross final electricity consumption (RES-E denominator)	12 396 .7	13 390 .8	14 102 .1	15 258	16 156	17 297	18 289	19 412
hydropower*	184.3	202.0	202.4	206	246	254	262	270
wind farms*	17.5	146.2	833.0	2020	2278	3290	3940	4746
photovoltaics	0.0	0.0	4.9	173	390	584	929	1274
biomass	120.4	507.8	776.2	822	835	1001	984	887
biogas	9.6	34.3	77.9	132	230	334	431	498
renewable municipal waste	0.0	0.0	0.0	17	25	30	35	40
share of technology in renewable energy consumption in the electricity sector [%]	2005	2010	2015	2020	2025	2030	2035	2040
hydropower	55.6%	22.7%	10.7%	6.1%	6.1%	4.6%	4.0%	3.5%
wind farms	5.3%	16.4%	44.0%	59.9%	56.9%	59.9%	59.9%	61.5%
photovoltaics	0.0%	0.0%	0.3%	5.1%	9.7%	10.6%	14.1%	16.5%
biomass	36.3%	57.0%	41.0%	24.4%	20.8%	18.2%	15.0%	11.5%
biogas	2.9%	3.9%	4.1%	3.9%	5.7%	6.1%	6.5%	6.5%
renewable municipal waste	0.0%	0.0%	0.0%	0.5%	0.6%	0.5%	0.5%	0.5%

Source: Own study by ARE S.A., Eurostat

*Table 31. Projected gross final renewable energy consumption in **district heating and cooling** by sources [ktoe] and share of individual types of sources in renewable energy consumption in heating and cooling [%] – ECP scenario*

Gross final renewable energy consumption in district heating and cooling by sources [ktoe]	2005	2010	2015	2020	2025	2030	2035	2040
gross final energy consumption in district heating and cooling (RES-	38064. 0	39558. 3	35202. 3	35489	33472	31794	31141	30822

H&C denominator)								
geothermal	11.4	13.4	21.7	31	45	59	75	109
solar	0.1	10.0	45.0	108	271	455	570	591
solid biomass	3814.5	4554.6	4896.0	5597	6473	7288	7555	7950
biogas	40.9	50.8	88.4	135	243	341	436	508
heat pumps	0.0	9.9	25.6	177	431	728	1001	1247
renewable municipal waste	0.7	2.9	39.9	115	140	157	176	197
share of technology in renewable energy consumption in district heating and cooling [%]	2005	2010	2015	2020	2025	2030	2035	2040
geothermal	0.3%	0.3%	0.4%	0.5%	0.6%	0.7%	0.8%	1.0%
solar	0.0%	0.2%	0.9%	1.7%	3.6%	5.0%	5.8%	5.6%
solid biomass	98.6%	98.1%	95.7%	90.8%	85.1%	80.7%	77.0%	75.0%
biogas	1.1%	1.1%	1.7%	2.2%	3.2%	3.8%	4.4%	4.8%
heat pumps	0.0%	0.2%	0.5%	2.9%	5.7%	8.1%	10.2%	11.8%
renewable municipal waste	0.0%	0.1%	0.8%	1.9%	1.8%	1.7%	1.8%	1.9%

Source: Own study by ARE S.A., Eurostat

Table 32. Projected gross final renewable energy consumption in the transport sector by technology [ktoe] and the share of the technology in renewable energy consumption in transport [%] – ECP scenario

Gross final renewable energy consumption in the transport sector by technologies [ktoe]	2005	2010	2015	2020	2025	2030	2035	2040
gross final energy consumption in transport (RES-T denominator)	10178.7	14951.0	14488.0	20295	19804	18884	18673	18356
electricity	49.1	48.8	67.8	118	142	291	488	703
first-generation biofuels/first-generation HVO/CHVO	46.1	867.4	653.4	1274	1198	999	889	832
second-generation biofuels or second-generation HVO/COHVO	0.0	0.0	0.0	221	338	418	479	489
consumption of electricity for road transport purposes classified as renewable energy	0.3	0.34	0.48	13	53	150	295	473
consumption of electricity for rail transport purposes classified as RES	43.7	43.30	61.06	96	82	132	182	218
consumption of electricity in pipeline transport classified as RES	5.2	5.13	6.26	9	7	9	11	12
total consumption of electricity in transport	343.0	287.0	267.2	355	627	1004	1356	1769
including: for road transport purposes	1.8	2.0	1.9	39	234	517	819	1190
for rail transport purposes	305.2	254.9	240.6	290	363	457	507	550
in pipeline transport	36.0	30.2	24.7	26	29	31	31	30
[%]	2005	2010	2015	2020	2025	2030	2035	2040
share of electricity in renewable energy consumption in transport	51.6%	5.3%	9.4%	7.3%	8.4%	17.0%	26.3%	34.7%
share of biofuels in renewable energy consumption in transport	48.4%	94.7%	90.6%	92.7%	91.6%	83.0%	73.7%	65.3%
share of electricity used for road transport purposes	0.5%	0.7%	0.7%	11.0%	37.3%	51.4%	60.4%	67.3%
share of electricity used for rail transport purposes	89.0%	88.8%	90.1%	81.6%	58.0%	45.5%	37.4%	31.1%
share of electricity used in other types of	10.5%	10.5%	9.2%	7.4%	4.7%	3.1%	2.3%	1.7%

transport								
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Source: Own study by ARE S.A., Eurostat

5.1.2.2.2. Projected generation of electricity and heat in buildings

The projections on the production of electricity in buildings stem from the cost optimisation carried out with the use of the MESSAGE model, which takes into account existing legislation on the development of distributed RES-based energy and the anticipated potential decrease in the cost of associated technologies. In the model, distributed sources compete with the retail price of electricity and the cost of heat generation from various types of sources. As the technologies develop and the costs of energy generation by such installations decline, they should gradually gain in importance.

The results of analysis regarding the possible production potential of RES-based small installations and microinstallations, as presented below, are based on the assumption of a gradual decrease in technology costs, growing retail prices of electricity (mainly as a result of the rising costs of the purchase of CO₂ emission allowances for units fired with fossil fuels), as well as the functioning of specific support schemes, in particular the co-funding of investment costs (subsidies), availability of preferential loans, and availability of surpluses injected into the network by prosumers subject to the system of discounts provided for by the RES Act. The growth rate has been verified through comparisons with other European countries (based on progress recorded in statistics in the last decade and predictions by reputable research institutions for the timespan under study). The results of the analysis indicate that photovoltaics will be the fastest growing technology in the category of small installations and microinstallations in buildings (with the highest rate of cost decrease).

Tables 33 and 34 present projections of electricity and heat generation from renewable energy sources by small installations and microinstallations in buildings, including data on self-consumed electricity and electricity injected into the grid. The share of energy injected into the grid in individual periods has been determined on the basis of an analysis of historical data provided by the Energy Regulatory Office (URE)¹⁴. The projections on the production of heat by microinstallations are based on the STEAM-PL simulation model, which relies on such elements as the level of demand for usable energy, existing potential, technology costs, level of subsidies, user preferences, pace of development to date, forecasts of industry organisations and reputable Polish and foreign research institutions.

Table 33. Generation of electricity through renewable energy sources in buildings [GWh]

Total gross production [GWh]				
year	Biogas plants	Photovoltaics	Wind farms	Small hydropower
2015	0	9	0	0
2020	68	710	22	22
2025	331	1586	47	57
2030	594	2550	68	93
2035	857	4959	84	129
2040	1120	7323	99	165
Self-consumption [GWh]				
	Biogas plants	Photovoltaics	Wind farms	MEW
2015	0	5	0	0
2020	55	416	6	2
2025	265	928	13	6
2030	476	1492	18	9
2035	686	2901	22	13
2040	897	4284	27	16
Energy injected into the grid [GWh]				
	Biogas plants	Photovoltaics	Wind farms	Small hydropower

¹⁴ Zbiorcze informacje dotyczące wytwarzania energii elektrycznej z odnawialnych źródeł energii w mikroinstalacji lub małej instalacji za 2016 r. (art. 17 ustawy OZE) (Summary information on renewable electricity generation by microinstallations and small installations in 2016 (Article 17 of the RES Act)) – URE Report. Warsaw, April 2017.

2015	0	4	0	0
2020	14	295	16	19
2025	66	658	35	52
2030	118	1058	50	84
2035	170	2058	61	117
2040	223	3039	73	149

Source: ARE S.A. own study (STEAM-PL, MESSAGE-PL)

Table 34. Generation of heat through renewable energy sources in buildings [ktoe]

Total gross production [ktoe]					
	Biogas plants	Solar collectors	Biomass-fired boiler heaters	Heat pumps	Geothermal
2015	0	45	1054	26	0
2020	46	108	1253	177	0
2025	133	271	1592	431	0
2030	221	455	1991	728	0
2035	277	570	2117	1001	0
2040	294	591	2300	1247	0
Self-consumption [ktoe]					
	Biogas plants	Solar collectors	Biomass-fired boiler heaters	Heat pumps	Geothermal
2015	0	45	1054	26	0
2020	46	108	1253	177	0
2025	133	271	1592	431	0
2030	221	455	1991	728	0
2035	277	570	2117	1001	0
2040	294	591	2300	1247	0
Energy injected into the grid [ktoe]					
	Biogas plants	Solar collectors	Biomass-fired boiler heaters	Heat pumps	Geothermal
2015	0	0	0	0	0
2020	0	0	0	0	0
2025	0	0	0	0	0
2030	0	0	0	0	0
2035	0	0	0	0	0
2040	0	0	0	0	0

Source: ARE S.A. own study (STEAM-PL, MESSAGE-PL)

5.1.2.2.3. Comparison of projected renewable energy consumption – ECP vs REF

Table 35 and Figure 9 summarise the results of comparisons for the two scenarios, namely ECP and REF, in terms of the nationwide and sectoral RES shares to be attained by 2030 (with an outlook for 2040). The figures reveal differences following from the assumption of a steep increase in the share of RES by 2030 in the ECP scenario. The results obtained for 2040 assume maintaining the pace of renewable technology development within the various sectors and technologies used after 2030, but they should be looked at with some caution, both due to the rather distant perspective and due to limited possibilities of verifying the possible technical potential. **All subsectors demonstrate considerable differences between the scenarios; in each of them, the 2030 ECP scenario shows percentages higher by 4-12.4 pp for the RES share, and by 7.8 pp for total gross energy consumption.**

Table 35. Comparison of nationwide and sectoral RES shares – ECP vs REF

	2005	2010	2015	2020	2025	2030	2035	2040
Nationwide RES share (ECP)	6.9%	9.3%	11.9%	15.0%	18.4%	23.0%	25.8%	28.5%
Nationwide RES share (REF)	6.9%	9.3%	11.9%	13.2%	13.9%	15.2%	16.9%	18.0%
	2005	2010	2015	2020	2025	2030	2035	2040

Share of RES in electricity (ECP)	2.7%	6.6%	13.0%	22.1%	24.8%	31.8%	36.0%	39.7%
Share of RES in electricity (REF)	2.7%	6.6%	13.0%	15.0%	16.5%	19.4%	23.9%	25.9%
	2005	2010	2015	2020	2025	2030	2035	2040
Share of RES in district heating and cooling (ECP)	10.2%	11.7%	14.5%	17.4%	22.7%	28.4%	31.5%	34.4%
Share of RES in district heating and cooling (REF)	10.2%	11.7%	14.5%	15.6%	16.5%	17.7%	18.8%	19.7%
	2005	2010	2015	2020	2025	2030	2035	2040
Share of RES in transport (ECP)	1.6%	6.6%	6.4%	10.0%	11.2%	14.0%	17.7%	22.0%
Share of RES in transport (REF)	1.6%	6.6%	6.4%	10.0%	10.4%	11.2%	12.1%	13.0%

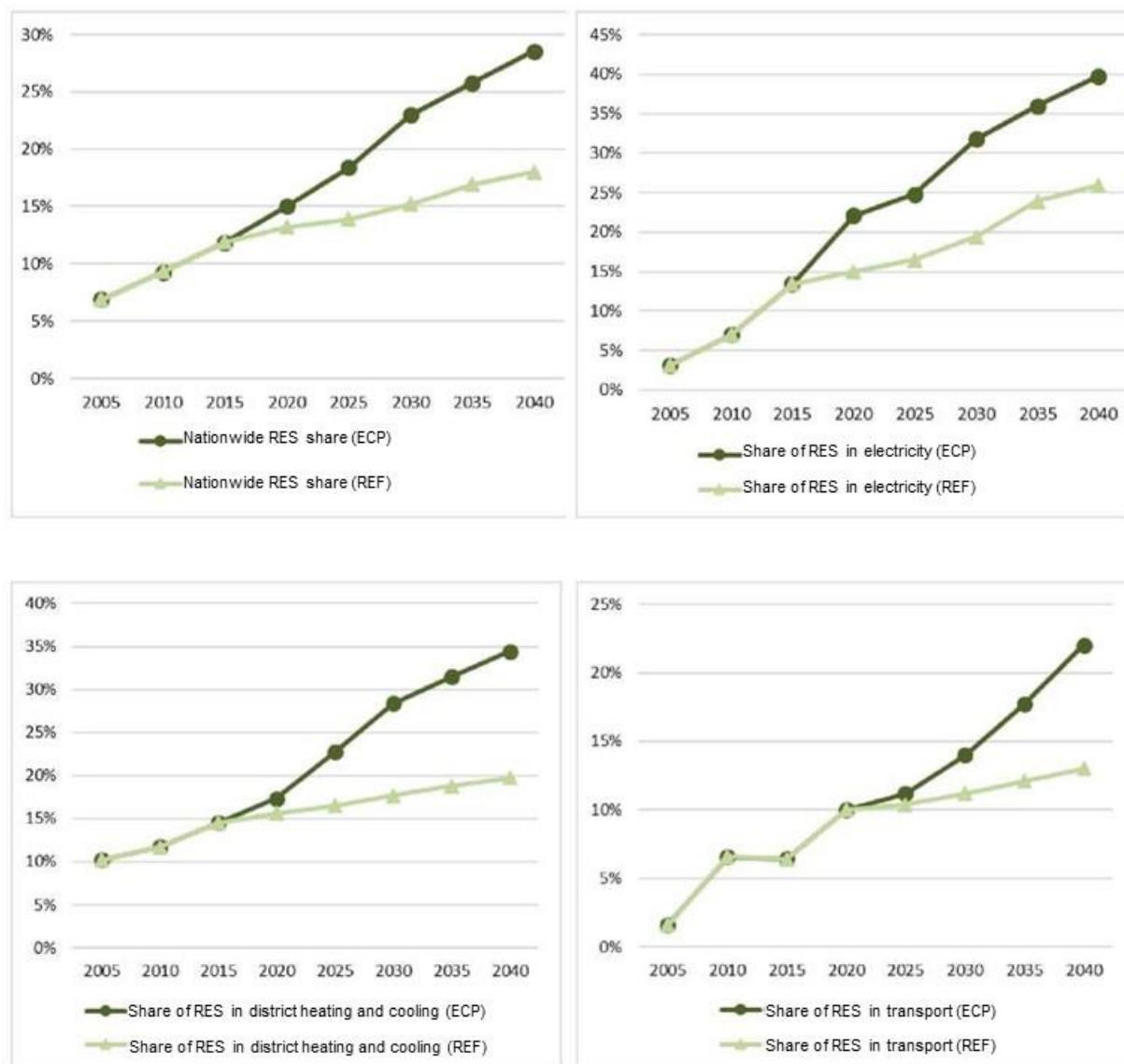


Figure 10. Comparison of nationwide and sectoral RES shares – ECP vs REF

5.1.3. ‘Energy Efficiency’ dimension

Poland intends to continue its policies that improve the energy efficiency of the economy, not only because they are consistent with the corresponding EU efforts, but also – most importantly – because they produce measurable economic and environmental benefits. It is also one of the main pillars of sustainable development. Despite the progress made in this area, the energy intensity of the Polish economy continues to deviate from the EU average. The primary energy intensity of Poland’s GDP, climate corrected, as expressed in constant 2010 prices and taking into account purchasing power parity in 2016, amounted to 0.138 kgcoe/euro10ppp and was 15% higher than the European average (0.120). The discrepancy fell by 26 percentage points compared to 2000. In 2000-2016, Poland was improving its energy intensity almost twice as fast (2.9%/year) as the EU average (1.7%/year).

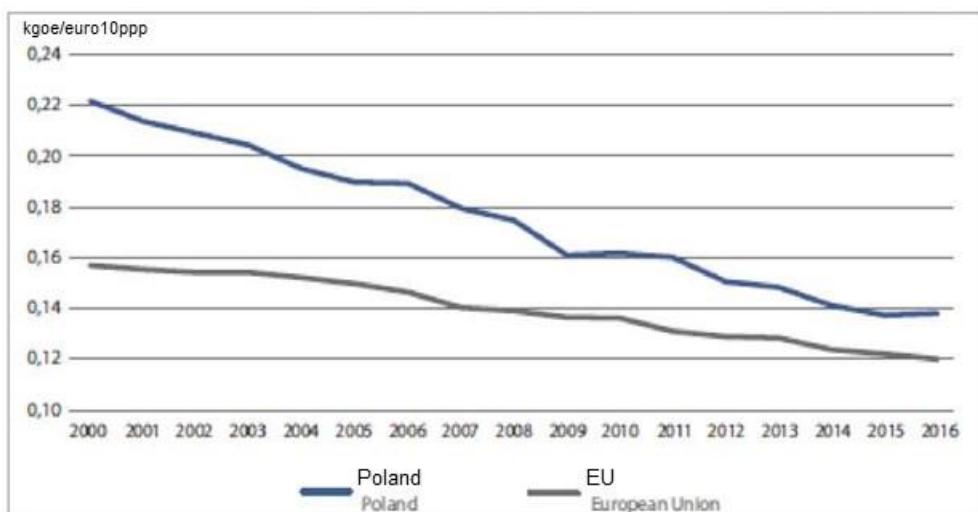


Figure 11. Primary energy intensity of GDP, climate corrected¹⁵

Reducing energy consumption is a priority in the EU. Actions to improve energy efficiency are recognised not only as a means of ensuring sustainable energy supplies, mitigating greenhouse gas emissions, improving security of supply and reducing spending on energy imports, but also as a tool for promoting EU competitiveness. In 2007, EU leaders set a 20% EU-wide consumption reduction target for 2020, and in 2018, they defined a 32.5% target for 2030. Member States

5.1.3.1. Primary and final energy consumption

The table and figure below summarise the historical and projected primary and final energy consumption in Poland. The projections presented for the ECP scenario show a decrease in demand for both primary and final energy. The results of projections stem from a number of assumptions, in particular those on the possibilities of improving energy efficiency (as described further below) in the individual sectors of the national economy and the pace of RES growth.

Table 36. Total primary and final energy consumption [ktoe]

	2005	2010	2015	2020	2025	2030	2035	2040
Primary energy consumption including non-energy use	92 560	101 558	95 739	101 890	99 893	96 848	94 556	93 391
Primary energy consumption	87 952	96 589	90 104	96 400	94 396	91 317	88 963	87 736
Final energy consumption including non-energy use	62 080	70 199	66 409	75 211	73 180	71 040	70 821	70 767

¹⁵ “Efektywność wykorzystania energii” (Efficiency of energy use) – GUS. Warsaw 2016, 2017, 2018, 2019.

Final energy consumption	57 472	65 230	60 775	69 720	67 682	65 509	65 229	65 112
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*including non-energy use

Source: ARE S.A. own study (STEAM-PL, MESSAGE-PL), EUROSTAT

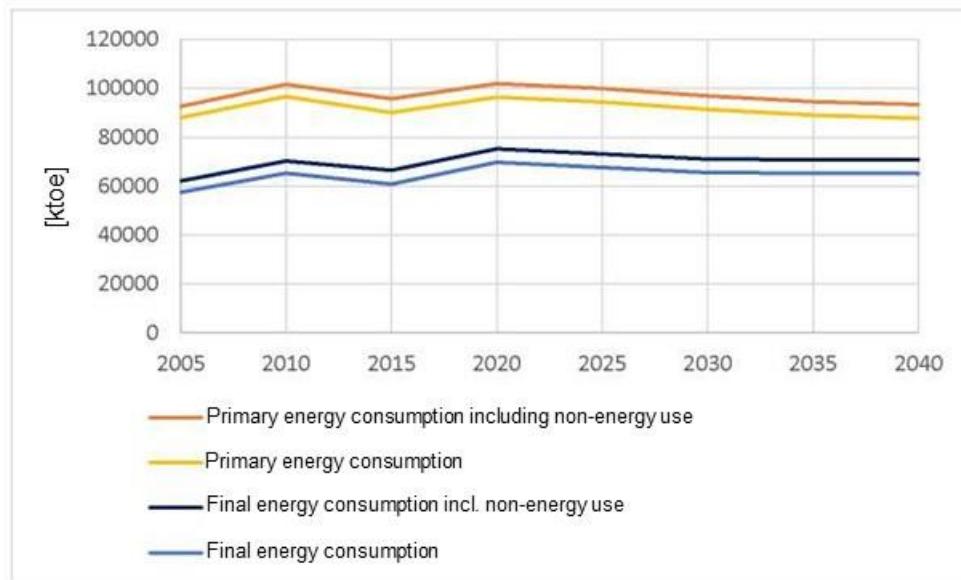


Figure 12. Total primary and final energy consumption – ECP scenario

The table below presents projections by years for 2021-2030.

Table 37. Total primary and final energy consumption in 2021-2030 [ktoe]

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Primary energy consumption including non-energy use	102 175	101 965	101 187	101 018	99 893	99 317	98 503	98 053	97 441	96 848
Primary energy consumption	96 706	96 486	95 704	95 528	94 396	93 813	92 993	92 533	91 916	91 317
Final energy consumption including non-energy use	74 905	74 557	74 140	73 674	73 179	72 753	72 278	71 839	71 388	71 040
Final energy consumption	69 436	69 077	68 657	68 184	67 682	67 249	66 768	66 319	65 863	65 509
Final energy consumption (Europe 2020-2030)	71 276	70 895	70 447	69 944	69 408	68 939	68 420	67 934	67 443	67 053

Source: ARE S.A. own study (STEAM-PL, MESSAGE-PL), EUROSTAT

The projections taking into account measures to improve energy efficiency in individual sectors of the national economy are based on the following assumptions:

- the policy oriented to increasing energy efficiency of the economy will be continued with a view to reducing its energy intensity;
- the national potential for improving energy efficiency will be exploited;
- the planned measures will be market-based to the maximum extent;
- the targets will be achieved following the minimum cost principle, that is by maximising the use of existing

- mechanisms and organisational infrastructure¹⁶;
- use will be made of any available energy efficiency improvement measures (horizontal measures, actions to improve energy efficiency in buildings and public institutions, industry, and small and medium-sized enterprises (SMEs), transport, and the electricity and heating sectors).

In order to determine the targets for improving energy efficiency in the EU, primary energy (without non-energy use) and final energy projections prepared for the European Commission in 2007 (PRIMES scenario – Baseline 2007) are used as the REF. In accordance with these projections, in 2030, the primary and final energy consumption in Poland will be 118.6 and 85.5 Mtoe respectively (109.8 and 77.4 Mtoe for 2020). The figure below presents the results of the projection of primary and final energy consumption in Poland against the background of the 2007 PRIMES scenario, which are the basis for determining the proposed percentage reduction.

The national 2030 target for improving energy efficiency is 23% and is calculated in relation to primary energy consumption in the PRIMES 2007 forecast. In absolute terms, it amounts to - 91.3 Mtoe in 2030. The results of calculations of final energy savings demonstrate that savings in final energy consumption of 21.5% relative to the PRIMES 2007 scenario are achievable. In absolute terms, the 2030 target is 67.0 Mtoe.

In 2030, the amount of primary energy saved in absolute terms is 27.3 Mtoe, which translates into a 23% reduction in relation to the consumption of energy at 118.6 Mtoe projected by the PRIMES 2007 reference scenario.

As can be seen in the projections, the 2020 energy efficiency improvement target set pursuant to Article 3(1) of Directive 2012/27/EU will be achieved. In absolute terms, meeting the commitment means primary energy consumption of up to 96.4 Mtoe (12.4% primary energy savings). However, attention must be drawn to the possible difficulties caused by adjustments to statistical data as a result of the curbing of illegal trade in liquid fuels. **The 2020 final energy savings target of up to 71.6 Mtoe¹⁷ will be achieved.**

The projections reveal a slight increase followed by a decrease in the demand for primary energy (including non-energy use) in Poland from 95.7 Mtoe in 2015 to 96.8 Mtoe in 2030 and 93.4 Mtoe in 2040. Final energy consumption first increases from 66.4 Mtoe in 2015 to 71.0 Mtoe in 2030 to stabilise at a similar level until 2040. The results of the projections are associated with a number of assumptions, in particular those related to the possibility of improving energy efficiency in the various sectors of the national economy and the pace of RES growth. The Polish economy is undergoing dynamic development, which entails increasing consumption. It is worth noting that currently the consumption of primary and final energy per capita is one of the lowest in Europe. Depending on their intensity, efforts to improve energy efficiency may hinder further growth or, at best, contribute to a partial reduction in current levels of energy demand.

The figure below compares projected primary and final energy consumption against the background of 2007 projections, which serve as the baseline for measuring energy savings.

¹⁶ "The National Energy Efficiency Action Plan for Poland", Ministry of Energy, Warsaw 2017.

¹⁷ "The National Energy Efficiency Action Plan for Poland", Ministry of Energy, Warsaw 2017.



Figure 13. Projected primary and final energy consumption against the background of the 2007 PRIMES scenario projections.

The forecast for the 2007 PRIMES scenario only spans the period until 2030, therefore the trajectories of domestic primary and final energy consumption for 2040, as shown in the figure above, are the result of extrapolation of the 2005-2030 figures. The extrapolation results obtained have been used as the REF for determining the percentage reductions in 2040, which amount to 27.3% and 23.5% for primary and final energy consumption, respectively.

The graph below depicts the year-by-year trajectory of primary and final energy consumption in 2021-2030.

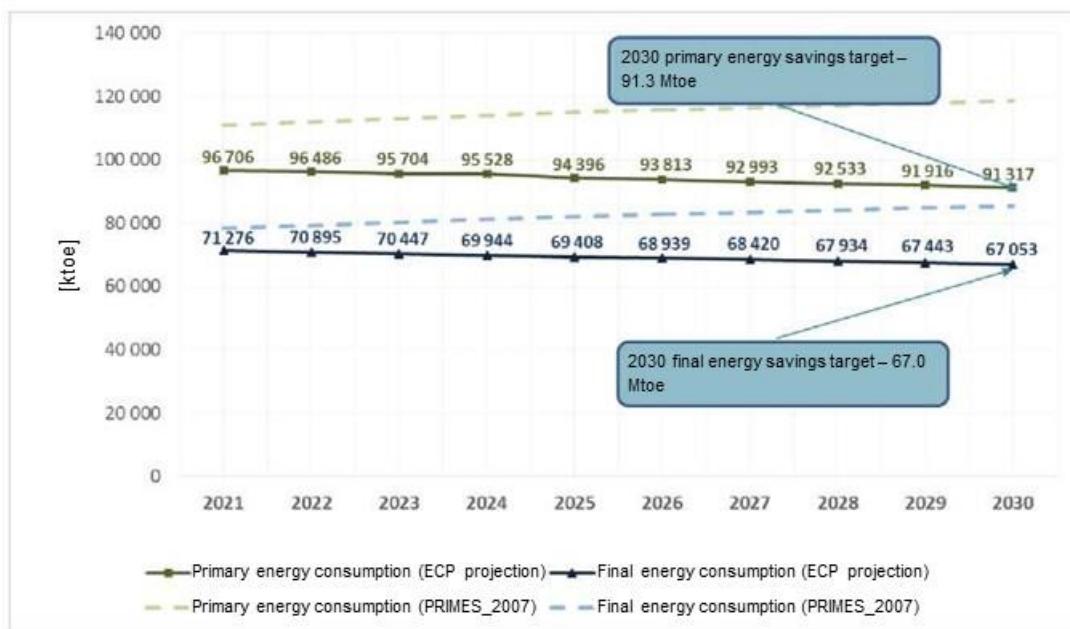


Figure 14. Projected primary and final energy consumption in 2021-2030 and energy efficiency improvement targets for 2030.

5.1.3.2. Comparison of projected primary and final energy consumption – ECP vs REF

The tables and figures below summarise the results of projections of primary and final energy demand in Poland for the ECP and REF scenarios. The differences in energy consumption between the ECP and REF scenarios represent the projected amount of energy reduction to be obtained as a result of the planned energy efficiency policies and measures over the timespans considered. Energy savings within individual energy efficiency improvement measures accumulate over time, which means that savings in a given year consist of savings from the previous year plus savings achieved through new actions implemented in a given year.

Table 38. Total primary and final energy consumption – ECP vs REF [ktoe]

	2005	2010	2015	2020	2025	2030	2035	2040
Primary energy consumption (ECP)	87 952	96 589	90 104	96 400	94 396	91 317	88 963	87 736
Primary energy consumption (REF)	87 952	96 589	90 104	98 943	102 217	104 778	103 199	102 680
Primary energy savings	-	-	-	2 543	7 821	13 462	14 235	14 944
Final energy consumption (ECP)	57 472	65 230	60 775	69 720	67 682	65 509	65 229	65 112
Final energy consumption (REF)	57 472	65 230	60 775	72 117	75 078	77 327	78 300	78 784
Final energy savings	-	-	-	2 397	7 396	11 818	13 071	13 672

5.1.3.3. Final energy savings

Below is detailed information on the methods and measures employed by Poland to implement Article 7 of

Directive 2012/27/EU on energy efficiency (EED)¹⁸.

5.1.3.3.1. Calculation of the level of the energy savings requirement to be achieved over the whole period from 1 January 2021 to 31 December 2030

Commission Recommendation on transposing the energy savings obligations under the Energy Efficiency Directive¹⁹ provides guidance on how to calculate the total amount of new final energy savings to be achieved under the obligation spanning the period 2021-2030 and specifies which statistical datasets can be used.

In accordance with the Commission Recommendation, the total amount of energy savings is to be calculated and reported under the ‘final energy’ category, which is why the analysis in this paragraph is conducted in this category.

The value of averaged annual final energy consumption and the baseline on which the energy savings will be calculated are presented in the table below, according to Eurostat data. The values of final energy consumption will be used to determine energy savings.

Table 39. Final energy consumption according to Eurostat data in 2016-2018 [ktoe]

item	category (NRG_BAL_C)	item	2016	2017	2018 (estimates)	average
FEC2020-2030	Final energy consumption [ktoe]	1	66 601	70 923	(71 700)	69 741
FC_TRA_E	Final energy consumption – transport [ktoe]	2	18 557	21 431	(22 444)	20 811
Final energy consumption (excluding energy consumed by transport) [ktoe]	3=1-2	48 044	49 492	(49 256)	48 930	

Source: own study based on Eurostat data

5.1.3.3.2. Total cumulative amount of final energy savings to be achieved in accordance with point (b) of Article 7(1) of Directive 2012/27/EU

In accordance with the first subparagraph of Article 7(1)(b) of Directive 2012/27/EU, the total energy end-use savings to be attained under the energy efficiency obligation scheme or through alternative policy measures must be equivalent to at least new savings in each year from 1 January 2021 to 31 December 2030 **at 0.8% of annual final energy consumption, averaged over the last three years preceding 1 January 2019** (69 741 ktoe on average).

In addition, according to the concept of the obligation period set out in paragraph (2)(i) of Annex V of Directive 2012/27/EU, it is considered that any individual action aimed at achieving energy savings contributes to attaining savings not only in the year when it is implemented, but also in the following years, until 2030. Therefore, the required amount of savings can “accumulate” from year to year.

¹⁸ Article 7(6) of Directive 2012/27/EU on energy efficiency (Directive of the European Parliament and of the Council (EU) 2018/2002 of 11 December 2018 amending Directive 2012/27/EU on energy efficiency) provides that Member States are required to describe in their integrated national energy and climate plans in accordance with Annex III to Regulation (EU) 2018/1999¹⁸, the calculation of the amount of energy savings to be achieved over the period from 1 January 2021 to 31 December 2030 referred to in the first subparagraph of Article 7(1)(b) of Directive 2012/27/EU and are required, if relevant, to explain how the annual savings rate and the calculation baseline were established, and how and to what extent the options referred to in Article 7(4) were applied.

Furthermore, pursuant to paragraph 5 of Annex V to Directive 2012/27/EU, Member States are required to notify to the Commission their proposed detailed methodology for the operation of the energy efficiency obligation schemes and alternative policy measures referred to in Articles 7a and 7b, and Article 20(6) of Directive 2012/27/EU.

¹⁹ Commission Recommendation of 25 September 2019 on transposing of energy savings obligations under the Energy Efficiency Directive, C(2019) 6621 FINAL.

The level of energy savings to be achieved under the obligation covering 2021-2030 was calculated in accordance with section 2.1 of the above-mentioned Recommendation.

The amount of final energy savings to be achieved in 2021 by implementing Article 7 is $(69\ 741 \times 0.8\% \times 1\ year) = 558\ ktoe$. In 2022, the cumulative amount of energy savings is $(69\ 741 \times 0.8\% \times 2\ years) = 1\ 116\ ktoe$ (including 558 ktoe from the previous year). The calculation has been made for each successive year until 2030, when the total required final energy savings is $(69\ 741 \times 0.8\% \times 10\ years) = 5\ 580\ ktoe$. **The total amount of final energy savings, understood as the amount of final energy savings cumulated from year to year, to be achieved overall in 2021-2030 is 30 690 ktoe.** The mechanism is presented in the table below.

Table 40. Final energy savings to be achieved in 2021-2030 – annual and cumulative (based on the provisions of EED) [ktoe]

year	required percentage of savings	annual energy savings [ktoe]										TOTAL
2021	0.8%	558										558
2022	0.8%	558	558									1 116
2023	0.8%	558	558	558								1 674
2024	0.8%	558	558	558	558							2 232
2025	0.8%	558	558	558	558	558						2 790
2026	0.8%	558	558	558	558	558	558					3 348
2027	0.8%	558	558	558	558	558	558	558				3 906
2028	0.8%	558	558	558	558	558	558	558	558			4 464
2029	0.8%	558	558	558	558	558	558	558	558	558		5 022
2030	0.8%	558	558	558	558	558	558	558	558	558	558	5 558
Cumulative savings in 2021-2030												30 690

Data used in the calculation of final energy consumption and sources of such data

The final energy consumption on the basis of which the energy savings are calculated are taken from the above-mentioned category (FEC2020-2030) in the Eurostat dataset. With respect to the statistical data used in calculating the required amount of final energy savings, section 2.2.1 of Commission Recommendation provides that all the elements that are required under the first subparagraph of Article 7(1)(b) of Directive 2012/27/EU are included in the relevant Eurostat category, i.e. in the category “final energy consumption – Europe 2020-2030”²⁰ (codeFEC2020-2030). This particular category in the Eurostat statistical dataset has been defined in relation to the contribution of Member States to energy efficiency and the energy savings obligation. Eurostat has revised the energy balance based on international recommendations on energy statistics published by the Statistical Commission.

5.1.3.3.3. Amounts of energy savings required using the options provided for in Article 7 item 2 of Directive 2012/27/EU

In accordance with Article 7(2) of Directive 2012/27/EU, Member States may make use of the option to count the amount of energy savings required in one or more of the following ways:

- (a) applying an annual savings rate on energy sales to final customers or on final energy consumption, averaged over the most recent three-year period prior to 1 January 2019;
- (b) **excluding, in whole or in part, energy used in transport from the calculation baseline;**
- (c) making use of any of the options set out in Article 7(4) of Directive 2012/27/EU.

At the same time (in accordance with Article 7(3) of Directive 2012/27/EU), where Member States make use of the above possibilities, they are required to establish:

- (a) their own annual savings rate; and
- (b) their own calculation baseline and energy used in transport, in whole or in part, excluded from the calculation [in ktoe];

²⁰ <https://ec.europa.eu/eurostat/documents/10186/6246844/Eurobase-changes-energy.pdf> (p. 25)

Poland will make use of the option provided for in Article 7(2)(b) of the Directive by excluding, in whole or in part, energy used in transport from the calculation baseline, as per the first subparagraph of Article 7(1) of Directive 2012/27/EU.

Consequently, the average annual final energy consumption in transport has been calculated on the basis of the Eurostat statistical dataset. The calculation has been made on the basis of statistical data from the three years (2016, 2017 and 2018) predating 1 January 2019 [in ktoe], which are given in Table 39 at the beginning of this subsection.

Table 41. Energy savings excluding energy consumed by transport

category (NRG_BAL_C)	2016	2017	2018 (estimates)	average	annual energy savings	rate
Final energy consumption [ktoe]	66 601	70 923	(71 700)	69 741	558	0.8%
Final energy consumption – transport [ktoe]	18 557	21 431	(22 444)	20 811	N/A	N/A
Final energy consumption (excluding energy consumed by transport) [ktoe]	48 044	49 492	(49 256)	48 930	563	1.15%

Table 42. Savings and rate for determining final energy savings

Final energy savings after exclusions	21 530 ktoe	These are the total final energy savings calculated using the 0.8% ratio excluding energy consumed by transport (48 930 ktoe x 0.8%)
Additional savings to be attained	9160 ktoe	These are the energy savings that are missing for the required minimum level of total energy savings to be achieved (30 690 ktoe - 21 530 ktoe)
Own savings rate required with transport excluded	1.15%	Own savings rate to be applied if energy consumed by transport is excluded from the calculation baseline (48 930 x 1.15% = 563)

The annual savings determined with the use of own savings rate are 563 ktoe, which exceeds the minimum required level, i.e. 558 ktoe (see Table 41).

In the second obligation period provided for by Article 7(1)(b) of Directive 2012/27/EU, the options referred to in Article 7(4)(b)(g) of Directive 2012/27/EU are not planned to be availed of. Consequently paragraph 2(d) and (e) of Annex III to Directive 2012/27/EU does not apply.

5.1.3.4. Final energy consumption by sectors

It follows from the projections that final energy demand is bound to stabilise in the long term, which is determined by two mutually balancing factors, namely economic growth, as measured by macroeconomic indicators, i.e. GDP and gross value added, which will generate increased demand for usable energy, and the planned energy efficiency improvement measures described in the previous subsections. As is shown by the analysis completed, reducing energy consumption beyond what is estimated by the above energy consumption reduction analysis in the situation of the anticipated economic growth in Poland may be very difficult, or at best very expensive.

By sectors (table and figure below), an increase in final energy demand is only anticipated for the transport and services sector.

The transport sector is an area where reducing or at least slowing down the growth rate will be an extremely difficult challenge. The level of motorisation in Poland is higher than in other European countries, even those with higher GDP rates. The demand for passenger and freight transport is growing and the trend is bound to

continue as a result of the improving economic situation of Poland and its efforts to catch up with the EU average level of economic development. The age and technical condition of vehicles used on Polish roads is also a serious problem. Imports of used cars with relatively high specific fuel consumption and high emissions are still on the rise, and from today's perspective, curbing it seems requisite in the context of reducing inland consumption of petroleum fuels and combating emissions.

A key focus of the plan in this respect will be on promoting electromobility, which, given the cost of technology and the need to build charging infrastructure from scratch, can in fact proceed at a significantly slower pace than assumed by the government. Therefore, it is recommended that additional measures be implemented to foster the use of CNG and hydrogen in passenger cars and commercial vehicles, which may compensate for the slower popularisation of electric vehicles. Creating conditions conducive to a road-to-rail shift is another crucial activity both with respect to passenger and freight transport.

Based on the assumptions made as regards measures to be taken to improve energy efficiency in the transport sector, the potential savings in this sector are estimated at 4.47 Mtoe in 2030 and around 4.9 Mtoe in 2040.

As mentioned above, an increase in final energy demand will also be observable in the service sector. Services are the most dynamically developing sector of the national economy (with the macroeconomic development path assumed, the added value in the sector is expected to double in 2015-2040). The increase in final energy consumption in services will primarily stem from the growing consumption of electricity. Energy savings have been estimated for all areas of energy use, i.e. space heating, WSW preparation, preparation of meals, use of electrical appliances, and room and street lighting. **Total energy reduction in services is 1.2 Mtoe in 2030 and 1.4 Mtoe in 2040.**

Energy demand is expected to decline in the other sectors. The fall is relatively small, but given the current situation and forecasts, achieving it will involve enormous effort. In households, this will depend on the success of the Clean Air programme, which entails large-scale thermomodernisation of single-dwelling buildings and complete replacement of low-efficiency solid fuel boilers until 2030. In addition, the model calculations take into account intensified actions to improve energy efficiency of electrical devices. The anticipated pace of replacement of energy-consuming devices is presented in the graphics below (figure below). The quantities on the y-axis mean the share of households that use devices from a given energy class in the total number of devices.

The final demand for energy in households in the time horizon considered drops slightly. On the one hand, the number of households is growing and housing conditions are improving, with a corresponding increase in the number of home appliances and electronic devices (a phenomenon inherent in the growth of household wealth), which drives energy consumption. On the other hand, energy efficiency of new devices is improving, which means that the potential for increased demand is also being limited. The Energy and Climate Policy scenario assumes that the pace of energy efficiency improvement will prevail over the factors that drive energy demand, which can reasonably be expected, in particular, given the high prices of energy carriers, which are a consequence of the energy and climate policy. **The projected household savings are 4.1 Mtoe in 2030 and 4.8 Mtoe in 2040**, with the highest energy efficiency improvement rate expected in 2019-2030.

In the manufacturing sector, energy demand drops very slightly. In principle, consumption stabilises if 2015 is taken as REF (increase by 3.6% y/y). **The estimated size of energy savings in the manufacturing sector is 1.7 Mtoe in 2030 and 2.2 Mtoe in 2040.**

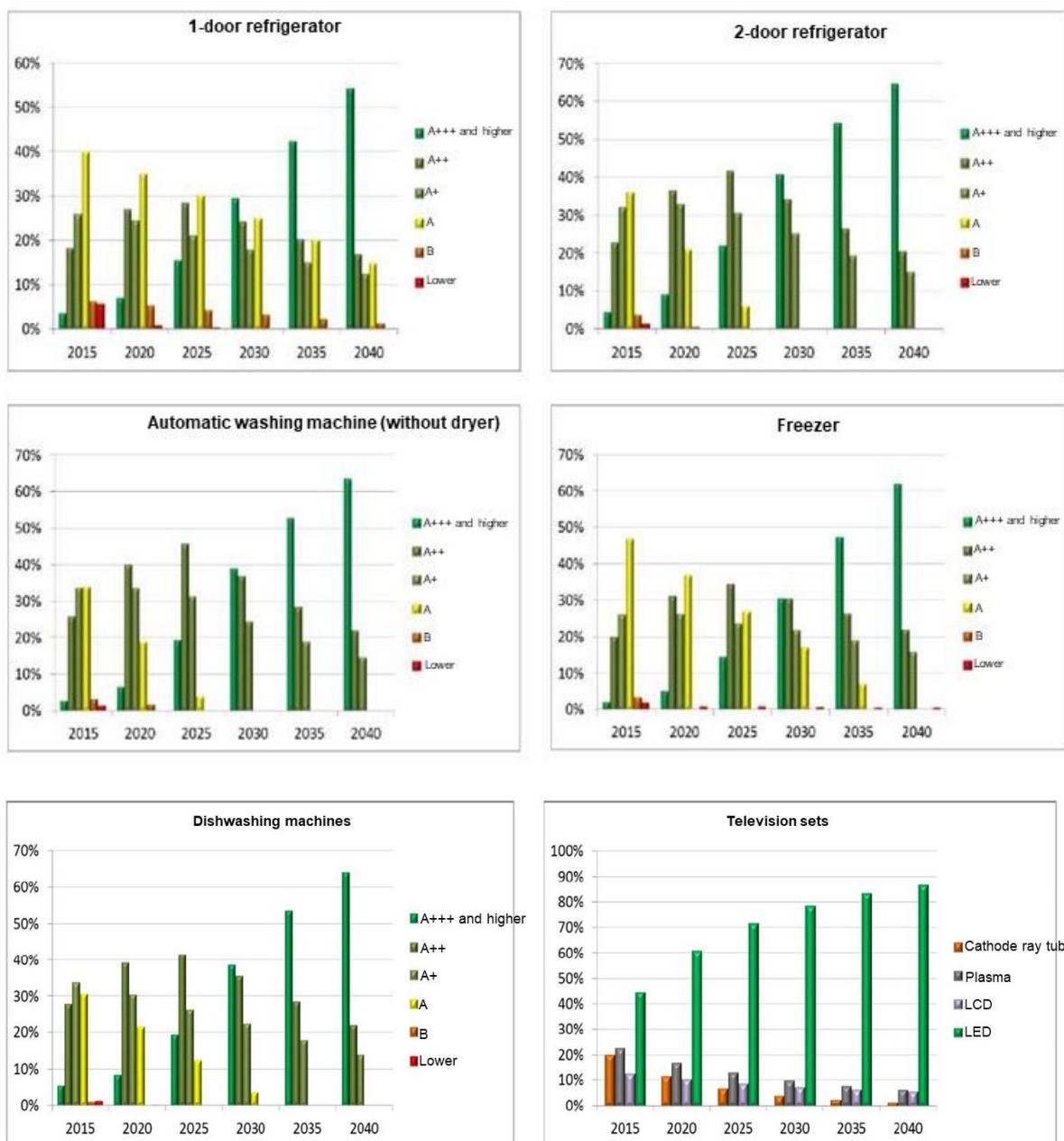


Figure 15. Household electrical device replacement rate

Table 43. Final energy consumption by sectors (excluding non-energy use) [ktoe]

	2005	2010	2015	2020	2025	2030	2035	2040
Industry	14 616	13 498	14 096	15 316	14 902	14 763	14 664	14 596
Transport	12 221	17 187	16 559	22 546	22 075	21 049	20 827	20 492
passenger	No data	No data	8 985	10 118	9 434	8 598	8 745	8 957
freight	No data	No data	7 494	12 346	12 557	12 364	11 995	11 449
Special purpose vehicles	No data	No data	79	82	84	86	87	87
Households	19 467	21 981	18 948	19 772	18 506	17 513	17 505	17 657
Services	6 730	8 833	7 842	8 343	8 586	8 700	8 853	9 079
Agriculture	4 438	3 730	3 330	3 743	3 613	3 485	3 379	3 287
TOTAL	57 472	65 230	60 775	69 720	67 682	65 509	65 229	65 112

Source: ARE S.A. own study (STEAM-PL), EUROSTAT

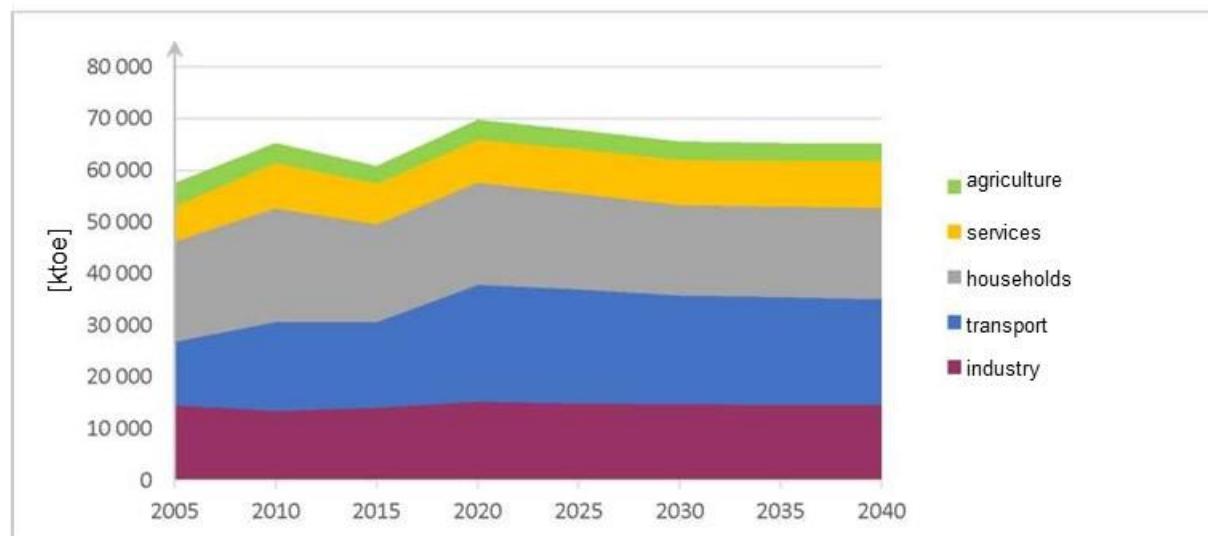


Figure 16. Final energy consumption by sectors (excluding non-energy use)

The table below presents the anticipated reduction of energy consumption in individual sectors. The negative energy savings values in the agriculture sector follow from the 2019 statistical corrections, which considerably increase the consumption of diesel in this sector.

Table 44. Reduction of final energy consumption by sectors [ktoe]

	2020	2025	2030	2035	2040
Households	496	2 483	4 102	4 566	4 758
Services	467	844	1 237	1 432	1 440
Transport	948	2 822	4 742	4 917	4 942
Industry	772	1 369	1 699	1 981	2 234
Agriculture	-287	-122	38	176	298
Final energy reduction	2 397	7 396	11 818	13 071	13 672
Energy sector	124	1 311	2 278	1 514	1 361
Primary energy reduction	2 520	8 707	14 096	14 586	15 033

Source: ARE S.A. own study

The tables and figures below summarise the results of projections of final energy demand in Poland for the ECP and REF scenarios in the individual sectors of the national economy. The differences reflect the amounts of energy savings to be obtained as a result of the planned energy efficiency improvement actions and measures.

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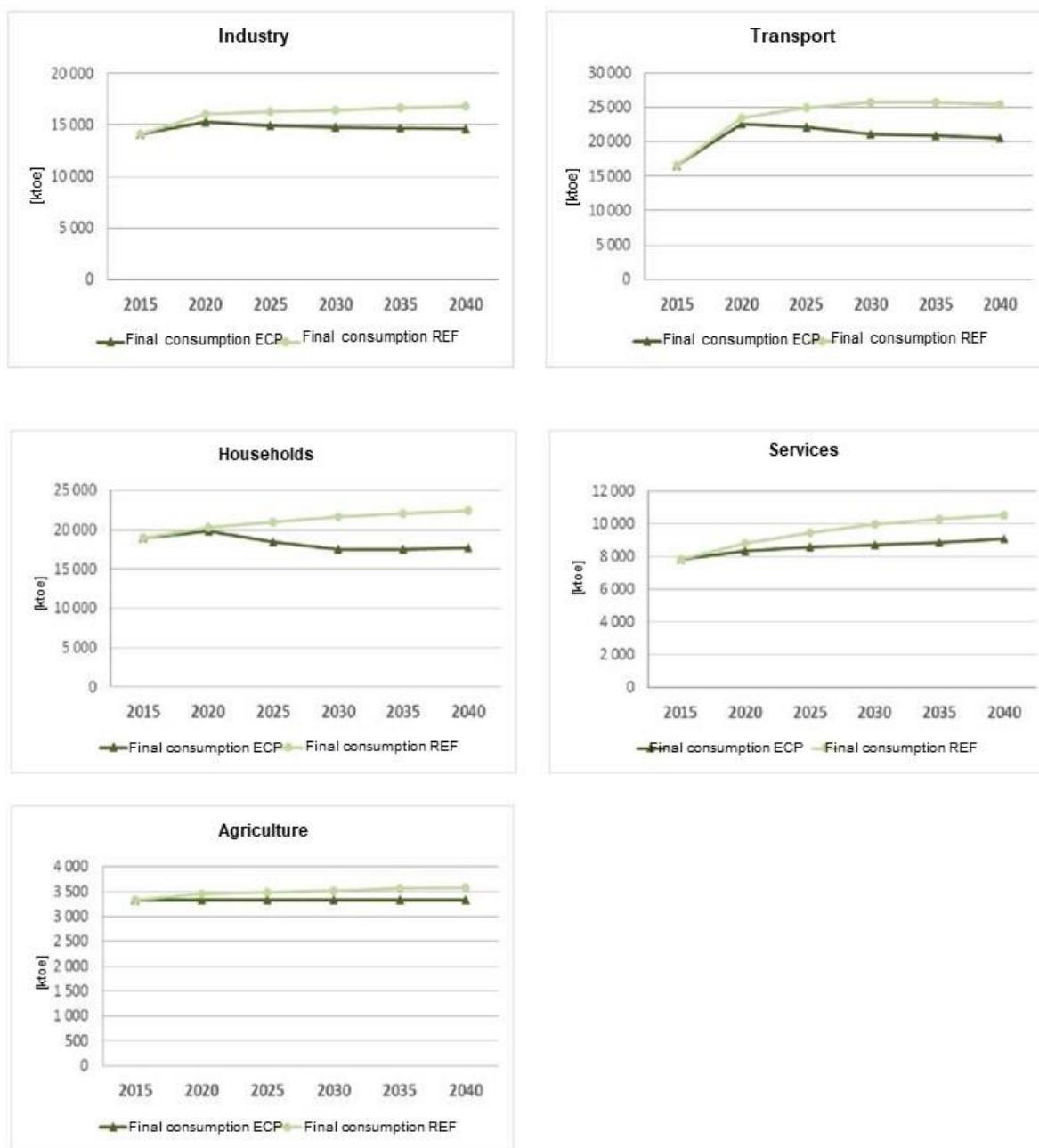


Figure 17. Final energy consumption by sectors – ECP vs REF

5.1.3.5. Final energy consumption by fuels and carriers

In final energy consumption, major changes in the fuel mix are observable. First of all, there is a significant reduction in coal consumption in the domestic economy (with the share for this carrier dropping from 18.5% in 2015 to less than 7.5% in 2030 and about 4.4% in 2040). By contrast, the consumption of electricity, natural gas and energy from renewable energy sources is gradually increasing, which is a natural consequence of the policy aimed at reducing emissions. Based on the assumptions made, a relatively small decrease in demand for district heat is expected as a result of the anticipated pace and scope of thermomodernisation of buildings and Commission's recommendations regarding the projected number of heating degree-days which reflects global warming. In turn, the limited pace of reduction follows from the assumption that efforts to connect new customers to district heating networks will be intensified in an effort to fight smog. The decrease in hard coal consumption is mainly associated with the slow but steady retrofitting of production plants (in the industry sector), which is partly required in connection with the ETS, which forces a switch to gas or electricity. The decrease in coal consumption will also be driven by the replacement of old, inefficient manually fed boilers in households,

supported by subsidies from the Clean Air programme and other dedicated schemes. Also the provisions of Regulation of the Minister of Economic Development and Finance on the requirements for solid fuel boilers²¹ which impose restrictions on boilers manufactured and installed in Poland with a capacity below 500 kW will add considerably to the reduction in the consumption of coal by households. Since its entry into force, solid fuel boilers must meet the requirements of emissivity class 5 according to PN-EN 303-5:2012. The projection assumes that all new boilers meet the criteria set forth by the Regulation.

Table 45. Final energy consumption by fuels and carriers [ktoe]

	2005	2010	2015	2020	2025	2030	2035	2040
Electricity	9 028	10 206	10 990	12 152	13 041	14 202	15 349	16 520
District heat	6 634	6 547	5 462	5 748	5 436	5 090	5 080	5 132
Coal	12 340	13 733	11 218	9 917	7 117	4 899	3 735	2 842
Petroleum products	17 563	20 213	18 646	23 822	22 602	20 911	20 063	19 124
Natural gas	7 917	8 884	8 487	10 144	10 353	10 327	10 277	10 108
Biogas	40	48	78	97	131	165	201	237
Solid biomass	3 755	4 306	4 639	5 295	5 916	6 439	6 681	7 036
Biofuels	46	867	653	1 490	1 531	1 413	1 364	1 317
Municipal and industrial waste	136	378	486	785	871	891	905	919
Solar collectors, heat pumps, geothermal	12	48	116	270	685	1 172	1 574	1 876
TOTAL	57 472	65 230	60 775	69 720	67 682	65 509	65 229	65 112

Source: ARE S.A. own study (STEAM-PL), EUROSTAT

5.1.3.6. Non-energy use

Non-energy use is the amount of energy carriers used for process needs in manufacturing certain products (e.g. consumption of gas for the production of mineral fertilisers or hard coal for the production of electrodes). The forecast assumes a moderate increase in the consumption of all energy carriers used previously for non-energy purposes in line with the historical trend observed (table below). This increase is highly correlated with economic growth. Differences in non-energy use compared to the REF scenario are negligible, and therefore are not included here.

Table 46. Non-energy use by fuels [ktoe]

	2005	2010	2015	2020	2025	2030	2035	2040
Coal	52	54	102	118	119	119	120	121
Coke	39	1	0	0	0	0	0	0
Peat	90	30	0	0	0	0	0	0
Kerosene	672	986	1 048	984	925	884	872	856
LPG	73	81	144	91	78	70	68	66
Other petroleum products	1 664	2 156	2 222	2 146	2 201	2 256	2 309	2 365
Natural gas	2 017	1 661	2 120	2 151	2 176	2 202	2 223	2 245
TOTAL	4 564	4 953	5 428	5 486	5 514	5 550	5 601	5 664

Source: ARE S.A. own study (STEAM-PL), EUROSTAT

5.1.3.7. Primary energy intensity

The table below presents the ratio of primary energy intensity to GDP for the ECP scenario. The indicator is gradually decreasing throughout the timespan considered in correspondence to the improvement in energy efficiency in the economy. As is shown by the comparisons, energy intensity per unit of GDP has been decreasing in Poland over the last several years more than twice faster than on average in the EU (it dropped

²¹ Regulation of the Minister of Economic Development and Finance of 1 August 2017 on the requirements for solid fuel boilers.

by approx. 30% relative to 2005). The primary energy intensity of GDP calculated for 2015, which amounts to 207 toe/EUR'2016 million, was almost twice higher than the EU average (approx. 89% according to EUROSAT data). The comparisons made indicate that there is significant potential for further efficiency improvement, but it is certainly not overly large and not easily obtainable. Another point is that the energy intensity index calculated by reference to the purchasing power parity (PPP), which was only 17% higher than the EU average in 2014, would be a much better indicator. The high values of the indicator lie not so much in low energy efficiency, but rather in the low values of GDP. The figure below compares the primary energy intensity/GDP ratio for the ECP and REF scenarios, while the next one compares the primary energy intensity relative to GDP for 2015 and its projected value for Poland against the background of EU countries.

Table 47. Primary energy intensity in relation to GDP [toe/EUR'2016 million]

	2005	2010	2015	2020	2025	2030	2035	2040
Country total – ECP scenario	292	254	207	181	152	128	111	99

Source: ARE S.A. own study

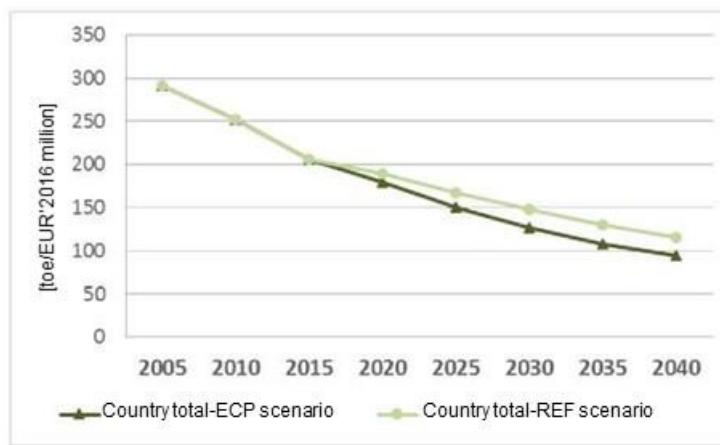


Figure 18. Ratio between primary energy intensity and GDP – ECP vs REF, Source: ARE S.A. own study

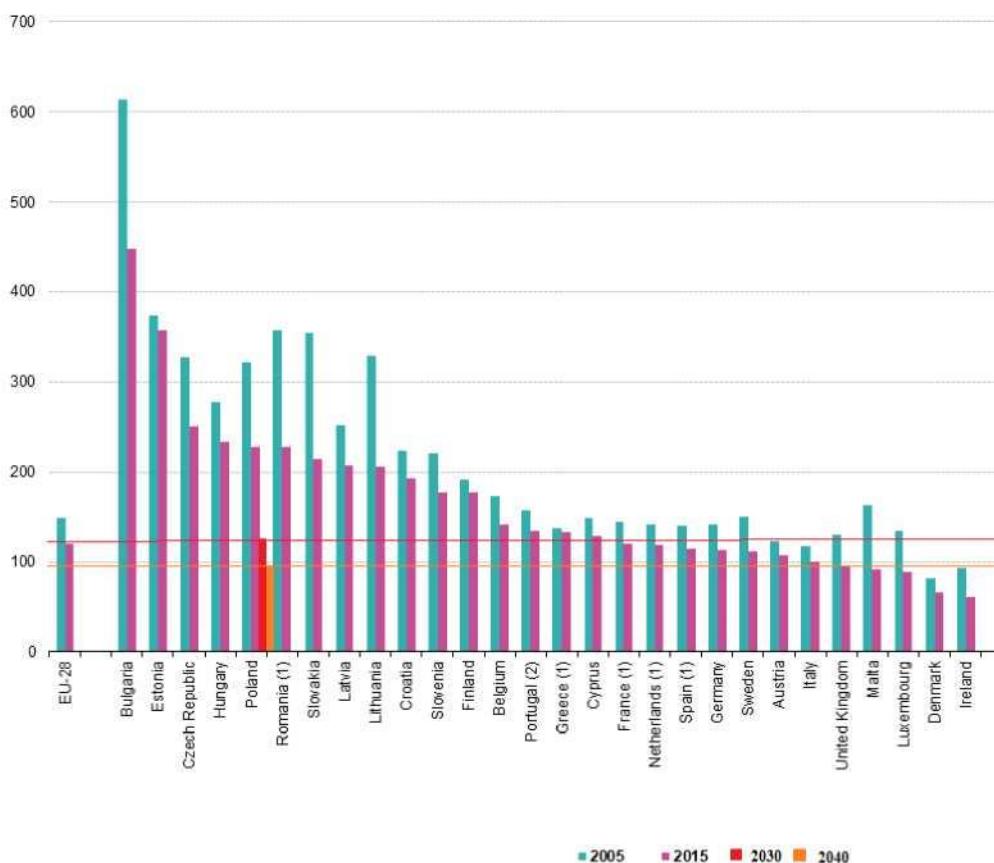


Figure 19. Primary energy intensity in Poland against the background of EU countries, Source: Eurostat, ARE S.A. (projections for Poland)

5.1.3.8. Final energy intensity by sector

The table below presents the ratios of final energy intensity by sectors. As is shown by the data, the indicators improve gradually over the period under analysis across the sectors of the national economy. The total final energy intensity for the country improves almost twice in 2015-2040. It decreases by 35% until 2030.

Table 48. Final energy intensity by sectors [toe/EUR'2016 million]

	2005	2010	2015	2020	2025	2030	2035	2040
Country total	196	175	144	134	111	94	83	75
Industry	225	156	139	132	114	100	92	85
Transport	677	930	644	727	654	581	538	501
including: passenger	no data	no data	347	324	278	236	225	217
freight	no data	no data	289	396	370	339	308	278
Services	41	43	34	30	26	22	20	18
Agriculture	431	363	349	385	364	344	326	311
Households [toe/household]	1524	1632	1357	1341	1198	1092	1059	1043

Source: ARE S.A. own study

5.1.3.9. Fuel input in electricity and heat generation

The table below presents projections of the consumption of fuels for the purposes of electricity and heat generation. The 2015-2040 consumption figures are a derivative of the optimal structure of electricity and heat production and capacity in the country determined by the dedicated model (MESSAGE-PL) and is described in detail further on.

The key conclusion that can be drawn from the results obtained is the anticipated phasing-out of coal and lignite use in the power and heating sectors, mainly due to the rising cost of CO₂ emission allowances, the need to put out of service units that are not able to meet environmental requirements, and the adverse regulatory and market environment for high-carbon plants. This is done with parallel increase in the share of fuels and technologies that are less burdensome for the natural environment (RES, gas, nuclear energy). Thanks to the introduction of a capacity market and the operation of mechanisms mitigating the effects of the sector's transformation (which is taken into account in the model), a major decrease in the consumption of coal by the power sector is noticeable only after 2030. The prices of CO₂ emission allowances assumed in the forecasting model in accordance with the Commission's recommendations rise in this period to 3040 EUR/tCO₂, pushing coal-fired plants out of the merit order curve. However, the prices of CO₂ emission allowances are a key element of uncertainty in the results obtained. During the period under consideration, the consumption of coal in the production of electricity and district heat falls from 35.3 Mtoe in 2015 to 26.6 Mtoe in 2030 and 14.9 Mtoe in 2040, which means a decrease of 25% by 2030 and 58% by 2040.²²

Table 49. Fuel input for electricity and heat generation [ktoe]

	2005	2010	2015	2020	2025	2030	2035	2040
Power plants								
Coal	2 265	1 118	507	4 722	5 925	5 990	6 047	4 796
Petroleum products	10	4	1	6	5	5	6	3
Gas	1	0	0	0	188	571	1 587	2 019
RES, waste	6	61	441	450	447	416	416	0
Combined heat and power plants								
Coal	34 392	33 935	32 375	24 369	22 282	19 746	12 223	9 681
Petroleum products	555	558	403	337	334	324	301	289
Gas	1 182	1 093	1 347	2 259	2 562	3 018	3 582	4 277
RES, waste	435	1 547	2 021	2 696	3 473	4 592	4 909	5 414
Nuclear fuel	0	0	0	0	0	0	4 624	6 936
Heat plants								
Coal	3 063	3 360	2 403	1 864	1 278	856	565	394
Petroleum products	52	36	16	23	21	20	21	24
Gas	295	277	209	154	127	111	105	109
RES, waste	40	47	42	82	193	404	423	448

Source: ARE S.A. own study (MESSAGE-PL)

5.1.3.10. Fuel input in other conversion processes

The transformation sector comprises the industrial plants that use technological processes where one form of energy (usually primary energy carriers, e.g. coal) is converted into another, derivative form of energy (e.g. electricity, heat, coke, gas from technological processes, etc.). In addition to power plants, combined heat and power plants and heating plants, which are discussed in the previous section, the transformation sector also includes refineries, petrochemical plants, gas works, coking plants, patent fuel plants and blast furnaces. Table 50 illustrates the total fuel consumption in these units. The presented data shows a slight increase in consumption associated with the growing needs of the developing economy. The consumption of all the fuel/energy carrier categories defined in the table consumed as fuel input in conversion processes is expected to increase. After 2030, the amount of processed oil decreases on account of the changes anticipated in transport (replacing petroleum fuels with other, more environmentally friendly types).

Table 50. Fuel input in other conversion processes [ktoe]

	2005	2010	2015	2020	2025	2030	2035	2040
Crude oil	18432	23188	26537	27247	27227	26784	26861	26754
Coal	9519	10559	11063	11197	10713	10601	10562	10606

²² In accordance with the EUROSTAT methodology (based on which all statistical data presented in this document is prepared), combined heat and power plants include units that generate even minimal amounts of heat (also in separate production processes, e.g. heating boiler units of utility power plants). There are few such units so the figures are small.

Petroleum products	1085	1703	1906	1864	1916	1942	1982	2009
Gas	204	308	638	649	630	596	571	545
RES, waste	0	0	0	0	0	0	0	0

Source: ARE S.A. own study (STEAM-PL)

5.1.3.11. Production of electricity through high-efficiency cogeneration

An indisputable advantage of cogeneration systems is their high energy efficiency, which significantly reduces the consumption of primary fuels, which in turn reduces emissions of CO₂ and other pollutants. In cogeneration plants, most energy savings are produced by more complete use of energy supplied in the fuel thanks to the utilisation of residual heat that accompanies separate production of useful heat and electricity. It follows from analyses, *inter alia* those carried out by ARE S.A., that Poland has the potential to install another 7.5 to 10 GW of cogeneration capacity²³²⁴. The new support scheme introduced by the Act of 14 December 2018 on the promotion of electricity from high-efficiency cogeneration should boost the growth of cogeneration and district heating and investment in new CHP sources, and the retrofitting of existing ones.

In the simulations under the model, the rate of cogeneration development in Poland is determined on the basis of projected useful heat demand, taking into account economic factors, and assuming continued support for high-efficiency cogeneration. The results of the calculations (table below) are indicative of an increase in the volume of electricity produced through high-efficiency cogeneration from approx. 26.2 TWh in 2017 to over 36.5 in 2030, which means a 30% growth. Further increase in production can also be expected until around 2035, after which electricity production will stabilise at 39 TWh (table below). The fastest-growing technologies include gas-fired CHP plants (the choice of the solution is particularly warranted by the availability of fuel and competitiveness in the face of the rising prices of CO₂ emission allowances), and renewable energy technologies supported by auctions (biomass and biogas).

Table 51. Electricity production through high-efficiency cogeneration [GWh]

	2015	2020	2025	2030	2035	2040
Total production	26 290	31 619	33 886	36 596	38 598	38 979

Source: ARE S.A. own study (MESSAGE-PL)

Despite the expected increase in electricity production through high-efficiency cogeneration, its percentage share in the total electricity generation nationwide will rise very moderately, from 16.0% in 2015 to 18.3% in 2030, to remain stable until 2035 and decrease gradually in the following years (table below). The differences between the ECP and REF scenarios result from the projected lower demand for useful heat and the steep increase in generation by electricity-only units (wind, photovoltaic and gas and nuclear after 2030).

Table 52. Percentage share of high-efficiency cogeneration in electricity production – ECP vs REF

	2005	2010	2015	2020	2025	2030	2035	2040
ECP	12.9%	17.6%	15.9%	19.3%	20.8%	18.5%	17.8%	19.1%
REF				19.3%	21.0%	21.4%	23.9%	24.4%

Source: ARE S.A. own study (MESSAGE-PL)

5.1.3.12. Production of heat in power plants, combined heat and power plants and heating plants

Currently, approx. 66%²⁵ of useful heat comes from cogeneration, while the remaining portion is produced in water boilers (heating plants and heating boiler units of utility power plants). Consequently, Poland has considerable potential that can be tapped primarily through the conversion of water boilers that do not meet the environmental requirements into cogeneration units. In addition, there are technical possibilities of utilising

²³ "Raport o stanie kogeneracji w Polsce w latach 2007-2014" (Report on the state of cogeneration in Poland in 2007-2014), ARE S.A.. Warsaw, 2015.

²⁴"Kogeneracja - wczoraj, dziś, jutro" (Cogeneration – yesterday, today, tomorrow), ARE S.A.. Warsaw 2016.

²⁵ Gospodarka paliwowo-energetyczna (Fuel and Energy Economy), GUS, Warsaw 2016

waste heat generated by industrial installations or other installations that produce waste heat. Micro-cogeneration and prosumer energy offer further opportunities.

The results indicate that heat production in combined heat and power plants will increase from approx. 185 PJ in 2015 to 213 PJ in 2025 to decrease gradually to approx. 206 PJ in 2030. **The decrease results from the lower overall demand for district heat over the period as a result of the efficiency measures taken, notably support provided for thermomodernisation and renovation investment projects.** In the last decade, there is a noticeable increase in production to around 213 PJ in 2035 and maintenance of the production level in the years that follow, mainly as a result of further replacement of coal-fired boiler plants by cogeneration units. As a consequence, heat production in heating plants will decline considerably – a fall of over 50% by 2040. There is a pronounceable decrease in heat production from coal, which stems from a shift towards natural gas and renewable energy in CHP plants, and from replacement of old coal-fired boilers into biomass-fired units in heating plants.

Table 53. Production of heat in power plants, combined heat and power plants and heating plants [TJ]

	2005	2010	2015	2020	2025	2030	2035	2040
Total production	336 391	335 831	280 106	290 684	275 843	259 615	256 690	258 732
Power plants	0	0	0	0	0	0	0	0
Combined heat and power plants	219 883	205 851	185 339	207 729	213 015	205 980	213 620	212 328
Heat plants	116 508	129 980	94 767	82 955	62 828	53 635	43 070	46 404

Source: ARE S.A. own study (MESSAGE-PL)

The table below compares the results for the ECP and REF scenarios. The differences in heat production volumes are attributable to the lower heat demand in the ECP scenario. There is also a decrease in the use of coal in the ECP scenario. The next table compares heat production in power plants and combined heat and power plants between the ECP and REF scenarios.

Table 54. Percentage share of cogeneration in district heat production – ECP vs REF

	2005	2010	2015	2020	2025	2030	2035	2040
ECP	65.4%	61.2%	66.2%	71.5%	77.2%	79.3%	83.2%	82.1%
REF				68.1%	71.4%	73.3%	76.0%	75.1%

Source: ARE S.A. own study (MESSAGE-PL)

Table 55. Production of heat in combined heat and power plants and heating plants by type of generation unit [TJ] – ECP vs REF

	2020	2025	2030	2035	2040
Combined heat and power plants (ECP)	207 729	213 015	205 980	213 620	212 328
Combined heat and power plants (REF)	200 060	218 230	230 000	244 539	247 396
% difference (ECP-REF)	3.7%	-2.4%	-11.7%	-14.5%	-16.5%
Heating plants (ECP)	82 955	62 828	53 635	43 070	46 404
Heating plants (REF)	93 662	87 302	83 902	77 096	82 182
% difference (ECP-REF)	-11.4%	-28.0%	-36.1%	-44.1%	-43.5%

The figure below presents heat production and the share of electricity and heat generated through cogeneration in relation to total electricity and heat production, based on the results presented in the tables above.

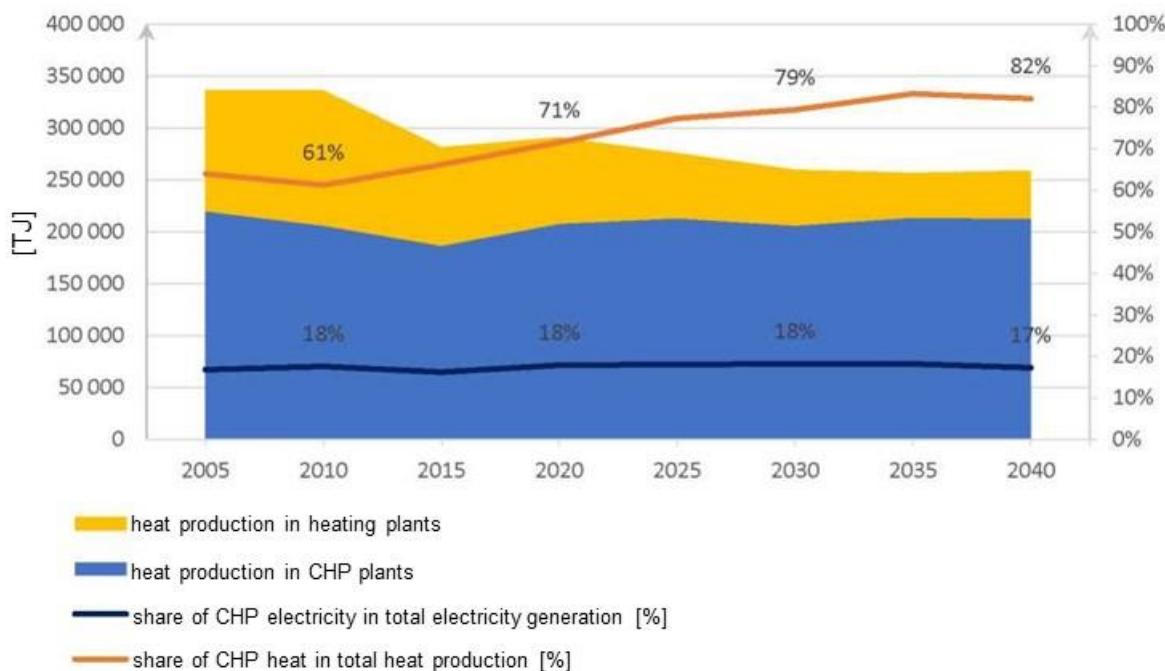


Figure 20. Heat production [TJ] and the share of electricity and heat generated through cogeneration in relation to total electricity and heat production [%]

5.1.4. ‘Energy Security’ dimension

5.1.4.1. Domestic production by fuel type

Table 56 illustrates the volume of domestic supply of individual fuels and energy carriers until 2040. The following conclusions can be drawn from the results obtained:

- Production of **hard coal** declines throughout the period – from 32.1 Mtoe in 2015 to 22.6 Mtoe in 2030 and 16.2 in 2040 (in natural units, this is 59.6 million t, approx. 36 million t and approx. 30 million t, respectively). The downward trend is associated with the decreased demand across the sectors of the domestic economy – for households to a much greater extent than in the REF scenario. The decrease in demand for coal in industry will be mainly attributed to the upgrade of production processes. In households and services, as part of anti-smog efforts, inefficient manually fed boilers will gradually be replaced by boilers meeting higher environmental standards (high energy conversion efficiency) and coal-based technologies will be replaced by more environmentally friendly ones (RES, gas, district heating). In the ECP scenario, the Clean Air programme and far-reaching thermomodernisation efforts will add considerably to the decrease in coal demand. Furthermore, it is worth stressing that to enhance the effectiveness of measures envisaged in air quality programmes and short-term action plans local governments have been provided with an additional tool as part of the amendment to the Environmental Protection Law (also known as the Anti-Smog Act) of 10 September 2015 (Journal of Laws of 2015, item 1593). Pursuant to Article 96 of the Environmental Protection Law of 27 April 2001 (Journal of Laws of 2017, item 519, as amended) provincial assemblies may, by resolution, restrict or prohibit the operation of installations in which fuels are combusted, in order to prevent an adverse impact on the environment. At the same time, such resolutions specify the types or quality of fuels that can be used or prohibited from being used.

The decommissioning of end-of-life generation units is bound to accelerate after 2030. The construction of new coal-fired units (except those for which the investment decision has already been made) will be more hindered in economic terms by the increasing prices of CO₂ emission allowances, ever tighter environmental requirements and the EU’s energy and climate policy. The Ostrołęka power unit is likely to be the last conventional coal-fired power plant built in Poland. Work on clean coal technology (CCT) may slow down the downward coal consumption trend, but foreign experience has not proven conclusively that CCT technology can be competitive. Installations fitted with CCS can only be competitive with high prices of CO₂ emission allowances, i.e. in excess of EUR 50/t.

- Extraction of **coking coal** (closely related to coke production) will fall slightly in the long term, from 9.2 Mtoe to 8.6 Mtoe in 2040. Domestic and foreign demand for coke depends on the rate of global economic growth, which means that it is subject to high, unforeseeable fluctuations. Consequently, the actual level of production may deviate considerably from the forecasts.
- The supply of **lignite** drops significantly after 2030. It is assumed that no new units will be built other than the one under construction in Turów (455 MW). The Złoczew and Ościsłowo opencast mines, which are to be launched, will supply lignite for existing generation units.
- The level of **crude oil** production will remain stable (relatively low – at around 1 Mtoe), as will domestic **natural gas** production (approx. 3.6-4 Mtoe per year).
- Fostering domestic production of first generation biofuels and launching domestic production of second and third generation biofuels are expected in response to the growing demand in the transport sector. With the use of first generation biofuels, the maximum allowable 7% share in diesel and petrol consumption can be achieved. The remaining amount of biofuels necessary to achieve the assumed RES share ceilings in the sector will be produced or imported in the form of first and second generation HCO/COHVO.
- In 2015-2030, **solid biomass** production will increase by around 56% in 2015-2030, and by 63% by 2040. The demand for biomass is bound to grow in all sectors. Along with the increase in prices of CO₂ emission allowances, the profitability of biomass utilisation in dedicated boilers, hybrid systems and installations co-firing coal should increase in the electricity and heating sector. In the household and service sector, intensified use of biomass will be associated with the replacement of outmoded coal boilers with modern pellet-fired ones. Importantly, this will be supported by the introduction as from 2021 of biomass certification to confirm compliance with EU-wide sustainability criteria. In addition, when calculating the reduction of greenhouse gas emissions from biomass, account will be taken of the release of carbon into the atmosphere, which will also affect the attractiveness of using biomass as fuel.
- Uranium ore mining and processing into nuclear fuel within Poland is not planned, but production of uranium by unconventional methods is not ruled out in the long run.

Table 56. Domestic production by fuel type [ktoe]

	2005	2010	2015	2020	2025	2030	2035	2040
Coal	45 736	35 302	32 136	29 367	27 433	22 615	18 831	16 210
Coking coal	9 948	8 216	9 155	9 339	8 809	8 668	8 588	8 564
Coke	5 721	6 701	6 666	6 653	6 397	6 401	6 456	6 560
Lignite	12 736	11 559	12 299	10 637	11 110	11 095	5 971	3 761
Crude oil	840	681	914	1 000	1 000	1 000	1 000	1 000
Natural gas	3 884	3 693	3 683	3 595	3 627	3 653	3 675	3 694
Nuclear fuel	0	0	0	0	0	0	0	0
Biofuels	117	446	936	1 100	1 133	1 042	1 006	972
Solid biomass	4 166	5 866	6 268	7 356	8 385	9 753	9 986	10 193

Source: ARE S.A. own study (STEAM-PL)

5.1.4.2. Net imports by fuel type

The import-export balance plays an important role in determining the ways of meeting demand and deciding on the electricity production mix, and influences the price of this carrier on the wholesale market.

Since 2014, a clear upward trend in the share of electricity imports has been observable in the National Power System (NPS) as a result of the growing import and export capacities and intensive subsidisation of RES, which are unstable energy sources, by neighbouring countries.

By around 2023, Poland is expected to become a net importer of electricity, unless extraordinary circumstances lead to a change in the current price relationships at interconnectors.

The planned completion of the decommissioning of German nuclear power plants in 2023 and the general

reduction in overcapacity in Central and Western Europe as a result of the shutdown and replacement of conventional energy sources may drive up prices on European energy markets. In addition, the country's energy security will be strengthened by the launch of a capacity market and commissioning of new investments (including Opole, Jaworzno, Turów, and Ostrołęka). **The strategic analyses for the NECP (i.e. of strategic nature) do not assume that the country's energy security will be based on imports.** Neither the Polish Government nor the transmission system operator are in the position to ensure availability of excess power from other EU Member States. Therefore, in the remainder of the forecast, the electricity import and export balance is expected to remain at a near-zero level, in keeping with the assumption of maintaining maximum energy self-sufficiency.

However, it must be emphasised that the precise determination of future volumes of exchange at existing and planned interconnections is characterised by high uncertainty, especially as regards the anticipated electricity prices on wholesale markets in neighbouring countries, which determine the direction and volume of transboundary trade, given that they are largely dependent on weather conditions, the legislative and regulatory environment, and many other fortuitous factors, including emergency shutdowns of power units.

Table 57. Net electricity import-export balance [ktoe]

	2005	2010	2015	2020	2025	2030	2035	2040
Electricity	-962	-116	-29	65	0	0	0	0

"-" before the value stands for exports

"+" before the value stands for imports

Source: ARE S.A. own study (MESSAGE-PL), Eurostat

The table below summarises the current situation and forecasts for net imports of other energy carriers. The data presented in the table shows the need for a slight increase in crude oil imports. Efforts to improve energy efficiency can slow down the very dynamic rate of growth in the consumption of petroleum products in transport. The negative consequences of implementing the PaMs include an increase in natural gas imports and considerable deterioration of the country's energy self-sufficiency. Steady hard coal exports is assumed in connection with the efforts to ensure liquidity, viability, and economic and financial efficiency of the hard coal mining sector.

Table 58. Net import-export balance [ktoe]

	2005	2010	2015	2020	2025	2030	2035	2040
Coal	-8 161	489	-1 588	-660	-3 148	-3 179	-3 101	-3 028
Coking coal	-1 801	944	275	57	148	223	286	342
Coke	-3 068	-4 227	-4 333	-4 090	-3 983	-4 101	-4 221	-4 341
Lignite	-2	-19	16	14	15	15	8	5
Crude oil	17 741	22 484	26 311	26 533	26 515	26 074	26 153	26 048
Natural gas	8 531	8 874	9 947	12 952	13 663	14 468	16 002	16 968
Nuclear fuel	0	0	0	0	0	0	4 624	6 936
Biofuels	-65	427	-144	397	409	376	363	350
Solid biomass	0	0	506	540	638	769	792	811

Source: ARE S.A. own study (STEAM-PL, MESSAGE-PL), Eurostat

Import dependency from third countries is defined as the total volume of energy imports from non-EU countries to gross inland energy consumption.

Table 59. Import dependency from third countries

	2005	2010	2015	2020	2025	2030	2035	2040
Electricity	1.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Coal	4.2%	13.1%	8.6%	9.3%	0.9%	0.5%	0.5%	0.5%
Coking coal	0.3%	18.3%	17.0%	15.3%	17.3%	18.4%	19.3%	20.0%
Coke	0.5%	1.2%	2.1%	3.4%	3.9%	4.4%	4.7%	4.9%
Lignite	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Crude oil	95.7%	95.9%	99.0%	97.2%	97.2%	97.2%	97.2%	97.2%

Natural gas	67.7%	61.8%	52.6%	59.0%	63.0%	65.4%	68.2%	69.8%
Nuclear fuel	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%	100.0%
Biofuels	0.0%	0.0%	6.5%	4.9%	4.9%	4.9%	4.9%	4.9%
Solid biomass	0.0%	0.0%	8.5%	7.8%	7.8%	7.8%	7.8%	7.8%
Total import dependency	12.9%	28.2%	29.7%	33.2%	32.5%	33.9%	38.6%	41.2%

Source: ARE S.A. own study

In 2015, Poland's import dependency was at a level of 29.7%. In light of the results of projections, it is bound to increase in the coming years, mainly due to imports of fossil fuels.

5.1.4.3. Main sources of imports (countries)

With respect to the main sources of imports, use is made of an expert approach that is based on an analysis of current directions of supply and prospects for the emergence of new sources. Therefore, for the majority of fuels and energy carriers analysed, no significant changes in the key sources of imports are expected (imports directions are largely determined by global developments, which are difficult to predict), with the exception of natural gas, which has been previously dominated by one supplier. The government's strategy provides for the diversification of gas supplies by the completion of an investment for transporting gas from Norway and by the intensification of purchase of liquefied gas from the United States.

Table 60. Main sources of imports (countries)

	2005	2010	2015	2020	2025	2030	2035	2040
Electricity	Germany	Germany	Sweden	Sweden	Sweden	Sweden	Sweden	Sweden
	Ukraine	Sweden	Germany	Germany	Germany	Germany	Germany	Germany
	Belarus	Czech Republic	Czech Republic	Lithuania	Lithuania	Lithuania	Lithuania	Lithuania
Coal	Russia	Russia	Russia	Russia	Russia	Russia	Russia	Russia
	Ukraine	Czech Republic	Czech Republic					
		Ukraine	Colombia					
		Kazakhstan						
Coking coal	Czech Republic	USA	Australia	Australia	Australia	Australia	Australia	Australia
	Australia	Czech Republic	Czech Republic	USA	USA	USA	USA	USA
	Germany	Australia	USA	Russia	Russia	Russia	Russia	Russia
Coke	Czech Republic	Czech Republic	Russia	Russia	Russia	Russia	Russia	Russia
		Russia						
	-	Germany	Czech Republic	Germany	Germany	Germany	Germany	Germany
Lignite			Germany					
	Russia	Russia	Russia	Russia	Russia	Russia	Russia	Russia
	Norway	Iraq						
Natural gas	Russia	Russia	Russia	Russia	Norway	Norway	Norway	Norway
	Uzbekistan	Germany	Germany	Germany	USA	USA	USA	USA
	Kazakhstan			USA	Germany	Germany	Germany	Germany
Nuclear fuel	-	-	-	-	-	-	No data	No data
Biofuels	-	No data	Germany	Germany	Germany	Germany	Germany	Germany
	-	-	Netherlands					
	-	-	Switzerland					
Solid biomass	-	No data	No data	No data	No data	No data	No data	No data

Source: ARE S.A. own study

5.1.4.4. Gross inland fuel and energy consumption

The gross inland consumption of individual fuels and energy carriers are presented in the table below²⁶. The following conclusions can be drawn from the presented data:

- An increase of inland **electricity** consumption in 2015-2030 – in absolute values, total electricity consumption increases from 14.2 Mtoe (164.6 TWh) in 2015 to 17.3 Mtoe (201.2 TWh) in 2030 to grow to 19.4 Mtoe (225.8 TWh) in 2040. The average annual growth rate in this category is 1.2% in 2016-2040. This pace is only achievable on conditions that decisive measures are taken to improve the efficiency in the use of electrical devices across the sectors of the national economy.
- The increase in the consumption of electricity by households is a consequence of the growing wealth of Poles (as measured by disposable income), the rising number of dwellings equipped with more and more appliances and their intensifying use, even though the declining consumption of electricity by these devices will slow down the pace.
- The increase in electricity consumption in industry will be mainly driven by the growing manufacture of industrial products, and by the modernisation and mechanisation of manufacturing plants.
- More electricity is also expected to be utilised in transport. In rail transport, this will be mainly driven by the improvement of the quality of rail passenger transport services and its growing popularity, while in road transport by the development of e-mobility.
- Unlike the REF scenario, a decrease in **district heat** consumption is expected as a result of the thermomodernisation of buildings (including single-dwelling ones). The projection assumes that measures to mitigate 'low-stack' emissions will provide incentives for investments in district heating development, which will slow down the downward trend, notably by increasing the number of users connected to district heating networks, even though the demand per consumer will be lower.
- The consumption of **coal and lignite** is expected to decrease as a result of the implementation of the energy and climate policy, including the reduction of emissions, high prices of CO₂ emission allowances, and limited consumption of coal by households, but also as a result of improved efficiency of generating units. The decline in coal consumption in the electricity and heating sectors accelerates considerably in 2030-2040.
- Inland consumption of crude oil and petroleum products is expected to stabilise as a result of actions taken to reduce consumption and emissions of pollutants in transport, which includes promoting alternative fuels and electromobility.
- The forecast anticipates further gradual increase in the demand for renewable energy carriers, such as biomass, biogas, biofuels and renewable municipal and industrial waste, which is a natural consequence of the process of replacing fossil fuels in the energy mix.

Table 61. Gross inland fuel and energy consumption [ktoe]

	2005	2010	2015	2020	2025	2030	2035	2040
Electricity	12 532	13 440	14 154	15 258	16 156	17 297	18 289	19 412
District heat	8 032	8 021	6 721	6 721	6 626	6 204	6 153	6 204
Coal	37 651	39 774	31 248	28 707	24 284	19 436	15 731	13 181
Coking coal	7 891	8 700	9 489	9 396	8 957	8 891	8 874	8 906
Coke	2 318	2 074	2 228	2 563	2 415	2 299	2 235	2 219
Lignite	12 726	11 576	12 283	10 651	11 124	11 110	5 979	3 766
Crude oil	18 459	23 184	26 506	27 247	27 227	26 784	26 861	26 754
Petroleum products	21 987	25 956	24 074	31 280	31 225	31 060	30 817	30 510
Natural gas	12 235	12 805	13 776	16 547	17 290	18 121	19 677	20 662
Coke oven gas	1 447	1 707	1 704	1 535	1 449	1 409	1 416	1 419
Blast furnace gas	560	526	632	576	532	489	454	428
Other gaseous fuels	161	149	163	88	76	76	75	75
Solid biomass	4 166	5 866	6 884	7 896	9 023	10 522	10 778	11 004
Biogas	54	115	229	284	318	352	388	425
Biofuels	54	868	664	1 497	1 542	1 418	1 369	1 322

²⁶ Gross inland fuel and energy consumption is calculated according to the following algorithm: (+) Final consumption

(+) Consumption in the electricity sector

(+) Consumption in the energy transformation sector

(-) Transmission and distribution losses

(+/-) Statistical differences

(=) Gross inland energy consumption

Nuclear fuel	0	0	0	0	0	0	4 624	6 936
Municipal and industrial waste	157	400	564	1 047	1 251	1 329	1 417	1 499

Source: ARE S.A. own study (STEAM-PL, MESSAGE-PL), Eurostat

5.1.4.5. Electricity and heat production

The table and graph below present data on the gross electricity and district heat production in Poland in the ECP scenario. As is shown by the projections, domestic electricity production is expected to grow from 164.9 TWh in 2015 to 201.2 TWh in 2030 and to 225.8 TWh in 2040. The percentage increase is 22% in 2015-2030 and 37% in 2015-2040. As regards domestic production of district heat, the projections anticipate a gradual decrease from 281 PJ in 2015 to 260 PJ in 2030 (over 7%) and stabilisation at a slightly lower level after 2030. The results of projections are based on the assumption that activities to improve the energy efficiency of buildings will be intensified through accelerated and more thorough renovation, and that the behaviour of heat energy consumers will change. Importantly, the volume of district heat production will be influenced by the projected number of heating degree-days, as recommended by the Commission, reflecting the global warming in our climate zone.

Table 62. Gross electricity and district heat production

	2005	2010	2015	2020	2025	2030	2035	2040
Electricity [GWh]	156 935	157 658	164 944	176 700	187 895	201 167	212 699	225 760
District heat [PJ]	336 292	335 831	281 393	290 684	275 842	259 615	256 690	258 732

Source: ARE S.A. own study (STEAM-PL, MESSAGE-PL), Eurostat

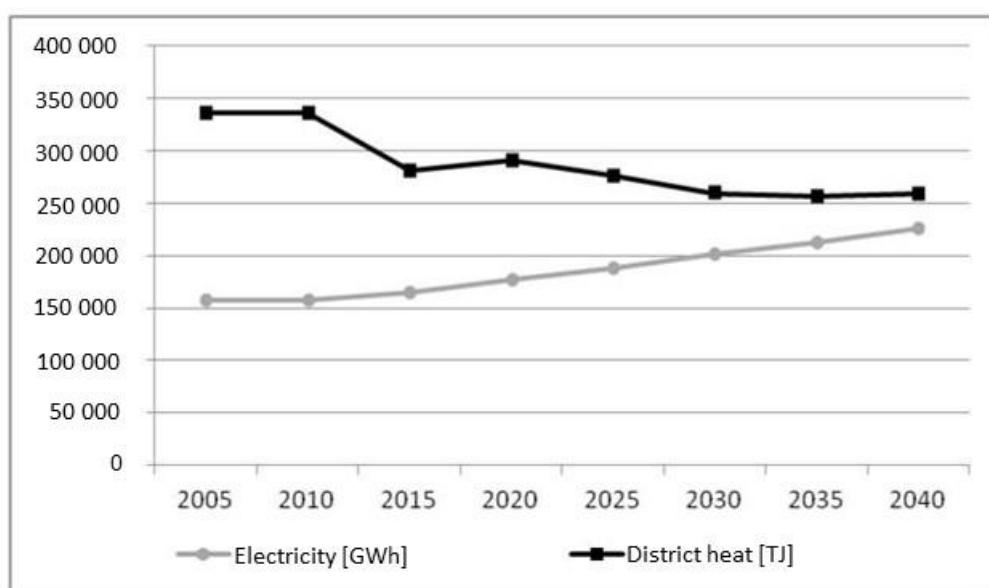


Figure 21. Gross electricity and district heat production

The table below compares the results of projections regarding electricity and district heat demand in Poland obtained for the ECP and REF scenarios. The slight discrepancies in electricity production are due to the forecast economic growth.

The results for heat vary greatly, which is attributed to the improvement of the efficiency of buildings and the ‘Clean Air’ programme. The decline occurs despite the stricter regulations regarding the obligation to connect customers to the network, as well as the wider use of district heating.

Table 63. Gross electricity and district heat production – ECP vs REF

		2015	2020	2025	2030	2035	2040
Electricity (ECP)	GWh	164 944	176 700	187 895	201 167	212 699	225 760
Electricity (REF)	GWh		178 374	192 875	204 915	212 924	220 887
Difference (ECP-REF)	%	-	-0.9%	-2.6%	-1.8%	-0.1%	2.2%
District heat (ECP)	TJ	281 393	290 684	275 842	259 615	256 690	258 732
District heat (REF)	TJ		293 722	305 532	313 902	321 635	329 578
Difference (ECP-REF)	%	-	-1.0%	-9.7%	-17.3%	-20.2%	-21.5%

5.1.4.6. Gross electricity generation by fuel

Electricity generation by fuel is presented in the table and figure below. An analysis of the lines of development of the national power sector indicate gradual shifts in the energy mix as a result of legislative and market developments. The development of renewable energy sources and requiring operators of coal-fired plants to purchase CO₂ emission allowances under the ETS will steadily decrease the share of coal-fired plants in the energy mix.

- The share of **coal-based units** in the generation structure is expected to decrease from approx. 80% in 2015 to approx. 56% in 2030 (113 TWh). The reduction in the share of coal will be mainly driven by the decommissioning of coal-fired units and the declining operating time of old coal-fired units, *inter alia* as a result of the expected enhanced use of low-carbon sources over the period (notably nuclear reactor units, high-efficiency steam-gas units and further upward trend in electricity generation from renewable energy sources, especially offshore wind farms and solar farms). Nevertheless, despite the high decline in the share, coal-fired power plants will still remain a crucial producer of electricity in the country, which is important for ensuring continued energy supplies to consumers. To a large extent, the power unit in Kozienice, the units in Opole and Jaworzno, and the unit in Ostrołęka contribute to this.
- The role of **gas-fired units** (the new ones mainly include high-efficiency gas-steam cogeneration units, and after 2024 also condensing units) grows from 4% in 2015 two and a half times until 2030 to grow at a similar pace to around 17% in 2040. The country's climate and energy policy will force the implementation of new low-carbon sources, a large proportion of which will be non-controllable intermittent renewable sources (wind farms and solar farms). Ensuring the anticipated number of such generation sources will require investing in flexible sources, demand side response (DSR), and energy storage, etc., which are necessary for the sources to be integrated with the power system. Therefore the presence of gas-fired units is crucially important for the operational security of the National Power System – gas-fired power plants are flexible enough to satisfy the increased requirements for the balancing of RES.
- The **share of renewable energy** in electricity production in 2015 (13%, 23 TWh) will more than double by 2030 (31.8%, approx. 64 TWh). By 2040, it will have reached approx. 40% (approx. 90 TWh), of which over three quarters will be produced from wind (approx. 55 TWh, 25% share in total production) and photovoltaics (ca. 15 TWh or 7%). The net volume of electricity generated from RES in 2040 may be up to four times higher than in 2015.
- The development of **nuclear energy** in Poland plays a central role in the decarbonisation policy. The first nuclear power plant unit is expected to be made operational by 2033, another two in 2035 and 2037, and three more at 2-3 year intervals. In 2040, the estimated production from nuclear power plants will be about 30.6 TWh, which translates into a 14% share in total electricity production.

Table 64. Gross electricity production [TWh]

	2005	2010	2015	2020	2025	2030	2035	2040
lignite	54.8	48.7	52.8	47.0	50.4	49.9	27.5	17.3
hard coal*	88.2	89.2	79.4	75.4	72.3	63.1	53.2	45.7
gaseous fuels**	5.2	4.8	6.4	12.0	15.3	20.7	31.3	38.4
fuel oil	2.6	2.5	2.0	1.9	1.9	1.9	1.8	1.7
nuclear energy	0.0	0.0	0.0	0.0	0.0	0.0	20.4	30.6
pumped-storage hydropower	1.6	0.6	0.6	0.6	0.8	0.9	1.2	1.5
hydropower	2.2	2.9	1.8	2.4	2.9	3.0	3.0	3.1

biomass	1.4	5.9	9.0	9.6	9.7	11.6	11.4	10.3
biogas	0.1	0.4	0.9	1.5	2.7	3.9	5.0	5.8
onshore wind	0.1	1.7	10.9	23.5	23.7	23.8	24.2	24.6
offshore wind	0.0	0.0	0.0	0.0	2.7	14.5	21.7	30.6
solar energy	0.0	0.0	0.1	2.0	4.5	6.8	10.8	14.8
other***	0.7	1.1	1.0	0.7	0.9	1.1	1.2	1.3
total	156.9	157.7	164.9	176.7	187.9	201.2	212.7	225.8

* Including coke oven gas and blast furnace gas

** Methane-rich and nitrogen-rich natural gas, mine demethylation gas, oil field gas *** Inorganic industrial and municipal waste

Source: ARE S.A. own study (MESSAGE-PL), Eurostat

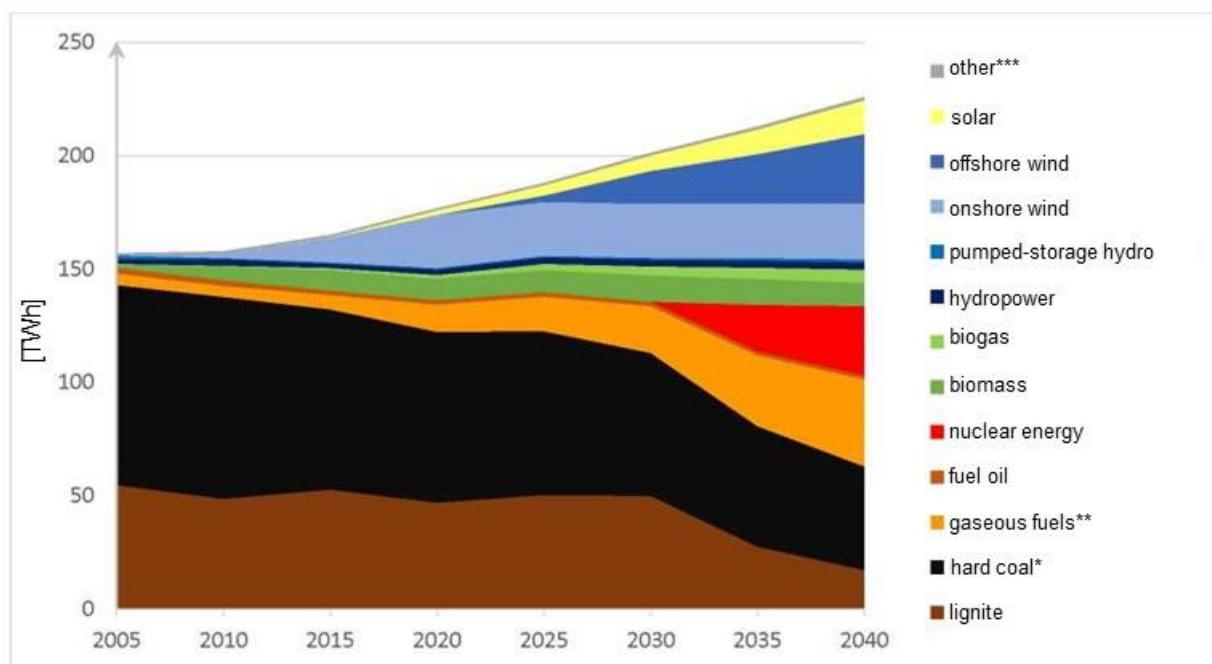


Figure 22. Gross electricity production in Poland by fuel [TWh]

The next figure presents the above-mentioned data at 5-year intervals and shows the share of coal fuels and renewable energy sources in electricity generation in 2020, 2030 and 2040. This illustrates the shift to take place in the energy mix in the next twenty years.

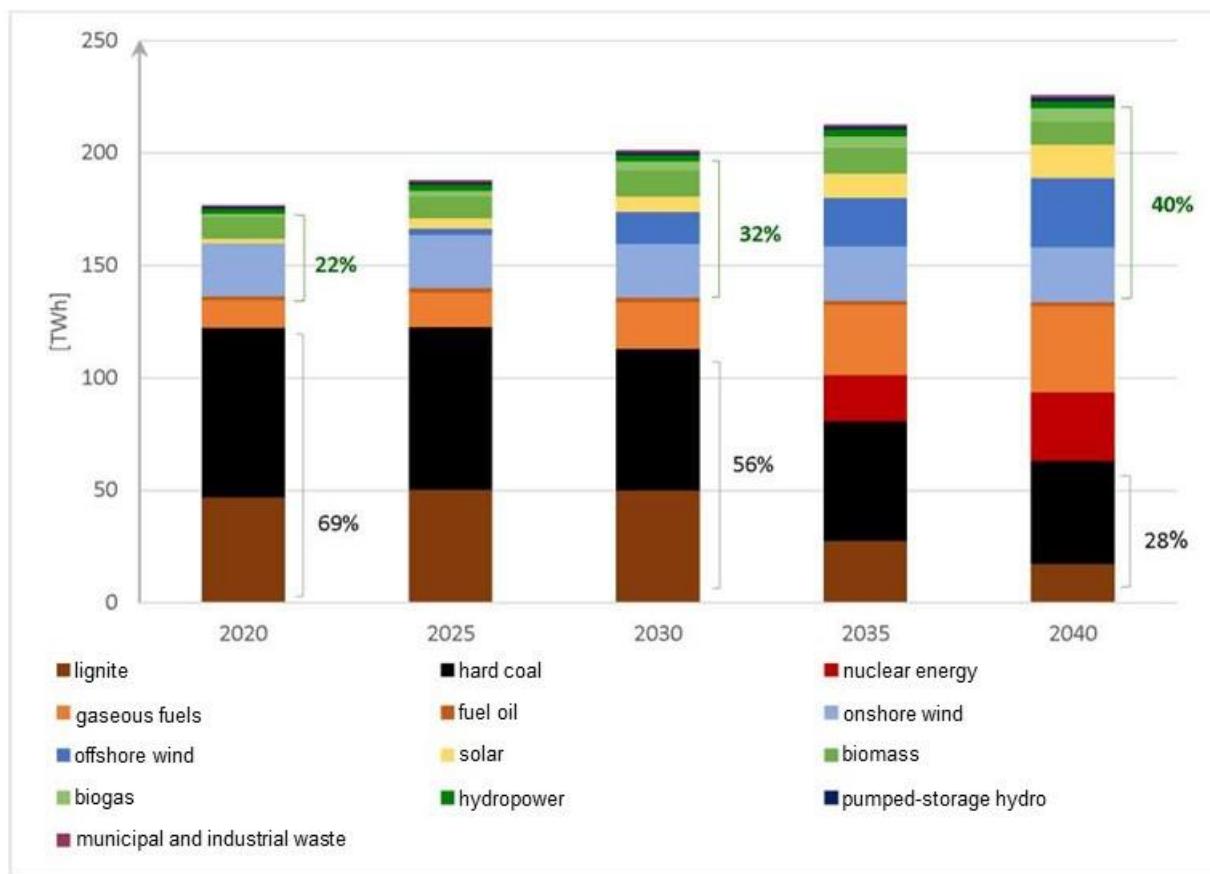


Figure 23. Gross electricity production in Poland by fuel [TWh] and shares of coal fuels and renewable fuels in the energy mix for 2020, 2030 and 2040

5.1.4.7. Electricity generation capacity by source

The results of analyses reveal a relatively large shift in the Polish electricity production mix until 2040, with the capacity of generation sources bound to increase from approx. 46 GW in 2018 (37.3 GW in 2015) to approx. 59 GW in 2030 (growth by ca. 58%) and to 72 GW in 2040, which means that it will almost double over the period (93%).

The share of **renewable energy sources** in the power balance increases gradually, from 18% in 2015 to about 40% in 2030 and 50% in 2040, mainly thanks to increased use of photovoltaic and wind power. There is an increase in the share of gas capacities, which are important for balancing the power system on account of the high operating flexibility they offer. Between 2030 and 2035, the **first nuclear unit** with a capacity of 1-1.5 GW appears in the electricity production mix (the projection assumes that a single unit will have a capacity of 1.3 GW, which does not imply what technology will be chosen). At intervals of 2-3 years, more units with a total installed capacity of approx. 6-9 GW will be made operational. The installed capacity of **energy storage** facilities and the level of DSR reserve capacities are bound to grow, too, as a result of the deployment of smart grids, increased awareness of energy consumers, and the expected popularisation of aggregators.

The projection envisages a reduction in the installed capacity of **coal-fired** utility power plants, especially past 2030. This applies in particular to near-end-of-life hard coal-fired units that will not meet the emissions requirements. Given their improved efficiency, the new coal-fired units that are currently under construction can generate more electricity with the same installed capacity (efficiency of approx. 38% vs ca. 45%). The share of installed capacity of coal- and lignite-fired units will fall from approx. 70% in 2015 to 40% in 2030 and to 19% in 2040.

The change in the fuel mix of installed capacity is **particularly noticeable after 2030**, which is connected with the decommissioning of end-of-life coal-fired units, which will be replaced by new, high-efficiency coal units (4.4 GW by 2025), development of renewable energy, construction of nuclear power units (3 units with a total

capacity of 4.5 GW), as well as with a major increase in the capacity of gas units (nearly 2 GW of new capacity may be created in gas-steam power plants by 2040). The capacity of lignite power plants is declining as a result of the decommissioning of existing units. A unit in Turów with a net capacity of approx. 450 MW is the only new lignite investment. The role of coal-fired CHP plants in the system will also be much less pronounced since most of the new cogeneration units will probably combust gas. By 2030, approx. 2.5 GW of this type of new units may be commissioned, with another 3.5 GW added in the following years until 2040. They will replace old coal-based power plants and combined heat and power plants, and after 2030, also some of the currently operating gas-fired CHP plants. Together with the new gas-steam power plants, they will improve the reliability of the power system operation, which is necessary with the large share of non-controllable renewable sources (wind and solar). Wind energy will continue to be the prevalent RES (66% of installed renewable energy capacity in 2040). The shares of the other sources in RES-E in 2040 are as follows: solar – 14.5%, biomass – 9.5% hydro – 6% and biogas – 3.5%.

Table 65. Net generating power of electricity sources by technology [MW]

	2005	2010	2015	2020	2025	2030	2035	2040
lignite-fired pp – old	8 197	8 145	8 643	7 481	6 992	6 992	4 098	2 939
lignite-fired pp – new	0	0	0	451	451	451	451	451
coal-fired pp – old	14 613	14 655	13 617	12 126	10 867	7 983	3 539	3 184
coal-fired pp – new	0	0	0	3 520	4 450	4 450	4 450	4 450
coal-fired cp	6140	6126	4 046	4 713	4 383	3 544	3 123	2 714
industrial cp			1 925	1 973	1 740	1 710	1 898	1 826
gas-fired pp	0	0	0	0	1 900	1 900	3 039	3 260
gas-fired cp	760	807	928	2 688	3 807	4 371	4 100	5 261
nuclear pp	0	0	0	0	0	0	2 600	3 900
pumped-storage hydropower	1 256	1 405	1 405	1 415	1 415	1 415	1 415	1 415
hydroelectric power stations	1 064	935	964	995	1 110	1 150	1 190	1 230
biomass pp and cp	102	140	553	658	1 143	1 531	1 536	1 272
biogas cp			216	305	517	741	945	1 094
onshore wind	121	1 108	4 886	9 497	9 574	9 601	9 679	9 761
offshore wind	0	0	0	0	725	3 815	5 650	7 985
photovoltaics	0	0	108	2 285	4 935	7 270	11 670	16 062
gas turbines	0	0	0	0	0	0	350	350
DSR/energy storage/interconnectors	0	0	0	550	1 160	2 150	3 660	4 950
total	32 253	33 320	37 290	48 656	55 167	59 073	63 391	72 103

pp – power plants, cp – cogeneration plants

Source: ARE S.A. own study

The figures below show the evolution in generating power of sources for the timespan under study (area chart) and at 5-year intervals (bar chart). The graph below also illustrates the share of coal-based sources and renewable energy sources in the energy balance in 2020, 2030 and 2040. In the 2040 perspective, these values nearly reverse, although it must be remembered that capacity installed in renewable energy sources, which are more weather-dependent, has a lower share in production. At the same time, the greatest the capacity of intermittent sources, the more reserve capacity should be available in the power system. This drives the costs of energy production due to the need to incur the capital expenditures on the dual capacities and fixed costs of 'backup' power plants. Therefore, the installed capacity is higher in the ECP scenario than in REF, too.

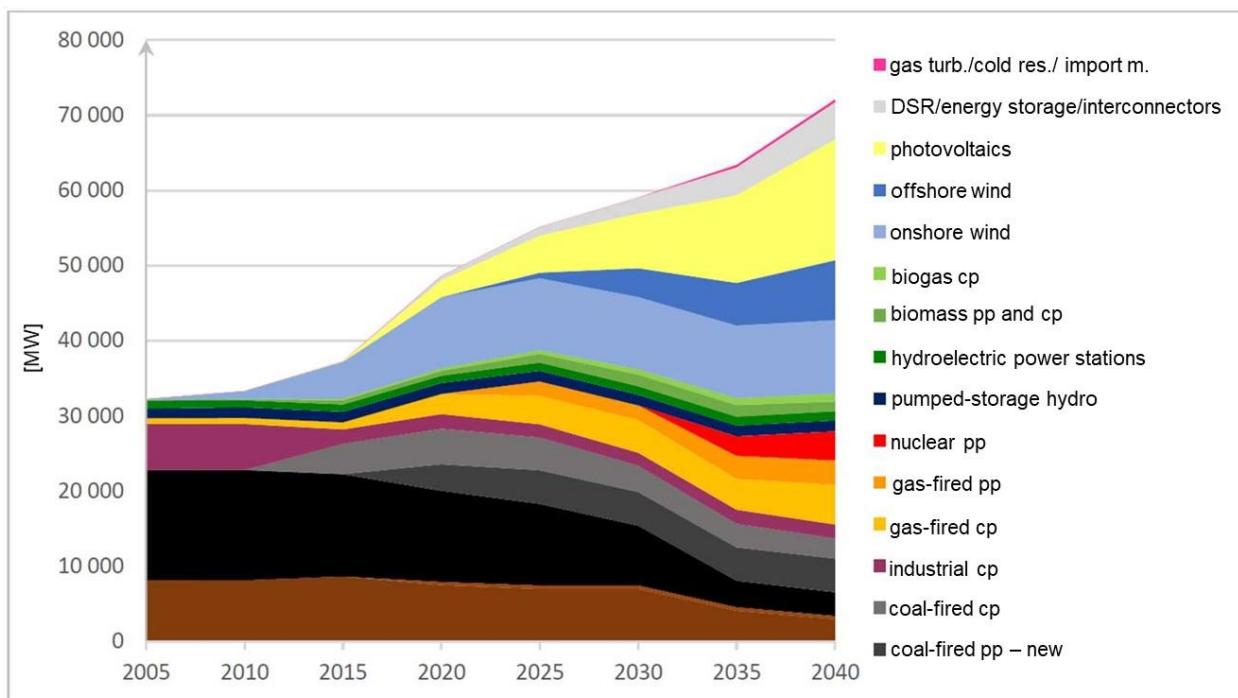


Figure 24. Generating power of electricity sources by technology [MW]

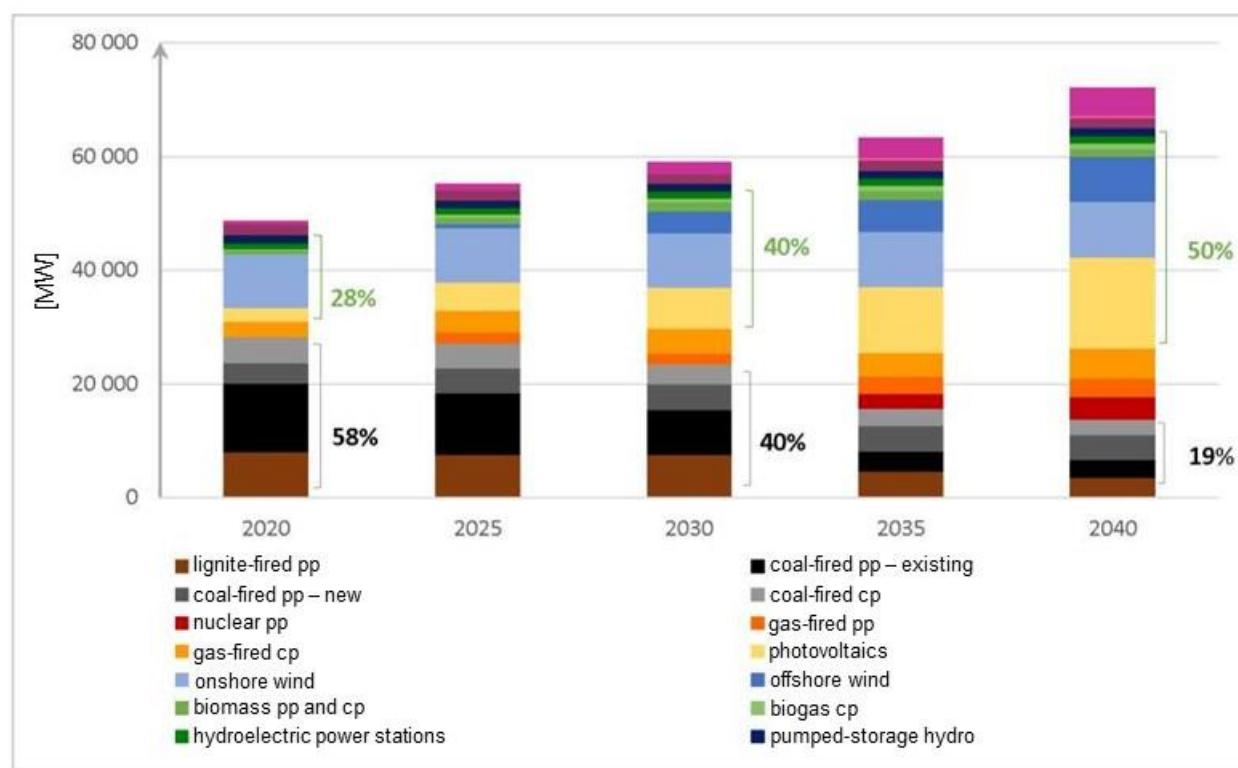


Figure 25. Generating power of electricity sources by technology [MW] and the share of coal and renewable fuels in 2020, 2030 and 2040 in the power balance

5.1.4.8. Projected decommissioning of power generation units

The timetable of the decommissioning of existing power units and retrofit plans will play an important role in building Poland's energy mix. The table below presents figures on decommissioned capacity, as broken down

into centrally dispatched generating units (CDGU) and non-centrally dispatched generating units (non-CDGU), i.e. those whose operation cannot be regulated by the transmission system operator. According to 2016-2040 estimates, approx. 26.5 GW of generation capacity will be permanently decommissioned, including approx. 15.8 GW of CDGU in thermal power plants and 3.2 GW in commercial combined heat and power plants from the non-CDGU group. The figure below illustrates the determined and planned permanent shutdowns of generating units in commercial and industrial power plants by technology.

The results are based on surveys conducted among power undertakings and information from annual reports of power undertakings. Since it was necessary to close the input of data into the analysis presented in this document, the figures given in the table may differ to some extent from the information presented in the latest documents of the transmission system operator, which always has the most recent and most detailed information in this regard. In addition, the shutdown timeline used in the projection optimisation model is based on expert assessment of the technical condition of the principal devices (boilers, turbines), the number of service hours, as well as derogations granted and the reasonableness of incurring capital expenditures in order to meet the EU requirements of emission standards following from the BAT conclusions, which can also produce discrepancies.

According to the analyses, the largest amount of generation capacity will be decommissioned after 2030, with the main sources being coal and lignite power plants. At the time, a large number of wind farms will also be shut down as a result of the end of life of the oldest turbines.

Table 66. Cumulative decommissioning in 2016-2040 [MWnet]

	2016-2020	2021-2025	2026-2030	2031-2035	2036-2040	2016-2040
Cumulative decommissioning, including:	3004	2626	4050	9806	7042	26 528
Thermal CDGU	2041	1756	2884	7398	1804	15 883
Non-CDGU commercial CHP plants	0	371	1016	1147	697	3 231

Source: own study by ARE S.A.

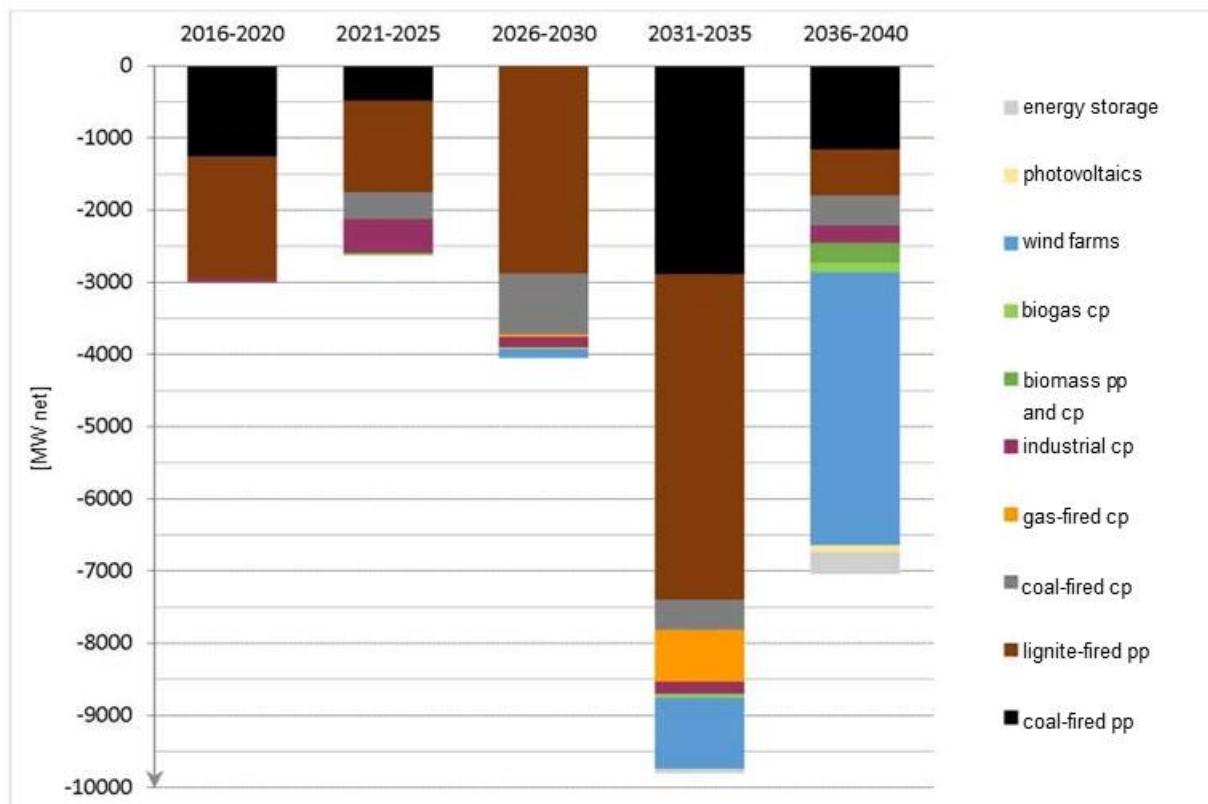


Figure 26. Projected decommissioning in 2016-2040

5.1.4.9. Electricity generation costs

The figure below shows the average annual costs of electricity generation assuming the production and capacity mix in the NPS established in the ECP scenario, as broken down into the following components: average annual capex, fixed costs, variable operations and maintenance (O&M) costs, fuel costs, and costs of CO₂ emission allowances.

The average cost of electricity production in the system in 2015 (approx. EUR'2016 9 billion) will increase by 40% by 2020 (approx. EUR'2016 13 billion), by 75% by 2030 (around EUR'2016 16 billion), and will more than double by 2040 (around EUR'2016 19.5 billion) compared to 2015. The average cost of production per unit of energy in 2015 (around EUR'2016 60/MWh) will increase by approx. 30% by 2020 (approx. EUR'2016 80/MWh), by 40% by 2030 (approx. EUR'2016 86/MWh) and by 50% by 2040 (approx. EUR'2016 90/MWh) relative to 2015.

On the one hand, the increase in the share of renewable energy reduces the costs of fuel and of the purchase of CO₂ emission allowances, but on the other, the need to build and maintain reserve capacity to stabilise the system drives fixed and capital costs up, which are several times higher in 2040 than in 2015. It must be emphasised that the costs presented here only contain the generation component, and do not include network costs, which are a condition for handling such a significant increase of power in the system (in addition to current investments to upgrade existing lines).

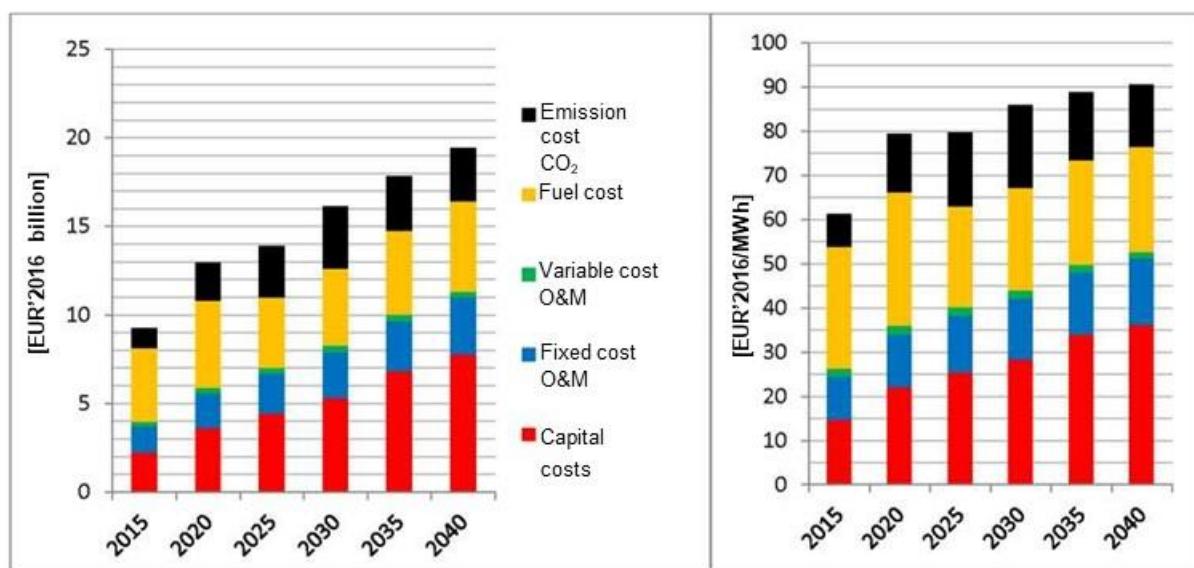


Figure 27. Average annual electricity production costs in Poland

The decarbonisation of the Polish energy sector will be a long-lasting and very costly process, which must be spread over time in such a way as to mitigate the resulting economic and social impacts. Estimates of anticipated capital expenditures for the ECP scenario are presented in section 5.3.

5.1.5. ‘Internal Energy Market’ dimension

5.1.5.1. Electricity transmission infrastructure

The main aim regarding the electricity transmission infrastructure in Poland is to balance the supplies of electricity with the demand for it and to ensure that the power system is capable of satisfying justified needs for domestic and transboundary transmission of electricity in the long run. Polskie Sieci Elektroenergetyczne S.A. (PSE S.A.), a state sole proprietorship, is the Polish electricity transmission system operator (eTSO) responsible for ensuring secure operation of the NPS and reliability of electricity supply.

The high and extra highest voltage transmission network consists of over 250 lines with a length exceeding 14 000 km and over 100 extra highest voltage transformer stations. Currently, Poland has active connections with Germany, the Czech Republic, Slovakia, Lithuania and Sweden (undersea cable), as well as two connections with a third country (Ukraine), one of which is out of service (Chmielnicka-Rzeszów). The internal energy market is being built by maximising cross-border exchange between interconnected power systems (while ensuring secure operation of these systems), which shapes, and consequently, aligns wholesale electricity prices across the EU. It must also be emphasised that Poland is of the opinion that security of electricity supply should be based on well-developed domestic generation, transmission and distribution infrastructures.

In order to achieve the above objectives, the eTSO will pursue activities consisting of the construction, extension and modernisation of substations, switchgear, lines and other devices, including those used for reactive power compensation within the high and extra highest voltage range (110-220-400 kV) over the whole timespan under analysis. As a result of the implementation of investment programmes until 2025, the following should be primarily ensured:

- possibility of evacuating power from the following power plants: Kozienice, Turów, Bełchatów and efficient transmission of power from the Dolna Odra Power Plant;
- extension of the network in the north, north-west (where a large proportion of windfarms are located on account of good wind conditions), north-east parts of Poland, as well as above and below the imaginary Warsaw-Poznań line;
- better use of the Krajanik-Vierraden interconnection (improved interconnections within the Poland-Germany-Czech Republic-Slovakia synchronous area);
- the exploitability of the Poland-Lithuania undersea connection (Harmony Link).

The distribution network is formed by over 700 000 km of high voltage, medium voltage and low voltage lines and almost 260 thousand substations, i.e. part of the 110 kV lines and all below. Distribution is a regulated activity, and electricity distribution system operators (eDSOs) are responsible for the operation and maintenance, and if necessary also the development of the distribution system and interconnections, as well as for ensuring that the system is capable of satisfying reasonable demand for power distribution in the long run.

In order to ensure the highest quality of electricity supply and development of electromobility (sufficient network capacity and possibility of connecting recharging points), DSOs pursue the objectives and tasks resulting from the quality regulation defined by the President of the Energy Regulatory Office (URE). Since 2018, the methodology for determining the supply quality indicators has taken into account both weather anomalies and the diversity of areas (large cities, cities with district rights, towns and villages), as well as the current level of development in the area of a given eDSO. Activities of eDSOs primarily comprise the restoration of infrastructure, building new lines, but also actions to increase the overhead-to-underground conversion ratio for the medium-voltage network.

5.1.5.2. Electricity transmission capacity

As regards enhancing the possibility of cross-border exchange for Poland, the key objective is to ensure secure operation of the NPS within the interconnected system. In the first place, this should be ensured through the optimal use of existing interconnections and the construction of the power lines missing within the national systems, changing the rules for sharing transboundary transmission capacities, optimising the methods of sharing these capacities with market participants (introduction of a flow-based approach – FBA), and installing

phase shifters if this is necessary to reduce unplanned flows of electricity across the NPS.

In connection with the above, by 2030, **there are plans to complete investments to develop the national transmission network and interconnections with a view to pursuing the above objectives.**

The table below summarises historical data and forecasts regarding the capacity of cross-border electricity interconnectors. In 2015, the total installed capacity at all interconnectors was approx. 10 GW.

Table 67. Projected capacity of existing and planned interconnections [MW]

	interconnection	2005	2010	2015	2020	2025	2030	2035	2040
Germany	Krajnik-Vierraden	592	592	592	2078	2078	2078	2078	2078
Germany	Mikułowa-Hagenverder	2730	2730	2730	2640	2640	2640	2640	2640
Czech Republic	Wielopole/Dobrzeń - Nosovice/Albrechtice	2772/2480	2772/2480	2772/2480	2772/2480	2772/2480	2772/2480	2772/2480	2772/2480
Czech Republic	Kopanina/Bujaków - Liskovec	800/794	800/794	800/794	800/794	800/794	800/794	800/794	800/794
Slovakia	Krosno Ikskrzynia - Lemesany	2078	2078	2078	2078	2078	2078	2078	2078
Sweden	Słupsk - Starno	600	600	600	600	600	600	600	600
Belarus	Białystok - Roś*	0	0	0	0	0	0	0	0
Ukraine	Rzeszów - Chmielnicka**	0	0	0	0	0	0	0	0
Ukraine	Zamość - Dobrotwór	381/310	381/310	381/310	381/310	381/310	381/310	381/310	381/310
Lithuania	Elk - Alytus***	0	0	488	488	488	0	0	0
Lithuania	Żarnowiec-Darbenai	0	0	0	0	0	700	700	700
TOTAL		9953/9584	9953/9584	10 441/10 072	11 837/11 468	11 837/11 468	12 049/11 680	12 049/11 680	12 049/11 680

with different availability in winter and summer marked: 'winter/summer'

*under liquidation, **out of service (determining the capacity of the interconnection will be possible after appropriate analyses and technical studies are completed), ***after the power systems of the Baltic states are synchronised with the system of Continental Europe, the total capacity of the interconnector will be dedicated to technical exchange; no trade exchange at this interconnector; the possibility of trade at this interconnection after 2025 will depend on the degree to which the Baltic states' systems are adapted to synchronous operation with the Continental Europe system.

Source: PSE SA, own study by ARE S.A.

The way interconnected power systems operate indicates that the level of interconnected transmission capacity made available by the TSO does not correspond to the thermal capacity of existing cross-zonal interconnections. Restrictions on power transmission stem, *inter alia*, from maintenance works and the activities of the eTSO carried out to ensure secure operation of the power system.

Pursuant to Regulation (EU) 2019/943 of the European Parliament and of the Council on the internal market for electricity, from 1 January 2020, TSOs should maximise the interconnection capacity offered for transboundary trade. As a consequence, Regulation 2019/943/EU requires that eTSOs provide market participants with cross-zonal capacity at a level not lower than 70% of the transmission capacity for a given border or critical network element/contingency (CNEC) pair, subject to operational security limits (hereinafter 'CEP 70% target'). The eTSO can use the remaining 30% for the purposes of reliability margins, loop flows, and internal flows at each critical network element.

Providing the 70% of transmission capacity is a challenge for the eTSO, as currently, the Polish bidding zone

suffers from structural network constraints. As a result, a decision has been made to prepare an Action Plan that best responds to the nature of structural network constraints in Poland. When the Action Plan is applied, the final deadline for achieving the CEP 70% target is 31 December 2025. The Action Plan will be carried out from 1 January 2020. The measures adopted under the Action Plan are scheduled for four years (1 January 2020 to 31 December 2023). The table below presents historical and forecast trading capacities with other countries. The table that follows presents the interconnectivity ratio as the quotient of net transmission capacity available for imports and total installed capacity in the NPS according to the currently projected trading capacity.

Table 68. Net transmission capacity of existing and planned interconnections [MW]

	2010	2015	2020	2025	2030	2040
PL→DE/CZ/SK	900	1000	1605/1587	3629/3525	3629/3 525	3629/3525
DE/CZ/SK→PL	0	0	605/587			
PL→SE	100	100	600	600	600	600
SE→PL	600	600	600	600	600	600
PL→UA	0	0	0	0	0	0
UA→PL	220	220	220	220	220	220
PL→LT	0	500	500	500	700	700
LT→PL	0	500	500	500	700	700
PL export	1 000	1600	2705/2687	4729/4625	4929/4 825	4929/4825
PL import	820	1 320	1925/1907	4949/4845	5149/5045	5149/5045

Source: ARE and PSE SA forecasts (with different capacities in winter and summer marked: ‘winter/summer’)

Table 69. Interconnectivity

	2010	2015	2020	2025	2030	2035	2040
NTC import [MW]	820	1 320	1 925	4 949	5 149	5 149	5 149
Installed capacity [MW]	33 320	37 290	48 656	55 167	59 073	63 391	72 103
Interconnections [%]	2.5	3.5	4.0	9.0	8.7	8.1	7.1

Source: ARE S.A. and PSE S.A. projections

5.1.5.3. Natural gas transmission infrastructure

In 2015, the maximum capacity of the national transmission system (NTS) to receive natural gas was over 25.8 billion m³ per year. In 2016, the LNG regasification terminal in Świnoujście was commissioned with an annual capacity of approx. 5 billion m³. Poland remains heavily dependent on natural gas supplies from abroad, mainly from the East, but also from Germany and the Czech Republic (in 2018, 79% of consumed natural gas came from imports and intra-Community purchases, with 61% originating from the East). In the coming years, the share of LNG in natural gas consumption may reach even 30%. The Polish terminal is a key item of infrastructure from the point of view of security of gas supply not only for Poland, but also for neighbouring countries. It is the only facility of this size in Central Europe, and the importance of LNG trade on the global natural gas market is growing, *inter alia* thanks to the increasing price competitiveness compared to gas supplied by gas pipelines. However, it is important to ensure access to gas to end users, which requires developing the national transmission, distribution and storage infrastructures.

The so-called Yamal contract²⁷, which currently ensures the majority of supplies to Poland, will expire at the end of 2022, therefore actions working towards real diversification of the sources of supply must be completed before the gas year 2022/2023 starts. This will break the monopoly-based price trends. In addition to infrastructure activities, it is vital that energy companies continue their efforts towards diversifying natural gas supplies on a contractual basis.

The key investment projects ensuring the country's energy security through diversification of sources and directions of natural gas supply include:

- construction of the Baltic Pipe – capacity of about 10 billion m³ towards Poland and 3 billion m³ towards

²⁷ Contract for the supply of natural gas to Poland signed between PGNiG and Gazprom in 1996.

Denmark and Sweden;

- expansion of the LNG terminal in Świnoujście - regasification capacity of approx. 7.5 billion m³;
- floating storage regasification unit in the Gulf of Gdańsk with a capacity of at least 4.5 billion m³;
- construction/development of interconnectors: with Slovakia – capacity of 5.7 billion m³ towards Poland and 4.7 billion m³ towards Slovakia; with Lithuania – 1.9 billion m³ towards Poland and 2.4 billion m³ towards Lithuania; with the Czech Republic – 6.5 billion m³ towards Poland and 5 billion m³ towards the Czech Republic; with Ukraine – 5 billion m³ in both directions.

The **national transmission network** must enable the imports infrastructure to be used to the full (the length of the natural gas transmission network is nearly 12 000 km), which requires developing the national gas pipeline system. The plan until 2022 (with an outlook for 2029) focuses on the development of the network:

- in western, southern and south-eastern Poland (from Świnoujście to the interconnections with the Czech Republic, Slovakia, and Ukraine) – this will allow gas to be transmitted from the LNG terminal and imported via the Baltic Pipe to domestic consumers, and to be exported to neighbouring countries and imported from new suppliers in the south;
- in north-eastern Poland (to the interconnector with Lithuania) – this will stimulate gasification in this part of Poland and will strengthen the energy integration of the Baltic states with Continental Europe.

The expansion and modernisation of the **distribution** infrastructure is another crucial element of the development of the national network. Currently, around 65% of Polish municipalities have access to natural gas, with the gasification level bound to increase to around 77% in 2022, and with further growth expected in subsequent years in response to market needs. A heavy emphasis has been placed on removing what is referred to as ‘white spots’ – places lacking access to gas. Where the construction of a gas pipeline is not viable, use will be made of LNG regasification stations (also known as virtual LNG pipelines). Alternatively, such areas can be supplied with biomethane (biogas purified and processed to natural gas quality) from local biogas plants, if there is potential for biogas production in the region. Local access to gas means that it can be used in heating, transport and as a reserve for renewable energy sources, which depend on weather conditions. At the same time, the use of gas and/or renewable energy sources – as low-emission heat sources – is an alternative to individual boilers fired by low-quality solid fuels in areas where access to district heating is not available.

5.1.5.4. Gas transmission capacity

The above investments will create conditions for Poland to become a gas transmission and trade hub for the countries of Central and Eastern Europe and the Baltic states, and will allow Polish infrastructures to be adapted so as to satisfy the dynamically growing demand for natural gas. The favourable geographical location of Poland makes it reasonable for it to strive to become a transit country for gas transmission along the east-west and north-south axes (gas transmission and trade hub). These projects constitute the Polish contribution to the Three Seas initiative, which aims to deepen the integration of the Baltic, Adriatic and Black Sea and EU's priority countries – the north-south gas corridor²⁸ for the CEE countries (an alternative to the east-west corridor and reduction of dependency on one gas supplier), and will add to the planned energy integration of Baltic states.

The table below presents the anticipated parameters of technical natural gas transmission capacity per year.

Table 70. Parameters of cross-border entry and exit points for the gas transmission system – annual technical transmission capacity [million m³ at 0°C]

interconnection	border point	entry/exit	2020	2025	2030	2035	2040
LNG terminal	LNG terminal	entry	4 993.2	7500	7500	7500	7500
Germany	GCP entry point (Lasów, Gubin)	entry	1 594.3	1 594.3	1 594.3	1 594.3	1 594.3

²⁸ The north-south gas corridor will connect the LNG terminal in Świnoujście and the Baltic Pipe, running across southern Poland, the Czech Republic, Slovakia and Hungary, with the markets of Southern Europe, in keeping with the Three Seas concept.

Germany	GCP exit point (Lasów Rewers, Kamminke)	exit	440.8	440.8	440.8	440.8	440.8
Czech Republic	Branice	entry	1.4	1.4	1.4	1.4	1.4
Czech Republic	Cieszyn*	entry	587.2	587.2	587.2	587.2	587.2
Ukraine	Drozdowicze	entry	4 380.0	4 380.0	4 380.0	4 380.0	4 380.0
Ukraine	Hermanowice towards Ukraine**	exit	02	02	02	02	02
Belarus	Tietierowka k/Białegostoku	entry	236.5	236.5	236.5	236.5	236.5
Belarus	Wysokoje k/Janowa Podlaskiego	entry	5 475.0	5 475.0	5 475.0	5 475.0	5 475.0
Belarus	Kondratki k/Białegostoku EUROPOL	entry	33 741.2	33 741.2	33 741.2	33 741.2	33 741.2
Germany	Mallnow k/Słubic EUROPOL	exit	30 602.4	30 602.4	30 602.4	30 602.4	30 602.4
Germany	Mallnow k/Słubic EUROPOL reverse flow	entry	6 132.0	6 132.0	6 132.0	6 132.0	6 132.0
Yamal	point of interconnection	entry	9 076.1	9 076.1	9 076.1	9 076.1	9 076.1
Denmark	Baltic Pipe	entry	0	10000	10000	10000	10000
Denmark	Baltic Pipe	exit	0	3000	3000	3000	3000
Slovakia	gas interconnection Poland-Slovakia (GIPS)	entry	0	5700	5700	5700	5700
Slovakia	gas interconnection Poland-Slovakia (GIPS)	exit	0	4700	4700	4700	4700
Lithuania	gas interconnection Poland-Lithuania (GIPL)	entry	0	1900	1900	1900	1900
Lithuania	gas interconnection Poland-Lithuania (GIPL)	exit	0	2400	2400	2400	2400
floating storage regasification unit (FSRU)	floating storage regasification unit (FSRU)	entry	0	4500	4500	4500	4500

* calculation takes into account seasonal variation; ** Intermittent capacity, continuous capacity available conditionally: 1463-2190 million m³/year, values above 1 463 million m³/year depending on the arrangements between GAZ-SYSTEM and Ukrtransgaz.

Source: own study by ARE S.A.

5.1.5.5. Electricity and gas markets, energy prices

One of the fundamental changes recorded last year on the electricity market was the entry into force of the Capacity Market Act of 8 December 2017, i.e. transition from a single-product market (only energy) to a two-product market (energy and capacity). The purpose of the capacity market is to ensure medium and long-term security of electricity supply to final consumers in a cost-effective, non-discriminatory, and sustainable manner. The Capacity Market Act provides for the payment for readiness to provide capacity and for providing power at times of hazard. The capacity market is to incentivise energy companies to invest in and retrofit their plants, as well as to prevent them from decommissioning existing generation sources prematurely. It operates in parallel to the electricity market, does not affect the prices on the wholesale electricity market, and is technologically neutral, which creates a level playing field for all electricity production technologies and DSR services. The first three main auctions with 2021, 2022 and 2023 supply dates took place in 2018, and the main auction for the 2024 deliveries was held in 2019.

The establishment of the capacity market will deactivate existing balancing mechanisms, i.e.: Cold Contingency Reserve (*Interwencyjna Rezerwa Zimna*), Interventional Operation (*Praca Interwencyjna*), Operational Capacity Reserve (*Operacyjna Rezerwa Mocy*), and Guaranteed DSR Emergency Programme (*Gwarantowany Interwencyjny Program DSR*, i.e. reduction in demand at TSO's request). Consequently, from 1 January 2021 onwards, the operating costs of these mechanisms will no longer be incurred. The costs of the capacity market will be transferred to final consumers of electricity through the so-called 'capacity fee' included in electricity bills. The fee will be charged as from 1 October 2020.

The new requirements for capacity mechanisms are set out by Regulation 2019/943 on the internal electricity market. With effect from 4 July 2019, the Regulation excludes from the participation in the capacity market new generating units (not engaged in commercial production before that date) that emit more than 550 g CO₂/kWh, and it does so for existing units (engaged in commercial activity before 4 July 2019) that emit more than 550 g CO₂/kWh and over 350 kg CO₂/kW (on average per year) with effect from 1 July 2025. Capacity contracts made before 31 December 2019 are exempted from the regulatory restrictions throughout their term.

5.1.5.5.1. Electricity prices by sector

The table below presents projections of electricity prices for three defined groups of end users. The presented figures are average prices offered under comprehensive and separate contracts, include taxes (the calculations assume an excise duty of PLN 0.5 /MWh at current prices and 23% VAT throughout the forecast horizon). As is shown by the results obtained, a gradual increase in electricity prices is expected for all the three groups of end users considered. The increase in prices is evenly distributed across the sectors, which is a consequence of the assumption of proportional distribution of the costs of all support schemes, with the exception of support for renewable energy (currently industry is partially exempted from the RES charge). The main factors behind the projected increase include the costs of CO₂ emission allowances, which increase over time, and the costs of generation unit and transmission infrastructure building and modernisation, as applicable.

VAT for industrial consumers is reimbursed by the State Treasury, therefore electricity prices including this tax for industrial consumers are presented for reference only.

Table 71. Electricity prices by sector [EUR'2016/kWh]

	2005	2010	2015	2020	2025	2030	2035	2040
Households	0.114	0.145	0.150	0.159	0.186	0.188	0.192	0.192
Services	No data	No data	0.135	0.140	0.167	0.170	0.173	0.173
Industry	0.066	0.100	0.082	0.110	0.123	0.124	0.127	0.123

Source: ARE S.A. forecasts

The figure below compares electricity price projections for the individual groups of consumers for the ECP and REF scenarios. The increase in prices compared to the REF scenario stems from the higher costs of the construction and improvement of energy infrastructure, including the development of offshore energy, distributed energy, electromobility, and the deployment of smart grids, as well as from market and regulatory developments that have taken place after 2017, which are not covered by the reference scenario.

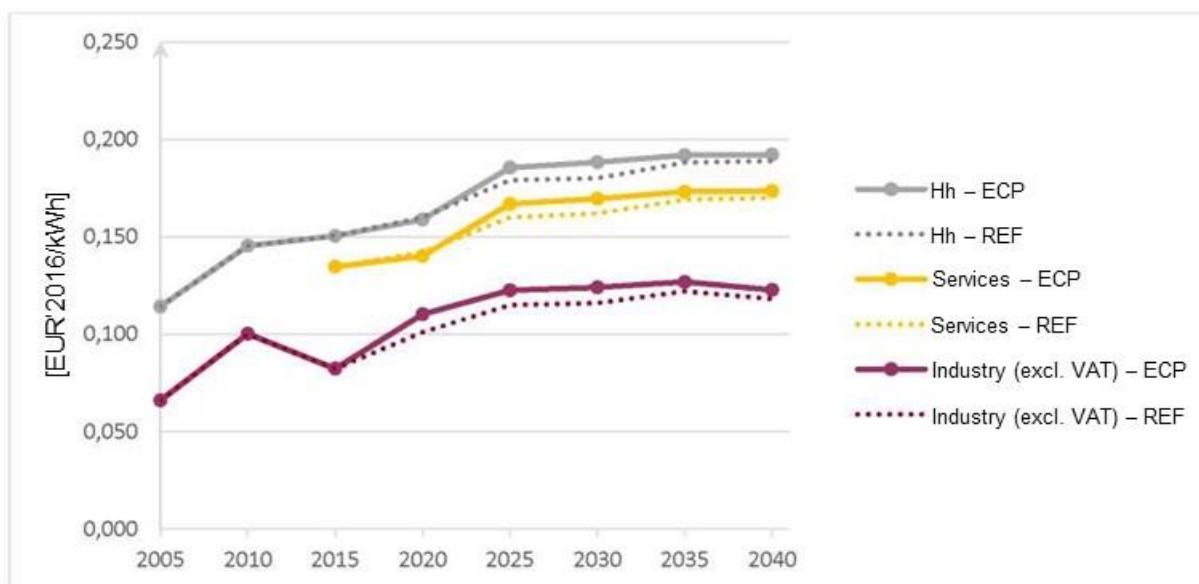


Figure 28. Comparison of electricity prices for final consumers – ECP vs REF

5.1.5.6. National retail prices of fuels

The model simulations distinguish between ex-mine/ex-yard coal prices by groups of consumers – energy sector, industry and small-scale consumers based on the domestic structure of prices taken from 2005-2015 statistics. Also for natural gas, the simulations take into account the costs and share of gas produced in Poland, the average costs of transport in the network, and costs associated with infrastructure investments. The projected prices of natural gas, coal and petroleum products are based on trends in global prices of these energy carriers. It is assumed that the prices of solid, liquid and gaseous fuels in the ECP scenario will not differ from those in the REF scenario. This is a simplifying assumption, but it is necessary in the light of the uncertainty inherent in the prices of energy carriers. However, implementation of some of the policies and measures defined in the ECP scenario may increase natural gas prices and reduce coal fuel prices to some extent. However, the extent of these fluctuations is difficult to estimate.

The results are presented in the table below.

5.1.6. ‘Research, Innovation and Competitiveness’ dimension

This dimension is described in detail in Parts 1 (National assumptions and objectives) and 2 (Policies and measures) of the NECP in the subsections relevant for this dimension.

Also Annex 1 to the NECP “Current situation and projections with existing policies and measures – state at the end of 2017 (REF scenario)” includes a description of the individual technologies.

Table 72. National retail prices of fuels [EUR'2016/ktoe]

	Natural gas								Steam coal					Coking coal
	industry (total)	industry (excise tax)	industry (VAT)	el. prod. (av. price)	el. prod. (nitrogen gas)	households (total)	households (excise)	households (VAT)	industry (total)	el. prod. (total)	households (total)	households (excise)	households (VAT)	industry (total)
2005	212 271	0	0	175 216	-	418 771	0	75 428	96 360	87 981	222 767	0	40 154	154 630
2010	379 524	0	0	243 484	-	645 043	0	116 229	147 186	129 740	299 987	0	54 089	224 466
2015	339 968	2 832	0	238 394	332 803	636 686	567	119 527	117 657	106 019	318 345	0	59 532	138 406
2020	291 002	2 666	0	215 286	304 723	621 916	0	116 293	106 616	97 046	318 830	0	59 619	142 442
2025	327 425	2 666	0	242 481	343 215	700 476	0	130 983	118 462	107 829	354 256	0	66 243	158 269
2030	350 711	2 666	0	259 868	367 815	750 703	0	140 375	125 231	113 990	374 499	0	70 028	167 313
2035	373 211	2 666	0	276 667	391 598	799 232	0	149 450	127 770	116 301	382 090	0	71 448	170 704
2040	382 210	2 666	0	283 386	401 114	818 643	0	153 080	130 308	118 611	389 681	0	72 867	174 096

	Light fuel oil					Diesel					Petrol			LPG			
	industry (total)	industry (excise tax)	households (total)	households (excise)	households (VAT)	comm. consum p. (total)	comm. consum p. (excise)	non-comm. consum p. (together)	non-comm. consum p. (excise)	non-comm. consum p. (VAT)	non-comm. consum p. (excise)	non-comm. consum p. (VAT)	comm. consum p. (total)	non-comm. consum p. (together)	non-comm. consum p. (excise)	non-comm. consum p. (VAT)	
2005	613 425	79 188	796 974	79 188	143 761	1 031 865	406 181	1 258 889	406 181	227 024	1 457 052	573 547	262 861	704 947	860 478	206 607	155 070
2010	730 719	74 717	929 669	74 717	167 791	1 130 529	415 357	1 379 244	415 357	248 825	1 573 408	573 598	283 685	792 309	966 616	199 271	174 417
2015	671 38 51	65 730	860 111	65 730	160 925	1 037 404	415 847	1 276 007	415 847	238 563	1 408 693	507 954	269 651	612 179	752 980	178 755	140 779
2020	745 110	61 857	739 697	61 857	138 278	1 120 631	391 342	1 378 376	391 342	257 745	1 479 352	478 352	276 627	716 135	834 678	168 221	156 078

Impact assessment of policies and measures (ECP scenario) – Annex 2 to the NECP

202	832	61	783 969	61 857	146 554	1 194 244	391 342	1 468 920	391 342	274 676	1 557 631	478 021	291 264	779 024	889 807	168 221	166 387
203	907	61	831 194	61 857	155 382	1 257 075	391 342	1 546 203	391 342	289 127	1 624 446	478 021	303 758	832 702	936 862	168 221	175 186
203	942	61	881 569	61 857	164 799	1 286 483	391 342	1 582 374	391 342	295 891	1 655 717	478 021	309 606	857 826	958 885	168 221	179 304
204	992	61	935 305	61 857	174 845	1 328 292	391 342	1 633 800	391 342	305 507	1 700 177	478 021	317 919	893 545	990 196	168 221	185 159

Source: own study by ARE S.A., EUROSTAT - "Energy prices and taxes"

5.1.7. Assessment of mutual interactions between existing and planned PaMs in the various dimensions and between current and planned PaMs related to other dimensions

Identification and understanding of mutual interactions between existing and planned policies within the five dimensions of the Energy Union analysed can be used for determining the positive or negative impacts on the effectiveness of the implemented solutions. In many areas, the impacts of the implemented PaMs overlap, which fosters the effectiveness of actions, leads to the mutual neutralisation of effects, or produces negative impacts, as the case may be. Suitable balancing of the type and scope of implemented solutions allows the energy and climate policy objectives to be attained with gradually declining use of resources and funds. The most frequently identified cases of overlapping PaMs occur in the ‘decarbonisation’ and ‘energy efficiency’ dimensions, with them predominantly strengthening the effect of action.

The following table summarises the interactions identified between existing and planned PaMs within the individual dimensions and those with PaMs pursued in other dimensions. In the table, ‘1’ stands for a positive impact of a given measure in a given dimension on another dimension, ‘0’ means no impact or inestimable impact, while ‘-1’ indicates a negative impact.

The table below presents the conclusions of an analysis of the interactions between existing and planned PaMs within the five dimensions of the Energy Union.

Table 73. Interactions between PaMs identified within dimensions

Dimension/measure	Dimension 'Decarbonisation'	Dimension 'Energy Efficiency'	Dimension 'Energy Security'	Dimension 'Internal Energy Market'	Dimension 'Research, Innovation and Competitive ness'
Dimension 'Decarbonisation'					
Measures to improve air quality					
Air Quality Programmes (elimination of 'low-stack' emissions and anti-smog efforts)		1	1	0	1
Fuel quality monitoring and control		0	0	0	0
Supporting use of alternative fuels in transport		1	1	0	1
Supporting the development of district heating and cooling		1	1	0	1
Actions to reduce greenhouse gas emissions					
Implementation of low-emission technologies and solutions		1	1/-1	0	1/-1
Supporting utilisation of coal-bed methane		1	1	0	1
Supporting RES (including distributed electricity production)		1	1/-1	1	1
Supporting low-carbon transport		1	1	0	1
Dimension 'Energy Efficiency'					
Stimulating energy efficiency measures (legal and financial incentives)	1		1	0	1
Thermomodernisation of buildings	1		1	0	1
Promoting the use of efficient alternative energy and heat supply systems for buildings	1		1	0	1
Promoting low-energy buildings	1		1	0	1
Supporting high-efficiency cogeneration	1		1	0	1
Supporting the development of smart networks	1		1	1	1
Dimension 'Energy Security'					
Deployment of nuclear power	1	-1		0	1
Implementation of a capacity market	1/-1	1/-1		0	0
Supporting the development and modernisation of transmission infrastructures	1	1		1	1
Supporting the development	1	1		0	1

of energy storage technologies					
Dimension 'Internal Energy Market'					
Empowering consumers on the energy market	1	1	1		0
Developing interconnections	1	0	1		1
Dimension 'Research, Innovation and Competitiveness'					
Fostering the competitiveness of the Polish economy by pursuing continuous technological advancement	1	1	1	1	
Supporting the development of innovative products and services	1	1	1	1	

1 - positive impact, -1 - negative impact, 0 - no impact

'Decarbonisation' dimension

Measures to improve air quality

- The main measures in this area are as follows:
- comprehensive thermomodernisation of buildings,
- replacement of old manually fed boilers with new low-emission or zero-emission ones,
- expansion of district heating networks.

All of these activities will have a positive effect on energy efficiency (reduction of primary energy consumption in connection with limited thermal needs and improved energy transformation efficiency of boilers), energy security (limited fuel imports) and competitiveness (lower specific fuel consumption and purchase costs, exploitation of the potential for implementing and using innovative thermomodernisation and heating technological solutions).

Promoting the development of alternative fuels in the transport sector, which is largely co-responsible for smog in cities, is another activity. Importantly, the planned activities will involve wide support for the use of electricity and CNG in road transport, which will gradually decrease Poland's oil imports dependency thereby improving the country's energy security. Reduced need to use biofuels to achieve the assumed RES target in road transport will be another positive effect of using electricity in road transport.

As regards the impact on Poland's competitiveness, the ICT industry has a chance to increase its potential based on the increase in production and sale of electric and autonomous vehicles. The development of electromobility will contribute to the modernisation of the Polish energy sector, lower transport costs and increase the share of own fuels and energy sources in the country's energy mix.

Creating conditions for the development of district heating is one of the priority tasks as regards improving air quality in Poland. Not only will fostering the use of district heating reduce emissions, but will also bring Poland closer to its energy efficiency targets.

Actions to reduce greenhouse gas emissions

The key actions aimed at reducing greenhouse gas emissions include the deployment of zero-emission renewable energy technologies. The process in this area takes place in virtually all sectors of the economy, and is mainly stimulated by various types of subsidies. Not only does the development of renewable energy sources (both on a large scale and distributed ones) contribute to reducing emissions of pollutants into the air, but it also works towards reducing primary energy consumption, especially in the electricity and heating sectors. The use of renewable energy is therefore important for energy efficiency, as it reduces the consumption of primary energy.

The effect of renewable energy development on energy security is twofold. On the one hand, it helps to reduce the consumption of fossil fuels, but on the other, it can have a destabilising effect on the operation of the power system due to intermittent operation. Generation sources such as wind and solar farms reduce security of supply and require reserves in the form conventional sources (which also generates additional costs). However, the expected development of storage technologies may eliminate these drawbacks in the future.

The impact of this factor on the competitiveness of the economy is ambiguous. The development of renewable energy in Poland can boost innovation provided that the opportunities that arise are properly utilised. One drawback is the increased cost of energy supply, which does not only include the costs associated with the production of electricity by more expensive sources and the costs of reserve generation units (including capex on both), but also the transmission, distribution and balancing costs. Competitiveness lies primarily in the ability of companies to compete on the global market, which is considerably hindered by high generation costs.

Promoting low-carbon transport is another important measure to reduce emissions. This priority is to be pursued through a wide range of activities that will contribute to improving the efficiency of energy use in this sector (including promotion of public transport and the use of alternative fuels). In turn, the greater the final energy savings produced in the sector, the lower the RES energy volumes required to attain the renewable fuel use targets.

'Energy Efficiency' dimension

The planned measures in this dimension are as follows:

- stimulating energy efficiency measures (legal and financial incentives)
- thermomodernisation of buildings
- promoting the use of efficient alternative energy and heat supply systems for buildings
- promoting low-energy buildings
- supporting high-efficiency cogeneration
- supporting the development of smart networks

All these activities will have a positive effect on emissions of greenhouse gases and pollutants, which will also improve energy efficiency. Improved energy efficiency will be also helpful in reducing the required volumes of energy from renewable energy sources counted against the national target (at the same time, increased use of RES will reduce primary energy consumption). Thus, improving energy efficiency is a measure that works towards the RES target. The implementation of solutions improving energy efficiency is also much more beneficial for the economy since most renewable energy technologies come from imports, while energy efficiency improvement measures can be largely sourced from inside the country.

'Energy Security' dimension

The deployment of nuclear energy in 2033 is a key element of this dimension, which corresponds to the other dimensions. The main purpose is to ensure stable electricity supply from a source that does not contribute to greenhouse gas emissions. Nuclear energy will provide large volumes of near-zero emission energy, reducing the pressure on the development of renewable energy, although it increases primary energy consumption.

The so-called 'capacity market', which is under implementation now, is the second element. Its main goal is to ensure the security of electricity supply in a situation of growing share of non-controllable RES generating units. On the one hand, it will enable further development of renewable energy sources in Poland. The mechanism will delay the decommissioning of coal-fired units, but with no renewable energy subsidies, their operation would be more beneficial in economic terms. The lack of the capacity market would mean the risk of no supplies of electricity.

The expansion and modernisation of generation infrastructure and development of energy storage technologies will also improve the share of renewable energy. In fact, they are a condition for the development of RES in the system.

'Internal Energy Market' dimension

Enhancing the role of consumers and activating them within the energy market is one of the actions envisaged in this area. The goal is, *inter alia*, to increase the number of prosumers, which will directly lead to the

development of distributed energy from renewable sources and, as a result, reduce emissivity and fuel consumption within a given area. In addition, it is assumed that increased consumer awareness will be an incentive to rationalise self-consumption and pro-efficiency activities.

The development of cross-border networks, as another action within a given area, may improve the security of energy supply. Interconnections with neighbours can be helpful during periods of power shortage in the national power system. The development of interconnections and transboundary trade in electricity may have a positive effect on the wholesale electricity market, depending on how price relations evolve on individual markets.

'Research, Innovation and Competitiveness' dimension

The activities specified in this dimension are intended to develop new technologies focused on decarbonisation and high energy efficiency. Examples include the development of new energy generation technologies, integrated high-efficiency and low-carbon energy storage, transmission and distribution systems, and electromobility.

5.2. Macroeconomic, health and environmental impacts on employment and education, as well as impacts on skills in this area and social impacts

5.2.1. Analysis of macroeconomic and social impacts in both scenarios – REF and ECP

The study uses a methodical approach based on the theory of macroeconomic development under conditions of gradual progress towards a general equilibrium (CGE-PL) in the modelled sectors of the national economy as a result of forcing impulses, i.e. the energy and climate policy intervention measures pursued in the national economy. The impulses disturb the balance in the base year (2015) and work towards a new equilibrium in the successive 5-year subperiods until 2040. The **macroeconomic analysis and adaptation assessment is presented for two scenarios – REF and ECP**.

The calculations are based on information exchange between macroeconomic models and energy models. The assessment entails a number of variables, ranging between the volume and dynamics of GDP, the volumes of value added sectors of the economy and their profitability, and the level and structure of employment. A central role is played by the CGE-PL macroeconomic model, which is crucial for the systemic approach to development-focused research that combine the assumptions and effects of the climate and energy policy on both the energy sectors and the remaining sectors of the national economy (manufacturing and consumption). It also takes into account the key relationships with the external environment, i.e. the balance of exports and imports of goods and services, and the relations with the natural environment – calculation of CO₂ emissions vs. the overall balance of the potential costs and benefits of the ETS EUA system in Poland. The Mezzo-Impact sectoral model is the component used for assessing the economic and social impacts.

5.2.1.1. Analysis of macroeconomic and social impacts in the REF scenario

5.2.1.1.1. Economic growth in 2015-2030 and the 2040 perspective – REF

This section presents the most relevant results of calculations for the REF scenario, with Tables 74-75 showing the calculated results (in the CGE-PL model) for GDP and added value in the aggregate sectors of the national economy (NE). They are almost identical to the assumptions on growth in the REF scenario. In the period 2015-2030, GDP grows by over 60%. In the decade of 2030-2040, GDP growth gradually slows down, but it doubles in the entire 2015-2040 period at an average annual rate of around 2.9%. In addition, the table below summarises the foreign trade balance calculated on the basis of CGE-PL, the estimated macroeconomic CO₂ emissions, and changes in employment and unemployment rates. The calculated GDP growth path and breakdown in the REF scenario are illustrated in the figure below.

Table 74. GDP level and trends of selected macroeconomic variables in the REF scenario – results of the CGE-PL model

Item/category	Unit	2015	2020	2025	2030	2035	2040
GDP level	EUR'2016 billion	462.4	550.8	649.2	747.1	843.7	937.1
GDP dynamics	2015=100	100	119.1	140.4	161.6	182.5	202.7
Foreign trade balance	EUR'2016 billion	14.3	5.4	5.8	14.7	8.8	19.5
Employment	thousand people	15 977	15 865	16 011	16 163	16 175	16 033
Unemployment rate	%	6.9%	5.0%	5.0%	4.0%	4.0%	4.0%
Model calculation subperiods	years	-	2016-2020	2021-2025	2026-2030	2031-2035	2036-2040
Annual average GDP growth rate over the five-year period	%	-	3.6%	3.3%	2.9%	2.5%	2.1%

Source: EnergSys's own study, CGE-PL model

Table 75. Changes in value added in the economy by economic sectors and industries in the REF scenario [EUR'2016 billion]

Item/category	2015	2020	2025	2030	2035	2040	2040/2015 ratio
Agriculture, forestry and	10.43	12	13	15	16	17.7	1.70

fishing							
Extraction of mineral resources	1.46	2	2	2	2	2.6	1.78
Manufacturing	85.5	98	113	130	146	158.0	1.85
Construction	34.6	39	44	55	61	65.4	1.89
Transport	27.40	32	37	44	49	56.0	2.04
Services	233.00	281	337	386	439	489.0	2.10
Fuel and energy sector	17.80	21	22	21	20	24.0	1.35
Total	410.19	486	568	654	734	812.7	1.98
GDP	462.4	550.8	649.2	747.1	843.7	937.1	2.027

Source: EnergSys's own study, CGE-PL model

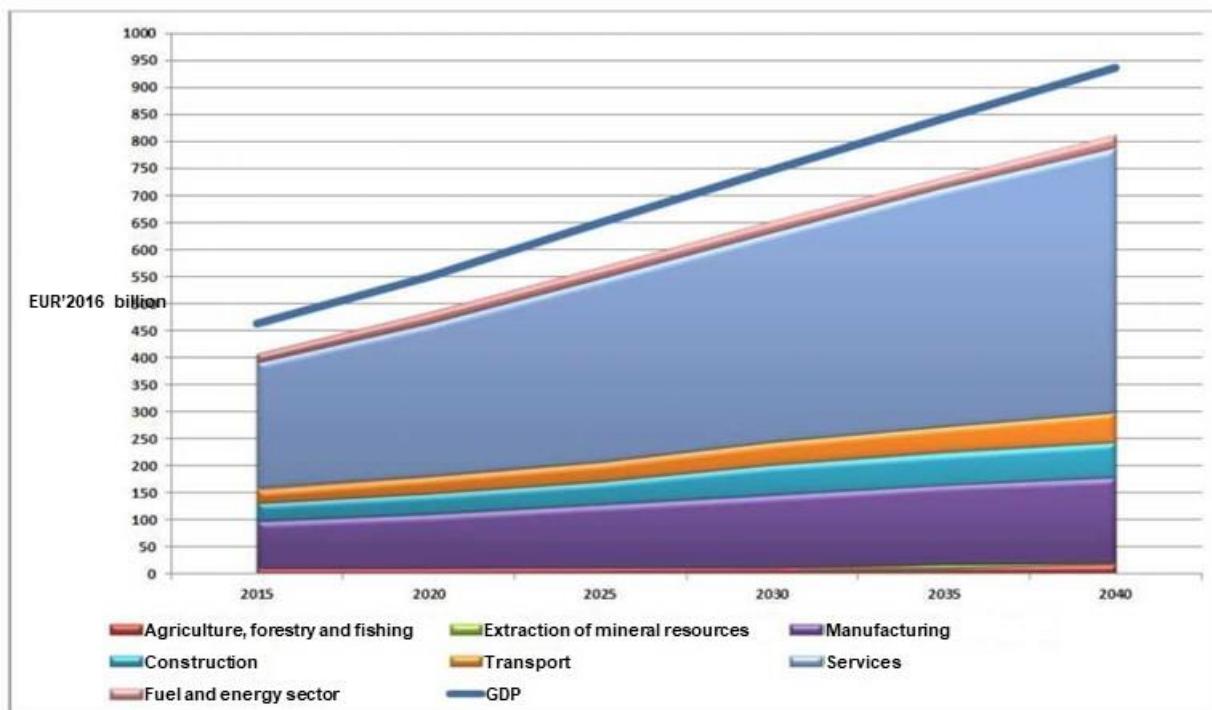


Figure 29. GDP level and value added in aggregate NE sectors – REF

In the REF scenario, the results of the calibration process in the CGE-PL model also include factors of production (engaged capital and labour) and changes in their sectoral productivity throughout the period concerned (2015-2040). The workforce in the REF scenario is estimated on the basis of employment data by the adoption of the following minimum unemployment rates in the successive years:

- 2015 – 6.9%;
- 2020 – 5.0%;
- 2025 – 5.0%;
- 2030-2040 – 4.0%.

The assumptions on the rate of growth of capital resources and capital expenditures in 2015-2040 are based on the likely range of their formation/accumulation in the Polish economy over the period analysed. The calculations allow a variability in the accumulation rate of 19-21 pp (in relation to GDP), in line with the actual values from the last five-year period (2011-2015). Sectoral productivities of the factors of productions, adjusted in an iterative cycle, were the parameters used for obtaining the required GDP volume in the CGE-PL model calibration process. The goodness of fit criterion was considered to be met if the difference was not greater than 0.1% of the assumed GDP (in REF) minus GDP calculated iteratively in the model calibration process.

The estimated values of production factor productivity paths for labour and capital are presented in the table below. Energy is another important factor of production, which is applied in the macroeconomic models (CGE-PL and Mezzo-Impact), using the results of calculations of energy models on the basis of the outcomes of projected fuel consumption.

Table 76. Resources of factors of production and their productivity in the REF scenario

	Unit	2015	2020	2025	2030	2035	2040
Workforce	thou. of employed	17 161	16 700	16 854	16 836	16 849	16 701
Gross capital formation (capital resource)	EUR'2016 billion	95	103	120	135	149	160
Capital formation dynamics	[-/-]	100	108	126	142	157	169
Changes in factors of production relative to GDP							
Labour productivity dynamics	[-/-]	100	120	140	160	180	202
Capital productivity dynamics			110	111	114	116	120
Dynamics of fuel and energy productivity in manufacturing (excluding households)			99.8	113	126	141	156
Dynamics of fuel and energy productivity in the country (including households)			102	116	130	144	159

Source: *EnergSys's own study, CGE-PL model*

The workforce constraints assumed make the desired path of GDP growth achievable only with a very fast increase in labour productivity, especially in labour-intensive sectors, i.e. agriculture and services. With the assumed major changes in labour productivity, accurate calibration of the model results did not require substantial changes in the numerical values of capital productivity parameters. This reflects the general trend of technical progress in the economy, with labour savings generated by provision of better technical equipment for workplaces. Notably, even in the REF scenario, limiting final energy consumption to the level Poland committed to (until 2015) will require far-reaching improvement in productivity – by over 25% in 2030 and around 45% in 2040. This means the productivity of energy use in the generation of the Polish GDP, net of fuel and energy consumption in the Hh sector (energy consumption). On the other hand, with account taken of the total energy demand (manufacturing plus households), final energy productivity increases by approx. 17% in 2030, following which it stabilises until 2040.

5.2.1.1.2. Analysis of the profitability, employment structure, and production prices of the manufacturing industry in the REF scenario

The study analyses the impact of the conditions of the REF scenario on the profitability of gross revenues in manufacturing industries. The results obtained are presented in the table and figure below.

Table 77. Changes in gross profitability of selected manufacturing industries in the REF scenario (current prices)

	2015	2016	2017	2018	2020	2025	2030	2035	2040
Food industry	4.7%	5.1%	4.5%	4.7%	4.6%	4.4%	4.3%	3.3%	2.7%
Light industry	6.8%	6.9%	6.1%	6.1%	7.3%	6.8%	6.9%	5.6%	3.3%
Paper industry	8.4%	8.3%	8.5%	9.5%	8.1%	7.4%	7.3%	6.2%	5.1%
Chemical industry	7.9%	8.2%	7.0%	6.7%	7.9%	7.2%	7.1%	5.8%	4.6%
Mineral industry	9.0%	8.6%	9.2%	8.6%	9.7%	8.9%	8.9%	8.1%	6.8%
Metallurgy	5.7%	6.4%	5.6%	5.7%	5.9%	5.2%	4.9%	4.0%	2.7%
Machinery industry	4.5%	4.4%	4.1%	3.8%	4.5%	4.9%	5.2%	5.0%	4.5%
Other industries	6.9%	7.0%	6.4%	5.5%	6.0%	5.1%	4.4%	3.2%	2.4%

Source: *EnergSys's own study, Mezzo-Impact model*

Compared to the 2015-2018 profitability ratios, it can be seen that after 2020 virtually all manufacturing

industries may experience increased operating costs in the REF scenario, with the exception of the light, mineral and machinery industries, which demonstrate an increase in profitability in 2020-2030. As is shown by the results of the CGE-PL model, the rate of cost growth outweighs the dynamics of revenue growth. The changes can be attributed to the change in the structure and volume of demand for industrial products as a result of differences in the increase in the prices of production of the individual industries and sectors of the national economy. This causes the gross profitability ratios of individual industries to decline overall, especially in 2030-2040.

The post-2030 changes in the operating conditions in the REF scenario prove to be relatively least severe for enterprises of the mineral industry, where production is highly energy-intensive and generates substantial carbon dioxide emissions (mainly process-generated ones). The prices of products of this sector rise the most in the manufacturing industry, which, however, does not significantly affect the volume of demand. The increased price of production generates revenues that compensate for the increase in production costs. The mineral industry owes its success to the large scale of construction projects in the economy, notably in the housing and energy sectors.

A more detailed analysis reveals that the scale of threat to the profitability of several industries can be largely attributed to the share of revenues of exports in total turnover. In the food, metallurgy and other industries, as from 2035 profitability ratios dive as a result of decreasing price competitiveness of products on international markets. In the CGE model, this is caused by a high price elasticity of demand for exports sales (relatively high price sensitivity/competitiveness of products on international markets).

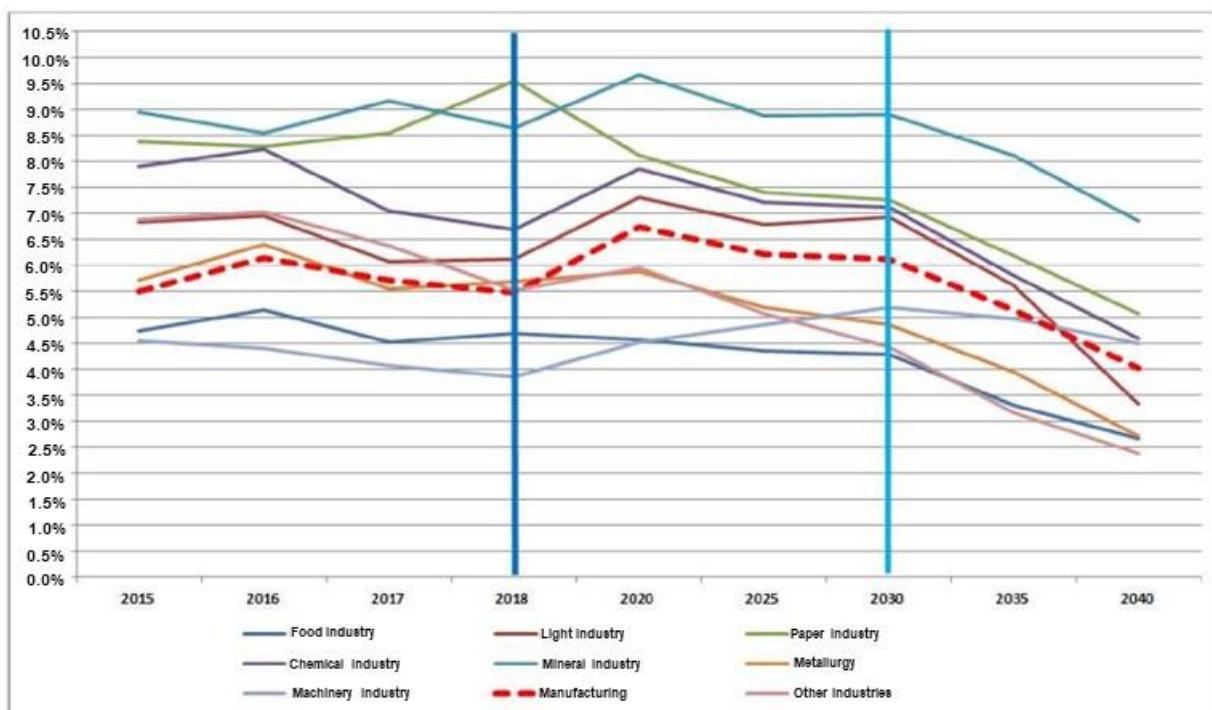


Figure 30. Changes in gross profitability of selected manufacturing industries in the REF scenario (current prices)

Changes in employment in the sectors of the NE used in the CGE-PL model are presented in the table below, while changes in the sectoral structure calculated for the period 2015-2040 in the graph that follows. According to the preliminary assumptions, the level of employment in the NE will fluctuate slightly, with shifts in the employment structure attributable mainly to a decline in the workforce in agriculture. In the period 2020-2030, the number of employees in the manufacturing, construction and service sectors rises steeply, and decreases in agriculture and the fuel and energy sector. In the decade that follows (2030-2040), employment in agriculture shrinks on a much smaller scale, while that in the sector of services, including public services, drops considerably. On the other hand, employment continues to rise in the manufacturing, construction and transport sectors.

Table 78. Employment in the economy by sectors and industries in the REF scenario [thousand employees]

Item/category	2015	2020	2025	2030	2035	2040
Agriculture, forestry and fishing	1 841	1 689	1 507	1 390	1 309	1 307
Extraction of non-energy raw materials	46	46	48	48	50	54
Manufacturing	3 250	3 191	3 240	3 609	3 548	4 054
Construction	1 157	1 127	1 134	1 290	1 336	1 410
Transport	652	614	571	592	604	652
Services	8 652	8 815	9 150	8 902	9 032	8 241
Fuel and energy sector	378	382	362	331	296	314
Total	15 977	15 865	16 011	16 163	16 175	16 033
Workforce	17 161	16 700	16 854	16 836	16 849	16 701

Source: own study, CGE-PL model

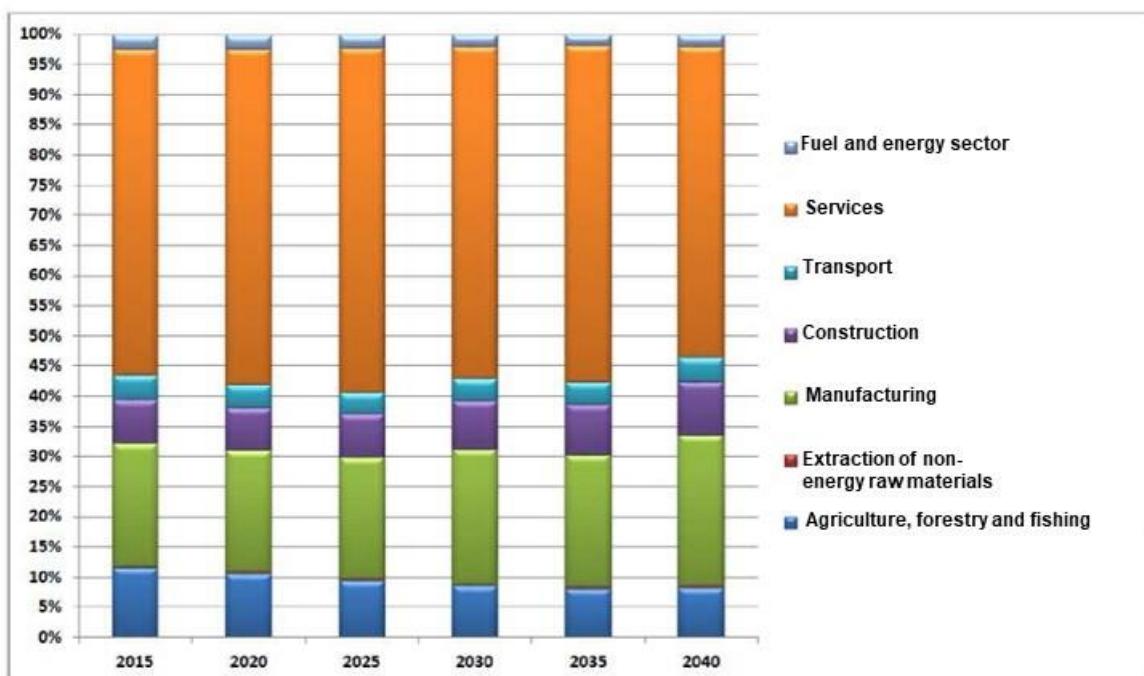


Figure 31. Employment structure in sectors of the NE in the REF scenario in 2015-2040

Thanks to the assumed major improvement in the efficiency of production factors, the projected economic growth is obtained with moderate inflation, despite strong inflation impulses related to the increase in CO₂ emission allowance and fuel prices on international markets. The results obtained are presented in the table and figure below. The inflation slows down as a result of the very moderate dynamics of service prices. The price dynamics in all sectors (excluding fuels and energy) grows fairly moderately in the period 2021-2030 to accelerate after 2030 in line with the rising trend in global prices, mainly of natural gas and CO₂ emission allowances, which highly adds to the increase of prices in the manufacturing industry, consuming high and growing amounts of electricity over time. As a consequence, increases in the prices of fuels and energy, and construction materials (cement, steel, chemicals), as well as a significant share of value added (salaries), together with a high rise in productivity, contribute jointly to a noticeable increase in prices of services in the construction sector. Relatively smaller price increases can be expected in the services and transport sectors, which function on competitive markets, often with relatively small barriers to entry.

Table 79. Evolution of inflation rate and nominal production price dynamics in sectors of the national economy in the REF scenario

Item/category	2015	2020	2025	2030	2035	2040
Inflation rate	100	107	116	119	126	132

Product and service price dynamics in sectors of the economy						
Agricultural, forestry and fisheries products	100	107	114	119	125	133
		108	118	123	127	137
		109	118	124	128	142
		108	116	122	131	143
		104	110	112	119	127
		104	111	110	116	118
		112	140	157	172	190

Source: EnergSys, CGE-PL model

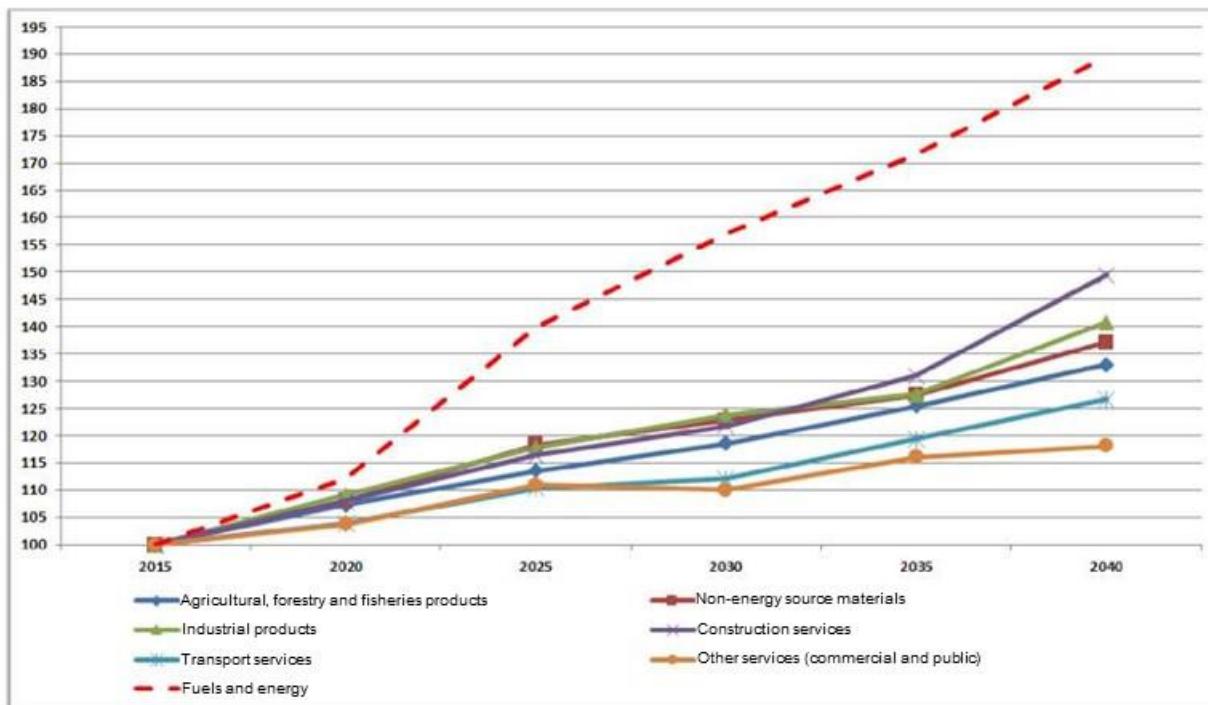


Figure 32. National nominal service and product price dynamics by sectors in the REF scenario [2015=100]

The figure above shows that, with the assumed global trends, rising prices of hydrocarbon fuels and ETS CO₂ emission allowances, a rapid increase in domestic fuel and energy prices can be expected. Over the whole period, these prices increase almost twice. However, a high increase in labour productivity along with the planned increase in salaries will have the strongest impact on the growth of prices in construction and manufacturing, which requires major investments in the latest Industry 4.0 technologies (automation and robotisation, digitisation and smart systems).

5.2.1.1.3. Analysis of social impacts in the REF scenario

This section analyses the social impacts that comprise the following macroeconomic categories over the 2030–2040 timespan:

- real wage dynamics,
- dynamics of disposable income of households (Hh),
- growth of households' expenditures on fuels and energy and their share in income, by five income groups (five quintiles: Nos 1 and 2 comprise the poorest households – 40% of all Hh, quintile No 3 comprises middle-income earners – 20% of Hh, while No 4 and 5 include the wealthiest 40% of Hh, according to the GUS criteria adopted for 2015).

The model analysis of social impacts is carried out using the Mezzo-Impact model – the Hh module, in which the results of calculations are influenced by a range of macroeconomic variables as determined in the CGE-PL

model. They constitute the so-called ‘driving force’ (impulse) in the calculations of the social impacts inherent in the implementation of the public policy instruments investigated by the Mezzo-Impact model. The trends in macroeconomic indicators calculated in the CGE-PL model in 2015-2040 are summarised in the table below.

Table 80. Disposable income of households, real wage dynamics, and nominal domestic fuel and energy price dynamics in the REF scenario

Item/category	Unit	2015	2020	2025	2030	2035	2040
Disposable income of Hh	EUR'2016 billion	270	320	376	421	473	521
Dynamics of real disposable income of Hh	[-/] 100	119	139	156	175	193	
Real wage dynamics		114	135	143	158	173	
Inflation rate		107	116	119	126	133	
Nominal value dynamics							
Nominal disposable income dynamics	100	127	162	185	221	256	
Solid fuels (coals and biomass)		110	122	131	138	155	
Liquid fuels (fuel oil and LPG in cylinder)		112	143	162	176	191	
Gaseous fuels		112	163	191	209	237	
Electricity and district heating		115	132	145	163	176	

Source: EnergSys's own study, CGE-PL model

Since the calculations in the CGE-PL model are made at current prices, use is made of the inflation rate. The evolution in disposable income of Hh reflects the gross revenues of Hh, as calculated in the CGE-PL model. Gross revenues of Hh include all value streams received by Hh, i.e. revenues (before tax) from all monetary and non-monetary sources (labour and capital). The growth of fuel and energy prices consumed by Hh is given in current prices.

Given the nature of the study, which consists in assessing the impact of changes in the share of the value of fuel and energy costs in the Hh spending basket, it is necessary to know the projected fuel and energy consumption in the period 2015-2040, taking into account shifts in the fuel mix and evolution in the volume of future consumption in the subperiods analysed. The data is based on energy consumption projections presented in the table below, which constitute one of the components discussed in the subsections dedicated to the forecast of final inland energy consumption.

Table 81. Direct consumption of fuels and energy in households in the REF scenario [PJ]

Item/category	2015	2020	2025	2030	2035	2040
Final consumption of fuels and energy in Hh, of which:	792	866	898	926	947	962
Solid fuels (coals and derivatives)	261	260	242	224	208	194
Renewable energy (biomass and others)	111	125	137	152	165	174
Liquid fuels (fuel oil and LPG)	24	25	25	25	25	25
Gaseous fuels	132	175	197	214	225	234
District heat	163	169	176	181	185	187
Electricity	102	112	121	130	138	148

Source: own study by ARE S.A.

The projected changes in consumption of energy carriers in the successive subperiods of the analysis influence future shifts in the consumption of fuels and energy by Hh. In the REF scenario, with the use of incentives already available on the market and availability of measures anticipated by the current energy policy, pro-efficiency changes in the use of fuels and energy are similar to the historically observed 2010-2016 trends.

Cumulatively, the figures in the table above and below are used to determine the social impacts of changes in the share of expenditure on fuels and energy in disposable income of Hh, which means the need to pay bills for consumed fuels and energy to their suppliers (sellers).

The results obtained for the REF scenario indicate that, despite the growing incomes of Hh and the anticipated bridging of the income gaps in society, the poorest households will continue to experience energy poverty until the end of the analysed period. What is more, sixty percent of the population can experience energy poverty until 2030, with only the relatively richest group of Hh in quintile 5 not likely to feel this kind of discomfort in their spending.

The table below presents evolution in the share of fuel and energy expenditure in disposable incomes of Hh as estimated in the Mezzo-Impact model by the quintile groups analysed.

Table 82. Evolution in the share of expenditure on fuels and energy in Hh budgets in the REF scenario, by income quintile groups, in per mille [%]

Item/category	Unit	2015	2020	2025	2030	2035	2040
First quintile							
Solid fuels	‰	37	27	22	19	15	14
Natural gas		28	26	33	36	35	35
Liquid fuels (fuel oil and LPG in cylinders)		1	1	1	1	1	1
Electricity, heat and renewable energy		85	67	63	64	63	60
Total expenditure on fuels and energy		151	121	119	120	113	109
Second quintile							
Solid fuels	‰	31	25	20	17	14	13
Natural gas		20	21	27	29	28	28
Liquid fuels (fuel oil and LPG in cylinders)		1	1	1	1	1	1
Electricity, heat and renewable energy		61	54	52	53	52	50
Total expenditure on fuels and energy		113	101	100	100	95	92
Third quintile							
Solid fuels	‰	28	24	19	17	14	12
Natural gas		19	22	28	31	30	31
Liquid fuels (fuel oil and LPG in cylinders)		1	1	1	1	1	1
Electricity, heat and renewable energy		55	53	51	52	51	50
Total expenditure on fuels and energy		104	99	99	101	96	93
Fourth quintile							
Solid fuels	‰	23	20	16	14	11	10
Natural gas		19	23	30	34	33	33
Liquid fuels (fuel oil and LPG in cylinders)		1	1	1	1	1	1
Electricity, heat and renewable energy		52	53	51	53	53	51
Total expenditure on fuels and energy		95	97	99	101	98	96
Fifth quintile							
Solid fuels	‰	11	10	8	7	6	5
Natural gas		15	19	24	27	26	27
Liquid fuels (fuel oil and LPG in cylinders)		1	1	1	1	1	1
Electricity, heat and renewable energy		39	41	40	41	41	40
Total expenditure on fuels and energy		66	71	73	76	74	72

Source: EnergSys Mezzo-Impact model, Hh module

The results of calculations in the table below are also illustrated in the charts that follow for the base year and 2020, 2030 and 2040. Each graph illustrates the share of expenditure on energy for all income quintiles, with an estimated breakdown by fuel and energy type, in the successive years of the modelled period (2015-2040). In addition, the red line in the figures marks the energy poverty line as ‘defined’ for Polish Hh (10% of the Hh budget). If the bars cross the “red line”, this indicates exposure to energy poverty in the income group (quintile) concerned.

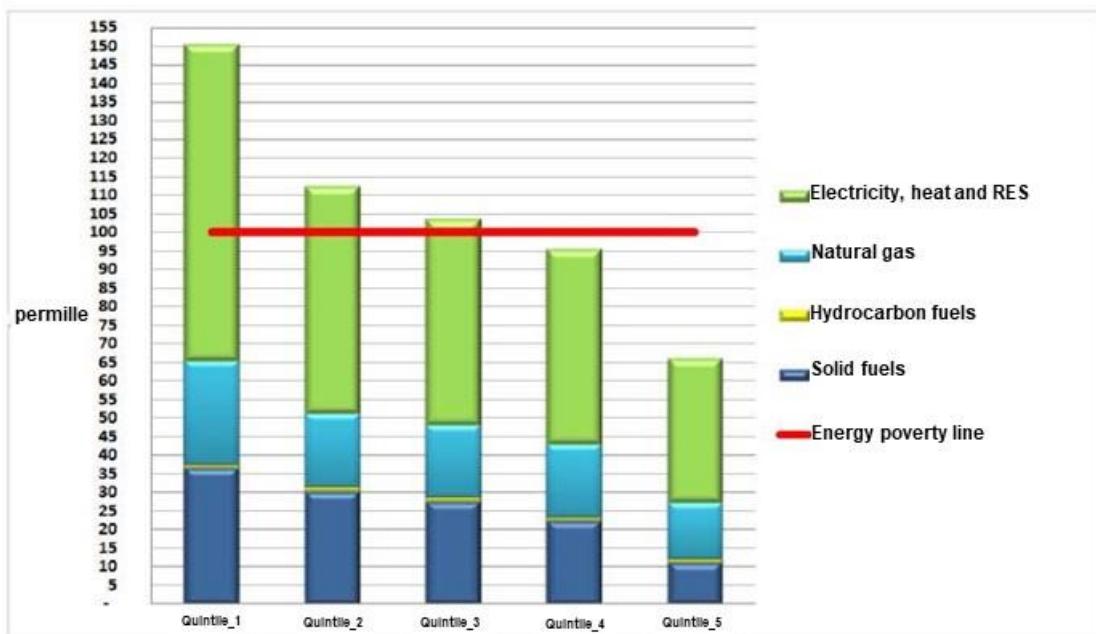


Figure 33. Structure and differences in the share of expenditure on fuels and energy by Hh income quintiles in 2015 (base year for the calculations) – REF scenario

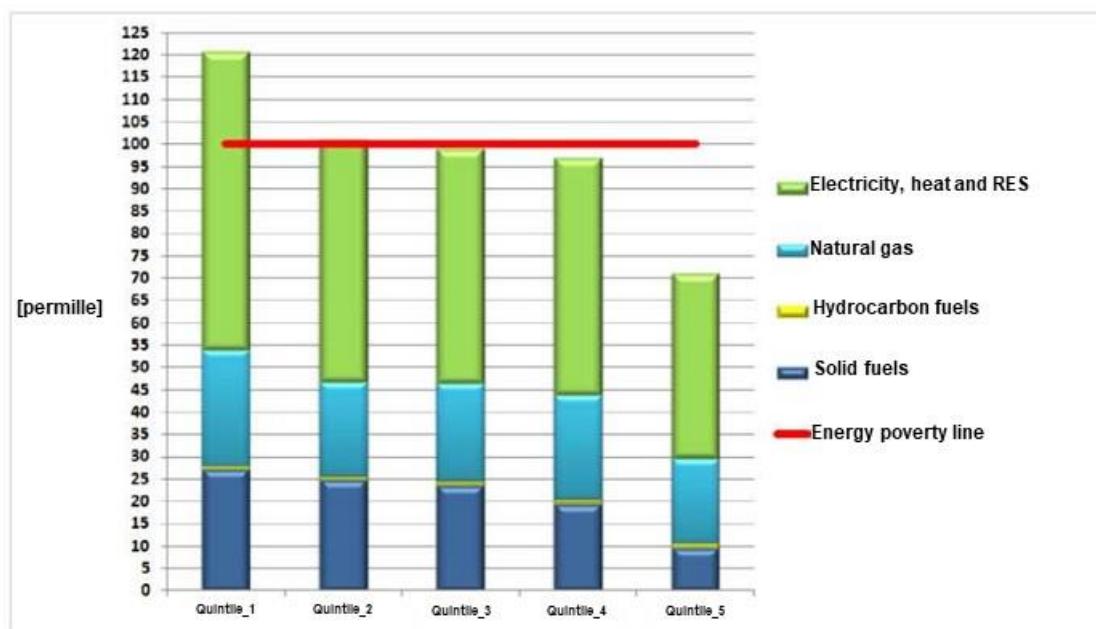


Figure 34. Structure and differences in the share of expenditure on fuels and energy by Hh income quintiles in 2020 – REF scenario

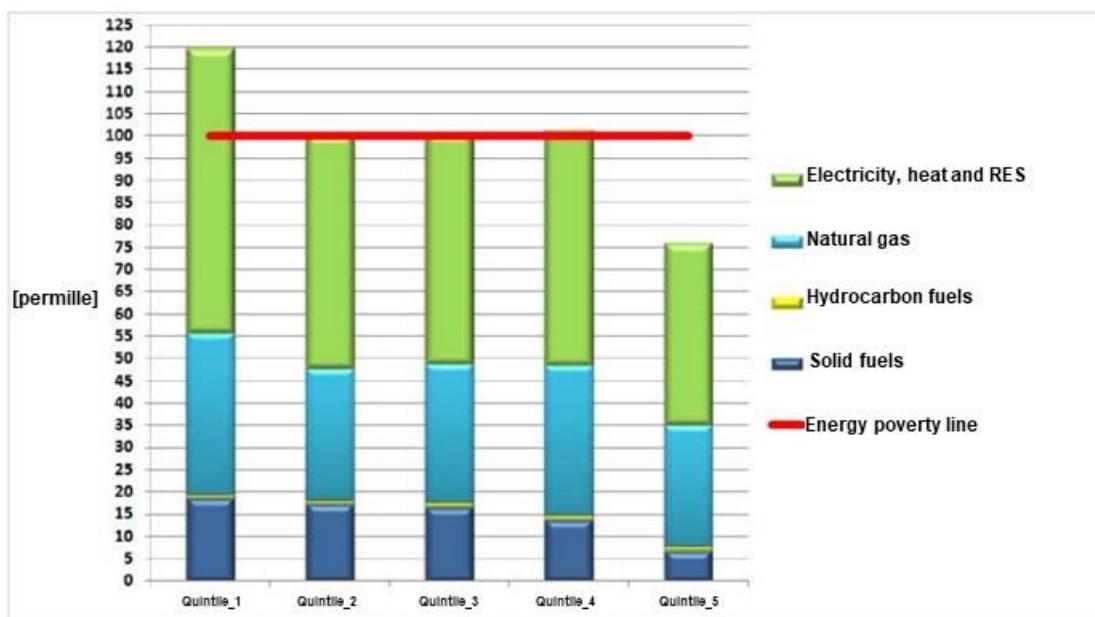


Figure 35. Structure and differences in the share of expenditure on fuels and energy by Hh income quintiles in 2030 – REF scenario

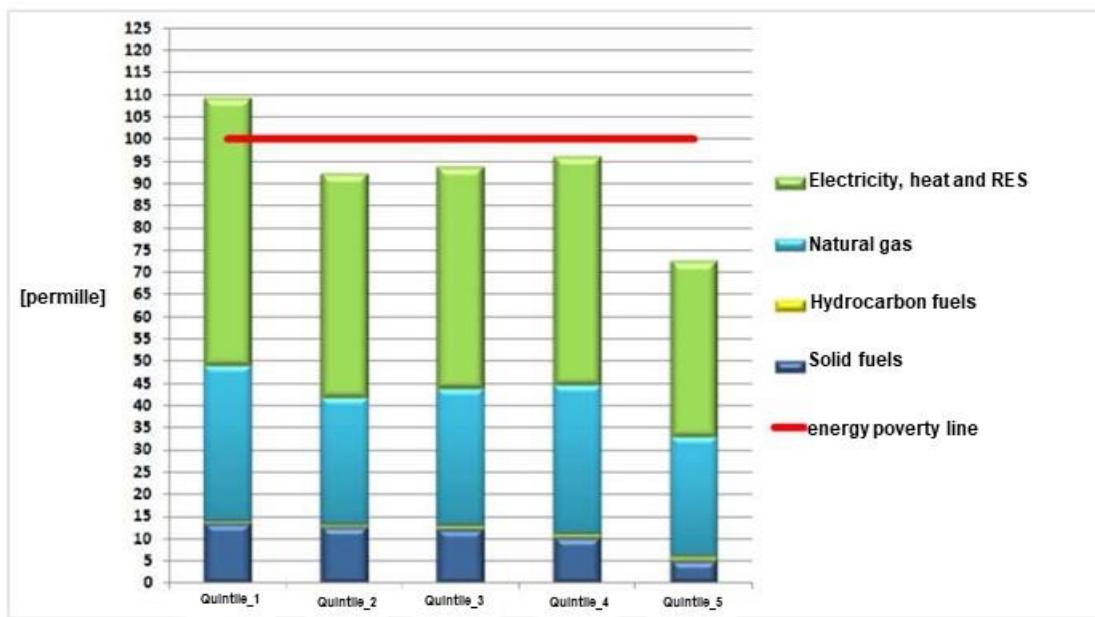


Figure 36. Structure and differences in the share of expenditure on fuels and energy by Hh income quintiles in 2040 – REF scenario

The main observation revealed by the analysis of social impacts in the REF scenario is that of a noticeable reduction in the share of expenditure on fuels and energy in Hh as a result of the expected increase in disposable incomes of Hh – both from paid work and from various forms of public support. Cumulatively these revenues contribute to a partial reduction, or actually to a weakening, of energy poverty by 2030 in the poorer income quintiles (2-4). At the same time, the calculations show that without major support for energy-savings programmes targeted at the poorest Hh – especially those from the 1-st quintile, energy poverty cannot be fully overcome even by 2040.

5.2.1.2. Analysis of macroeconomic and social impacts in the ECP scenario

5.2.1.2.1. Economic growth in 2015-2030 and the 2040 perspective

The calculations for the ECP scenario use the same – as in the REF scenario – assumptions regarding the prices of CO₂ emission allowances and fuel prices on global markets, and the assumptions regarding the development potential of the economy, i.e. evolution in the factors of production (capital, labour) and their sectoral productivity obtained in the CGE-PL model calibration process.

In relation to REF, the assumptions made for the calculations in the ECP scenario differ in terms of:

- the volume and carrier and sectoral structure of the energy demand and supply balance in manufacturing (production) of the national economy,
- the volume and carrier structure of energy demand in households,
- the capital expenditures needed to realise the ECP assumptions,
- the assumption that in both scenarios (REF and ECP) funds obtained from the sale of ETS emission allowances will be divided in the following proportions: 25% as a shield for households, 25% for the state budget, and 50% for modernisation investments.

The calculations of the ECP scenario take into account the increases (differences) in the volume and structure of capital expenditures compared to the REF scenario. Account is taken of both capital expenditures on obtaining, processing, and supplying fuels and energy as well as those related to use – aimed at saving and/or improving the efficiency of fuel and energy consumption for all consumers.

The table below presents the assumptions regarding the factors of production used in the calculations for the ECP scenario. The grey shading in the table stands for the elements that remain unchanged (by assumption) in both scenarios. The scale of the needed increase in energy productivity of manufacturing needs to be emphasised. The required growth rate for energy productivity is summarised in the last two lines of the table.

Table 83. Resources of factors of production and their productivity in the ECP scenario

	Unit	2015	2020	2025	2030	2035	2040
Workforce	thou. of employed	17 161	16 700	16 854	16 836	16 849	16 724
Gross capital formation (capital resource)	EUR'2016 billion	95	103	120	135	149	160
Capital formation dynamics	[/-]	100	108	126	142	157	169
Changes in factors of production relative to GDP							
Labour productivity dynamics	[/-]	100	120	140	160	181	202
Capital productivity dynamics			110	111	114	117	120
Dynamics of fuel and energy productivity in manufacturing (excluding households)			102	123	144	165	184
Dynamics of fuel and energy productivity in the country (including households)			120	140	160	181	202

Source: EnergSys's own study, CGE-PL model

The energy productivity growth rates demonstrate a much higher rate of growth in the anticipated energy productivity in the Hh sector, where excessive fuel and energy volumes are currently consumed. The planned measures and schemes in support of urgent thermomodernisation, combined with the replacement of heating devices and other appliances used in Hh are and will be a very important contributor to the fulfilment of the goals and assumptions of the NECP.

The following two tables present the results of calculations of the CGE-PL model regarding the volume of GDP and value added in sectors of the national economy (NE). In addition, evolution in the country's foreign trade balance, as well as the expected employment (workforce engagement) and unemployment rates calculated in CGE-PL are presented.

The results in the ECP scenario do not display large numerical differences from those obtained in the REF

scenario, which is connected with the productivity of labour and capital, which remains unchanged by assumption and is essential for the GDP growth rate. Therefore, the dynamics of GDP and shifts in its breakdown (the added value in the sectors of the national economy analysed) are highly similar. In 2015-2030, GDP potentially increases by around 60%. In the longer time horizon, economic growth gradually slows down, even though the GDP doubles over the entire 2015-2040 period. The results obtained are also shown in the figure below.

Table 84. GDP level and trends in selected macroeconomic variables in the ECP scenario

Item/category	Unit	2015	2020	2025	2030	2035	2040
GDP level	EUR'2016 billion	462.4	551	649	747	850	941
GDP dynamics	2015=100	100	119	140	162	184	203
Foreign trade balance	EUR'2016 billion	14.3	-0.8	7.0	-1.2	9.8	28.2
Employment	thousand people	15 977	15 855	16 004	16 175	16 193	16 020
Unemployment rate	%	6.9%	5.1%	5.0%	3.9%	3.9%	4.1%
<i>Model calculation subperiods</i>	years	-	2020-2020	2022-2020	2020-2020	2022-2020	2020-2020
<i>Annual average GDP growth rate over the five-year period</i>	%	-	3.6%	3.3%	2.8%	2.6%	2.0%

Source: EnergSys's own study, CGE-PL model

Table 85. Changes in value added in the economy by economic sectors and industries in the ECP scenario [EUR'2016 billion]

Item/category	2015	2020	2025	2030	2035	2040	2040/2015 ratio
Agriculture, forestry and fishing	10.43	12	13	15	16	17.7	1.70
Extraction of mineral resources	1.46	2	2	2	2	2.7	1.79
Manufacturing	85.5	97	109	127	143	153.0	1.79
Construction	34.6	39	44	56	61	65.4	1.89
Transport	27.40	33	37	44	49	55.4	2.02
Services	233.00	282	340	389	443	492.0	2.11
Fuel and energy sector	17.80	22	23	21	24	29.4	1.65
Total	410.19	486	569	654	739	816.0	1.99
GDP	462.4	551	649	747	850	941	2.03

Source: EnergSys's own study, CGE-PL model

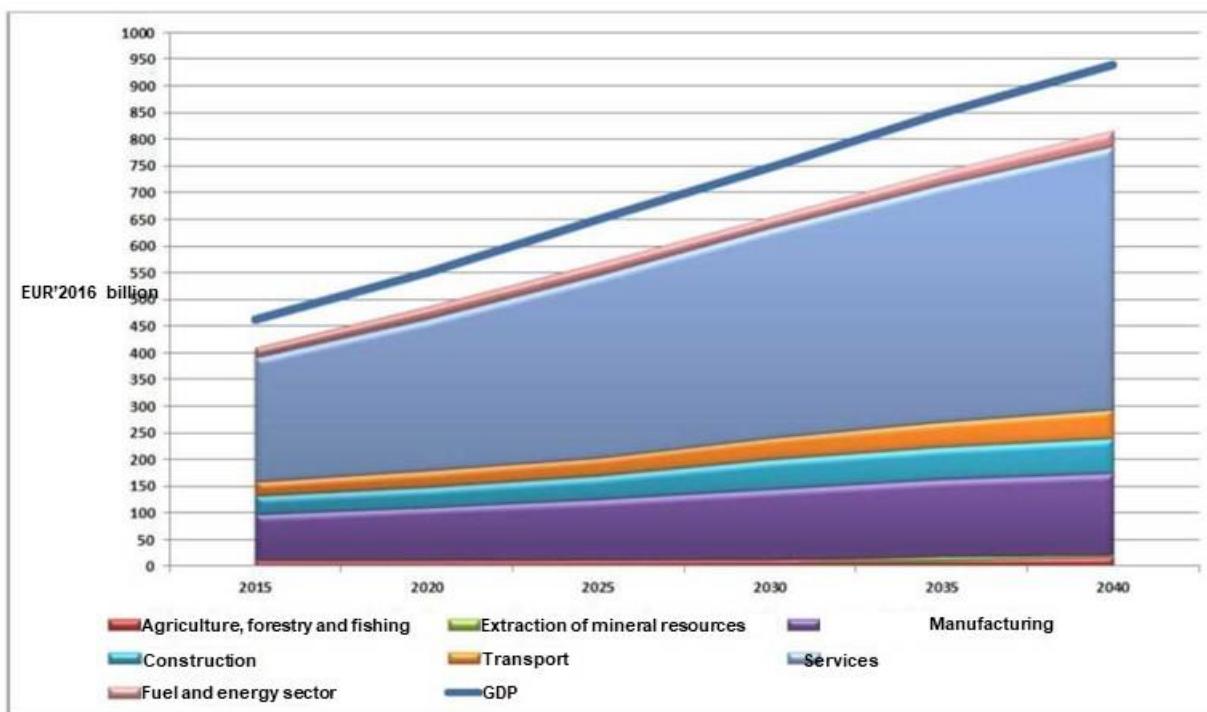


Figure 37. GDP and value added in aggregate sectors of the NE – ECP

In terms of shifts in the GDP generation structure, the results of the model are also close to the original assumptions of the REF scenario, although there are some differences. The table and figure below show a gradual increase in the share of the service sector, by nearly 1 pp in 2040 compared to 2015, and a radical increase in the share of the fuel and energy sector after 2030, which reaches several percentage points. **This is connected with the very large increase in capital expenditures on additional RES, which is much higher than in the REF scenario.** By contrast, the shares in manufacturing and transport decrease.

5.2.1.2.2. Analysis of the profitability, employment structure, and production prices of the manufacturing industry in the ECP scenario

The study analyses the impact of the conditions of the ECP scenario on the profitability of gross revenues in manufacturing industries. The results obtained are presented in the table and figure below.

Table 86. Changes in gross profitability of selected manufacturing industries in the ECP scenario (current prices)

	2015	2016	2017	2018	2020	2025	2030	2035	2040
Food industry	4.7%	5.1%	4.5%	4.7%	4.6%	4.4%	4.4%	3.4%	2.7%
Light industry	6.8%	6.9%	6.1%	6.1%	7.3%	6.8%	6.4%	5.5%	3.0%
Paper industry	8.4%	8.3%	8.5%	9.5%	8.0%	7.2%	7.1%	6.1%	5.0%
Chemical industry	7.9%	8.2%	7.0%	6.7%	7.9%	7.3%	7.2%	6.0%	4.9%
Mineral industry	9.0%	8.6%	9.2%	8.6%	9.3%	8.3%	8.3%	7.6%	6.5%
Metallurgy	5.7%	6.4%	5.6%	5.7%	5.7%	5.0%	4.8%	3.8%	2.7%
Machinery industry	4.5%	4.4%	4.1%	3.8%	4.3%	4.4%	4.8%	5.0%	4.5%
Other industries	6.9%	7.0%	6.4%	5.5%	5.9%	4.9%	4.3%	3.2%	2.6%

Source: *EnergSys's own study, Mezzo-Impact model*

As for the GDP creation volume and structure, the differences between the scenarios in terms of changes in the profitability of industries are not large, and their evolution trend is similar to that calculated in REF. This similarity of development on a national economy scale is attributable to the unchanged values of labour and capital productivity, similar way of redistribution of revenues from the sale of CO₂ emission allowances, and other development-related features of the national economy, determined, *inter alia*, by demographics and the mobility

and qualifications of the workforce.

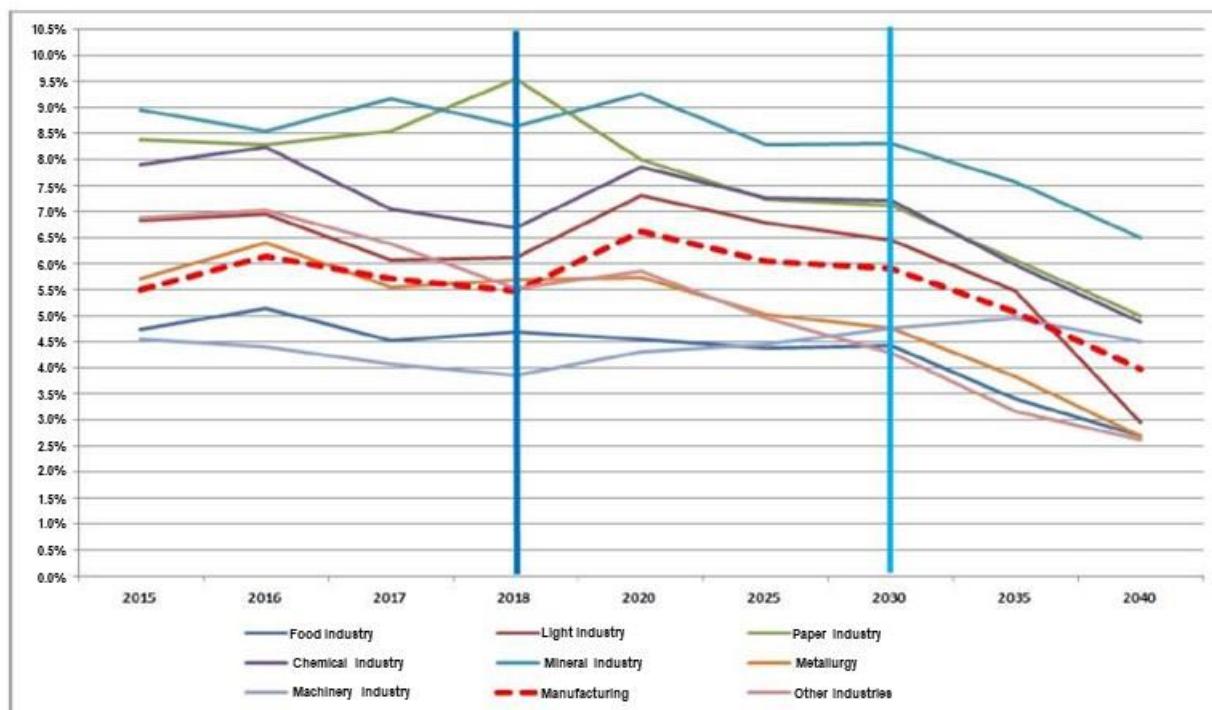


Figure 38. Changes in gross profitability of selected manufacturing industries in the ECP scenario (current prices)

The changes of employment in the sectors of the NE used in the CGE-PL model are presented in the table below, while the shifts in employment structure in 2015-2040 by sectors are shown in the graph that follows. Also for this element, the results of simulations in the model are very similar in both scenarios. The number of people employed in agriculture, and after 2035 also in services, goes down. In the period 2015-2040, the number of employees in the manufacturing and construction industries rises steeply, which stems from the adverse demographic processes in Poland.

Table 87. Employment in the economy by sectors and industries in the ECP scenario [thousand employees]

Item/category	2015	2020	2025	2030	2035	2040
Agriculture, forestry and fishing	1 842	1 701	1 524	1 441	1 438	1 388
Extraction of non-energy raw materials	46	45	46	50	52	55
Manufacturing	3 250	3 198	3 260	3 492	3 610	3 796
Construction	1 157	1 131	1 163	1 358	1 382	1 472
Transport	652	621	589	626	631	697
Services	8 652	8 877	9 284	9 163	9 051	8 547
Fuel and energy sector	378	372	367	330	312	299
Total	15 977	15 944	16 233	16 459	16 476	16 254
Workforce	17 273	16 695	17 087	17 145	17 162	16 931

Source: EnergSys's own study, CGE-PL model

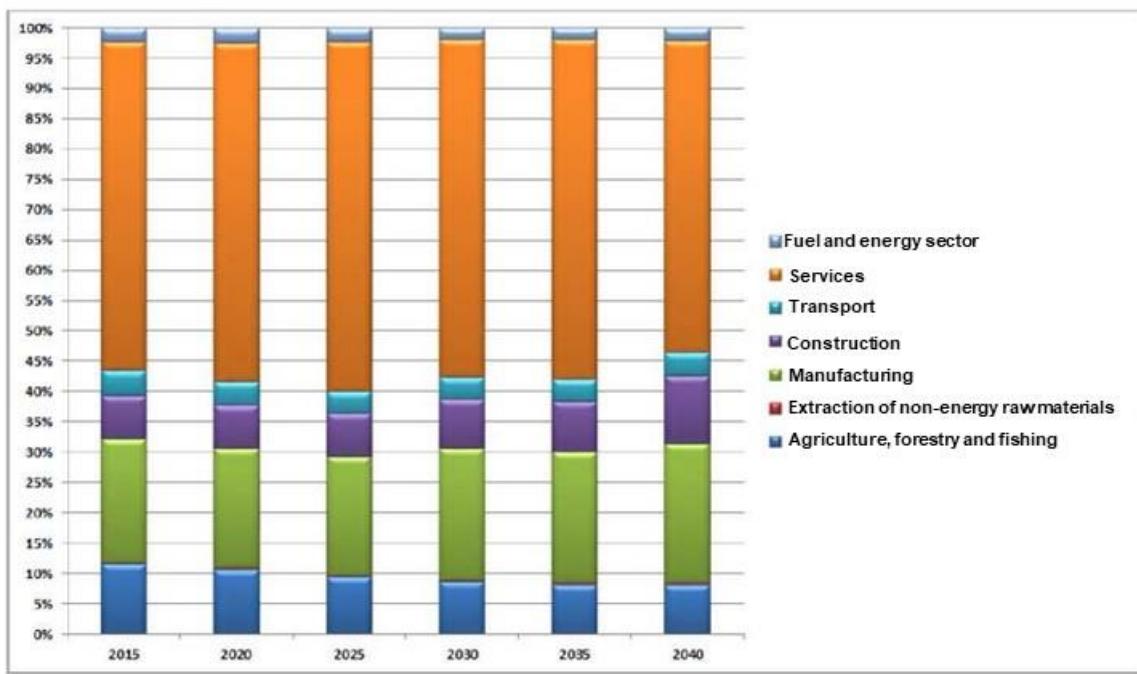


Figure 39. Employment structure in sectors of the NE in the ECP scenario in the period 2015-2040

Another major group of results is formed by the **price trends**, which are determined in the ECP scenario by dynamics indicators. They are slightly higher than those obtained for REF (*inter alia*, as a result of the reduction in the excise duty and the interim fee). For the ECP scenario, the price dynamics obtained in the calculations are presented in the table and figure below.

All prices rise quite strongly in 2021-2025 to slow down in 2026-2030, except for fuel and energy prices. Stronger price increases may occur especially in the 2035-2040 subperiod, which will potentially correlate with the anticipated cycles of the domestic and world economy. The differences in the pace and scale of price increases between the scenarios (ECP vs. REF) are mainly noticeable for fuel and energy prices, which do not grow so fast in the ECP scenario over the 2020-2035 period. This is attributable to the significantly higher energy efficiency improvement rate, including much higher fuel and energy savings in the Hh sector. The anticipated energy savings, combined with the development of distributed renewable electricity, will reduce the demand for final energy thereby relieving the tensions in the energy production and supply mix. The process, supported by stable public policies, will constitute one of the fundamental qualitative changes of development in the ECP scenario. These changes are based on sustainable energy transition, initiated and maintained by changes in the preferences and behaviour of consumers, followed by adaptation measures of producers and sellers of fuels and energy.

Table 88. Evolution of inflation rate and nominal production price dynamics in sectors of the national economy in the REF scenario

Item/category	2015	2020	2025	2030	2035	2040
Inflation rate	100	107	116	119	126	133
Product and service price dynamics in sectors of the economy						
Agricultural, forestry and fisheries products		107	114	119	125	133
Non-energy source materials		108	118	123	127	137
Industrial products	100	110	119	125	128	147
Construction services		108	117	122	131	143
Transport services		104	110	112	119	127
Other services (commercial and public)		104	111	110	117	119
Fuels and energy		113	139	154	166	187

Source: EnergSys's own study, CGE-PL model

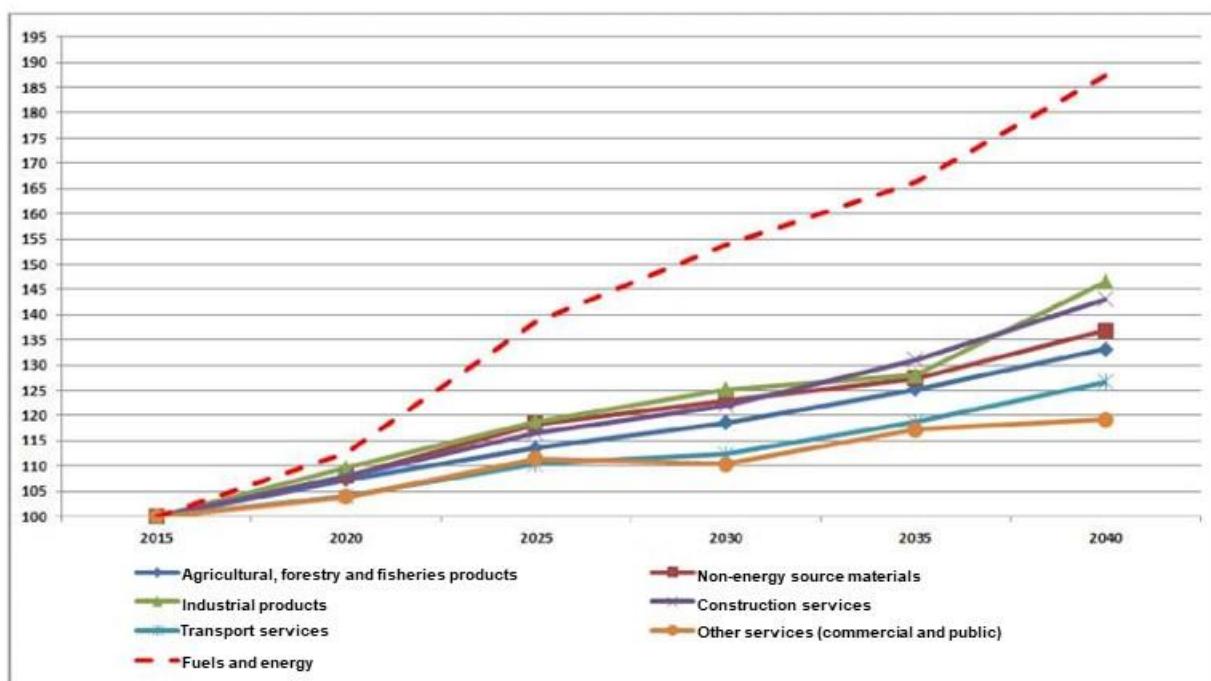


Figure 40. National nominal service and product price dynamics by sectors in the ECP scenario

5.2.1.2.3. Analysis of social impacts in the ECP scenario

This section analyses the social impacts comprising the following macroeconomic categories in the perspective of the country's economic development until 2040:

- real wage dynamics,
- dynamics of disposable income of households,
- growth of households' expenditures on fuels and energy and their share in income, with account taken of the income gap (five quintiles: Nos 1 and 2 comprise the 40% poorest Hh, quintile No 3 comprises middle-income earners – 20% of Hh, while No 4 and 5 include the wealthiest 40% of Hh, according to the GUS criteria adopted for 2015).

The model analysis of social impacts is carried out using the Mezzo-Impact model – the Hh module, in which the results of calculations are influenced by a range of macroeconomic variables as determined in the CGE-PL model. They constitute the so-called 'driving force' (impulse) in the calculations of the assessment of the social impacts inherent in the implementation of the public policy instruments investigated by the Mezzo-Impact model.

The macroeconomic categories calculated in the model for the period 2015-2040 are summarised in the table below. Importantly, in the CGE-PL model, calculations are made in current prices, while the macro categories in real prices are determined with account taken of the inflation rate, as calculated in the model.

Table 89. Disposable income of households, real wage dynamics, and nominal domestic fuel and energy price dynamics in the ECP scenario

Item/category	Unit	2015	2020	2025	2030	2035	2040
Disposable income of Hh	EUR'2016 billion	270	318	373	416	482	522
Dynamics of real disposable income of Hh	[-/-]	100	118	138	154	178	193
Real wage dynamics			114	134	142	160	172
Inflation rate			107	116	119	126	132
Nominal value dynamics							

Nominal disposable income dynamics	100	126	161	183	224	255
Solid fuels (coals and biomass)		112	121	122	134	151
Liquid fuels (fuel oil and LPG in cylinder)		112	140	162	170	206
Gaseous fuels		111	162	190	207	233
Electricity and district heating		116	131	141	155	168

Source: *EnergSys's own study, CGE-PL model*

The table below presents a forecast of demand for fuels and energy in the household sector resulting from projections prepared for the ECP scenario.

Table 90. Direct consumption of fuels and energy in households in the ECP scenario [PJ]

Item/category	2015	2020	2025	2030	2035	2040
Final consumption of fuels and energy in Hh,	792	845	793	751	751	757
of which:						
Solid fuels (coals and derivatives)	261	243	169	109	80	57
Renewable energy (biomass and others)	111	122	143	166	186	206
Liquid fuels (fuel oil and LPG)	24	26	25	23	23	22
Gaseous fuels	132	177	183	182	181	182
District heat	163	169	157	147	148	149
Electricity	102	108	116	124	133	143

Source: *own study by ARE S.A.*

Even though the dynamics of fuel and energy prices determined in the ECP scenario is similar to the prices in REF, the level of fuel and energy consumption in households in ECP is much lower – by approx. 20-22% in 2030-2040. By contrast, the dynamics of disposable income of households, real wages and inflation rates are very similar in both scenarios. The results of calculations summarised in the table at the beginning of this subsection and the real wage dynamics indicate that in the successive 5-year subperiods the share of expenditure on fuels and energy, even among the poorest Hh (quintiles 1 and 2), may decrease considerably in the period analysed. In the table below expenses in excess of this level are marked in red. Under the ECP scenario, if energy-savings projects in households are implemented quickly, until 2020, energy poverty will affect up to 40% of households, and in the REF scenario, as many as 60%. This is a major and beneficial change, but one dependent on enormous scale of support for energy-savings measures.

Table 91 below presents the evolution in the share of fuel and energy expenditure in disposable incomes of Hh (until 2040) as estimated in the Mezzo-Impact model by the quintile groups. They are determined using the macroeconomic categories compiled in the table at the beginning of this subsection and projected energy consumption shown in the table above, as well as the assumed shifts in the quintiles.

Table 91. Evolution in the share of expenditure on fuels and energy in Hh budgets in the ECP scenario, by income quintile groups, in per mille [%]

Item/category	Unit	2015	2020	2025	2030	2035	2040
First quintile							
Solid fuels		37	26	15	9	6	4
Natural gas		28	26	31	31	27	27
Hydrocarbon fuels		1	1	1	1	1	1
Electricity, heat and renewable energy		85	66	61	60	56	56
Expenditure on energy		151	120	108	100	90	87
Second quintile							
Solid fuels		30.5	24.1	14.1	8.0	5.2	3.6
Natural gas		19.9	21.1	25.0	25.4	22.2	21.9
Hydrocarbon fuels		1.0	0.9	0.8	0.8	0.6	0.6

Electricity, heat and renewable energy	61.2	54.2	49.8	49.2	46.5	46.8
Expenditure on energy	113	100	90	83	75	73
Third quintile						
Solid fuels	27.8	22.8	13.4	7.7	5.0	3.6
Natural gas	19.5	22.1	26.3	26.9	23.7	23.5
Hydrocarbon fuels	1.0	0.9	0.9	0.8	0.7	0.7
Electricity, heat and renewable energy	55.4	52.4	48.5	48.2	45.9	46.6
Expenditure on energy	104	98	89	84	75	74
Fourth quintile						
Solid fuels	22.6	18.8	11.1	6.4	4.2	3.0
Natural gas	19.5	23.6	28.2	29.0	25.6	25.6
Hydrocarbon fuels	1.0	1.0	0.9	0.9	0.7	0.8
Electricity, heat and renewable energy	52.4	52.9	49.2	49.1	47.0	47.9
Expenditure on energy	95	96	89	85	78	77
Fifth quintile						
Solid fuels	11.3	9.4	5.6	3.2	2.1	1.5
Natural gas	15.0	19.2	22.9	23.5	20.7	20.6
Hydrocarbon fuels	1.0	1.0	0.9	0.9	0.8	0.8
Electricity, heat and renewable energy	38.8	41.3	38.3	38.2	36.5	37.1
Expenditure on energy	66	71	68	66	60	60

Source: Mezzo-Impact module

The results of calculations in the table below are also illustrated in the four successive graphs that follow for the years 2015, 2020, 2030, and 2040. Each graph illustrates the share of expenditure on energy for all income quintiles, with an estimated breakdown by fuel and energy type, in the successive years of the modelled period (2015-2040). In addition, the red line in the graphs marks the energy poverty line as 'defined' for Polish Hh. Such a situation occurs when the energy spending bars cross the 'red line' of energy poverty for the respective Hh income quintile.

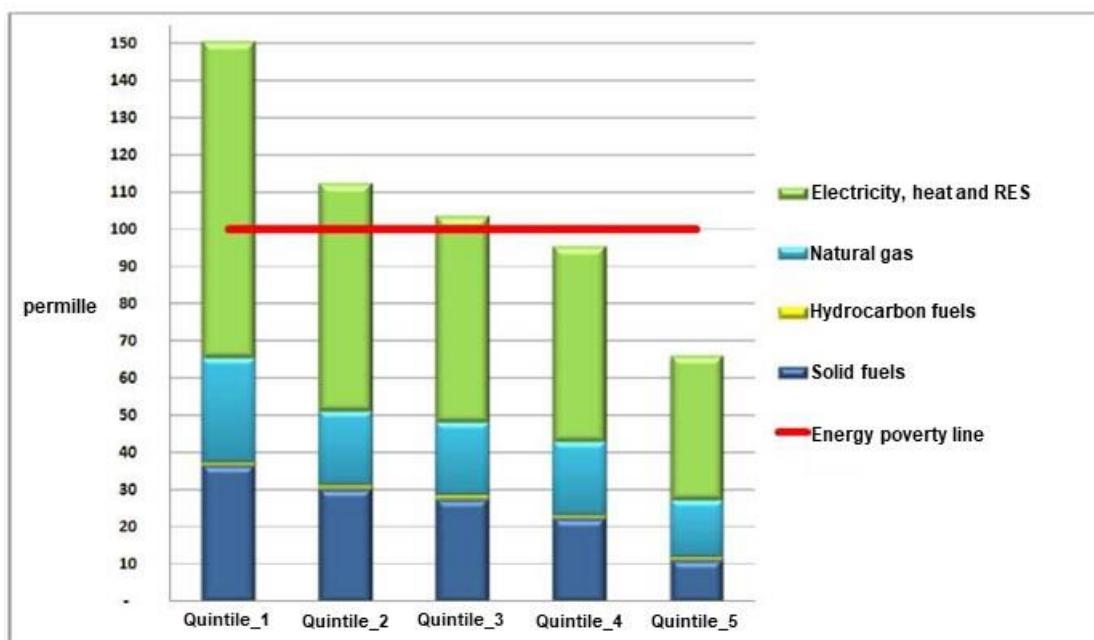


Figure 41. Structure and differences in the share of expenditure on fuels and energy by Hh income quintiles in 2015 – ECP scenario

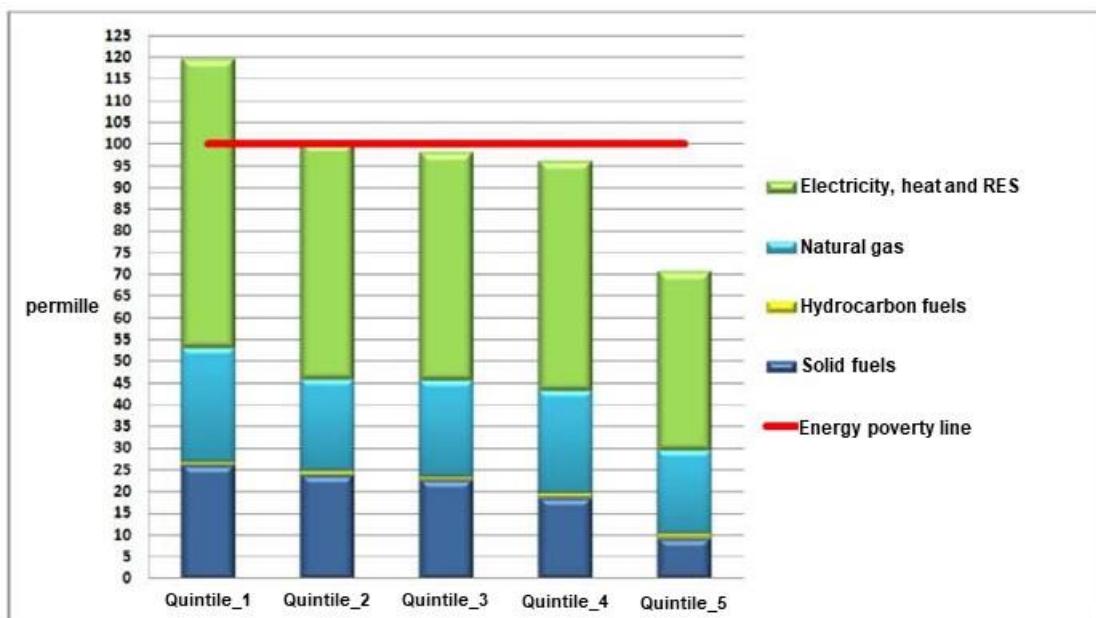


Figure 42. Structure and differences in the share of expenditure on fuels and energy by Hh income quintiles in 2020 – ECP scenario

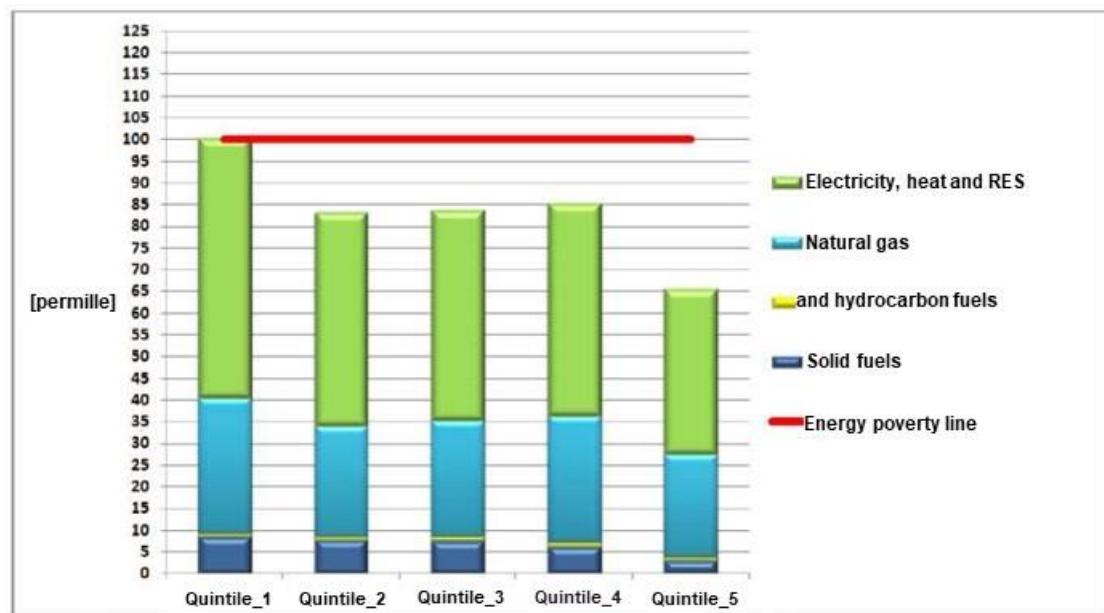


Figure 43. Structure and differences in the share of expenditure on fuels and energy by Hh income quintiles in 2030 – ECP scenario

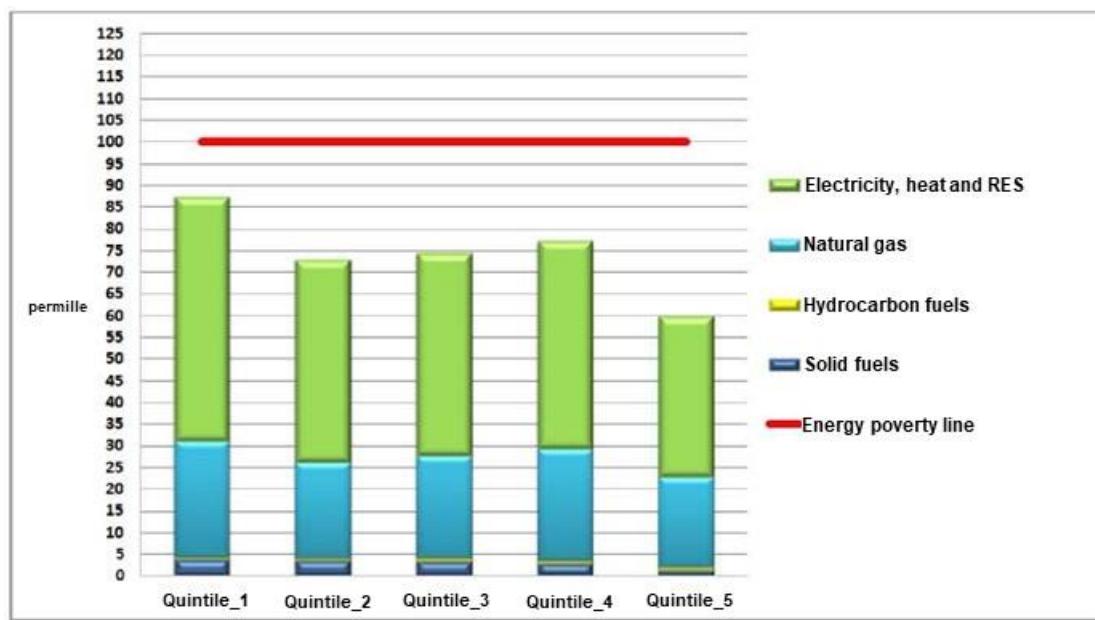


Figure 44. Structure and differences in the share of expenditure on fuels and energy by Hh income quintiles in 2040 – ECP scenario

The key conclusion that can be drawn from the analysis of social impacts in the ECP scenario is one on a fairly radical reduction in expenditure on fuels and energy in Hh, which directly reduces the scale of energy poverty, especially in the poorer quintiles, namely 1-3, of the population of households.

5.2.2. Macroeconomic and social impact assessment for both scenarios – REF and ECP

The macroeconomic and social impacts for both scenarios are assessed by comparing the REF and ECP variants. The assessment is completed through an analysis and comparison of the obtained results of model calculations, taking into account changes in the energy mix and capital expenditures. The changes occur in:

- the volume and breakdown of domestic demand for fuels and energy in the period 2015-2040,
- the volume and structure of demand for fuels and energy in Hh throughout the period,
- the volume of capex in the fuel and energy sector and the volume of expenditure on improving fuel and energy management among final consumer sectors (households, transport, industry, services, agriculture).

The other values of macroeconomic variables, i.e. capital, workforce and their productivity in industries and economic sectors, do not change by assumption. Also the paths of global fuel prices and ETS CO₂ emission allowance prices remain unchanged in both scenarios (REF vs ECP).

Based on the above assumptions, a comparative assessment of the impacts of changes in the economy and Hh expenditure on fuels and energy in the investigated scenarios is possible. The impacts result from changes in the volume and demand-supply fuel and energy mix to be attained as result of the ECP scenario. In the CGE model, the adaptation changes in the industry and sector structure of value add and GDP creation are also driven by changes in the volume of capex. With the limited resources in the national economy, mainly of capital and workforce, (with their ceilings set in the REF scenario), using them on a much greater scale for remodelling the energy sector causes (in accordance with the general equilibrium concept) them to be less available for other sectors and/or industries of the national economy.

It should be emphasised that a large proportion of the planned capital expenditures is to be allotted for either efficiency and health projects (large-scale thermomodernisation investments and elimination of 'low-stack' emissions in the housing and service sectors) **or projects focused on supporting development activities, such as promoting electromobility, mainly in cities.** This will produce synergy effects throughout the economy, as a result of which the spending should generate much higher multiplier effects. This is confirmed by the results of macroeconomic modelling presented below.

5.2.2.1. Macroeconomic impact assessment

The table below summarises the key macroeconomic indicators that underlie the results and assumptions in both scenarios.

The differences between the results for GDP and employment are not particularly pronounceable (greater variations in employment occur between economic sectors, as is described in the subsection dedicated to the impact assessment for selected manufacturing industries). Both GDP volume and employment in the economy are slightly higher in the ECP scenario from 2030. The value added in the services sector is also higher, while that in manufacturing is slightly lower compared to REF.

More pronounced differences between the scenarios can be seen for the foreign trade balance and the productivity of fuels and energy consumed for manufacturing (excluding Hh) and in the country (including Hh).

The trends in the aggregate fuel and energy prices in the scenarios are also slightly different. Although in both scenarios the increase in this price in 2015-2040 is almost twofold, in the ECP scenario the price of fuels and energy rises much slower in 2025-2035. A key role is played by changes in the volume and mix of fuels towards an increased share of low-emission fuels (RES), which produce a lower price impulse than imported fuels and rising prices of CO₂ emission allowances.

The **much higher productivity of final energy in manufacturing in the ECP scenario as compared to the productivity in REF** is noteworthy. This mainly stems from the assumed larger-scale energy-savings measures across the sectors of the economy, which will allow Poland to maintain competitive advantage on the EU and global markets.

Table 92. Summary of selected macroeconomic categories in the REF and ECP scenarios

Model category	Unit	Scenario	2015	2020	2025	2030	2035	2040
GDP level EUR'2016 billion	'000	REF	462	551	649	747	844	937
		ECP	462	551	649	747	850	940
Employment	%	REF	15 977	15 865	16 011	16 163	16 175	16 055
		ECP	15 977	15 855	16 004	16 175	16 193	16 060
Inflation rate	%	REF	100.0	107.1	116.2	118.5	126.4	132.6
		ECP	100.0	107.4	116.4	118.6	125.7	132.1
Foreign trade balance EUR'2016 billion		REF	14.3	1.6	13.0	8.4	2.2	21.7
		ECP	14.3	-0.8	7.0	-1.2	9.8	28.2
Share of service sector in value added	%	REF	57.3	57.9	59.4	59.1	59.8	59.9
		ECP	57.3	58.1	59.8	59.6	59.9	60.0
Share of manufacturing in value added	%	REF	19.9	20.3	19.9	20.0	19.9	19.5
		ECP	19.9	19.9	19.2	19.4	19.4	18.9
Labour productivity dynamics 2015 = 100		REF	100	120	140	160	180	202
		ECP	100	120	140	160	181	202
Capital productivity dynamics 2015 = 100		REF	100	110	111	114	116	120
		ECP	100	110	111	114	117	120
Fuel and energy productivity dynamics in manufacturing 2015 = 100		REF	100	100	113	126	141	156
		ECP	100	110	130	148	156	169
Fuel and energy price dynamics 2015 = 100		REF	100	112	140	157	172	190
		ECP	100	113	139	154	166	189

Source: EnergSys, CGE-PL model

The chart below presents the differences in GDP creation between the two scenarios. The results of second loop calculations indicate that, as in the first stage of the study, the differences in the dynamics of GDP growth in the ECP and REF scenarios are insignificant. However, a comparison of the version of the climate and energy policy planned with the conditions of the REF scenario indicates that there is no clear impulse for the economy as a whole until 2030, mainly as a result of the medium- and long-term nature of investments in retrofits and in other sectors of the economy. In addition, it is necessary to emphasise the far higher unit consumption of capital by RES installations (photovoltaics, wind farms) in combination with their much lower production efficiency

(lower usable capacity per year), connected with Poland's geographical conditions. Consequently, the considerably higher capital invested in lower-efficiency RES installations will start to bear fruit after a longer period than it would if invested in alternative projects. Also the effects of energy-savings measures, in particular the housing stock thermomodernisation plan, are likely to produce economic effects after about 20-25 years, which is confirmed by the assessment of cost-effectiveness implied by a number of energy audits.

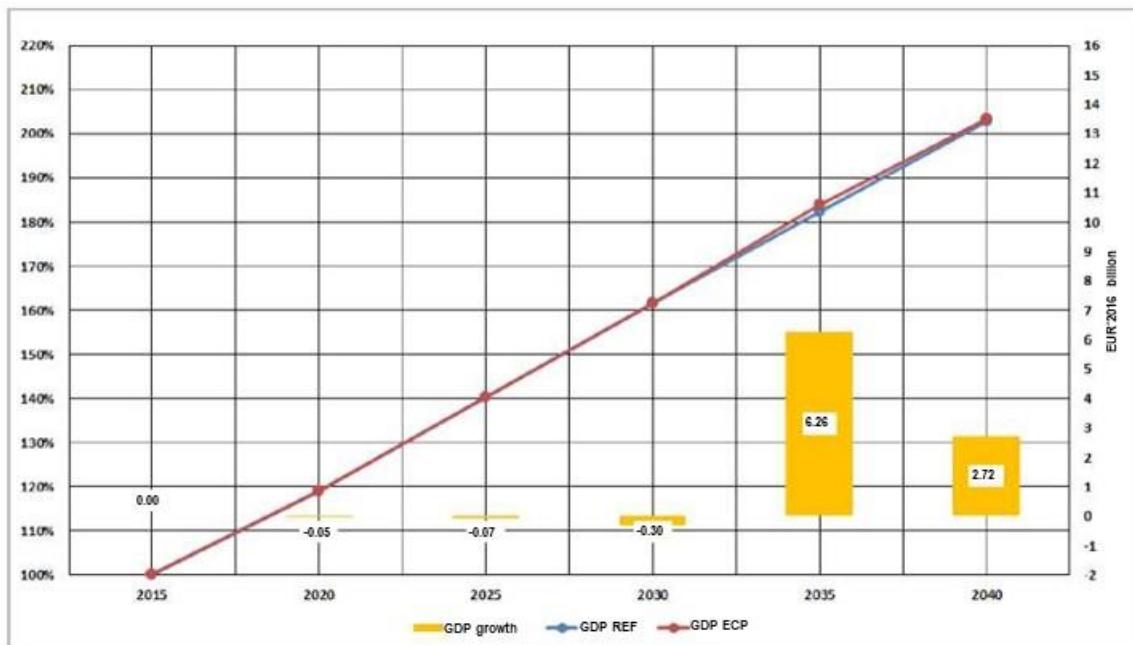


Figure 45. Comparison of GDP dynamics in the ECP and REF scenarios

The differences (see the figure above) in **GDP** are in the order of tens of millions of EUR, although they are in favour of the REF scenario in the early years (until around 2030). Economic acceleration as a result of the completion of the ECP scenario can only be expected after 2030. In 2035, the 'gain', as measured in GDP growth, reaches EUR 6 billion, and in 2040 nearly EUR 3 billion. Additionally, calculations of the sensitivity of GDP to the use of decarbonisation instruments, including those to improve energy efficiency, only in the ECP scenario, highly improve the economic efficiency of the ECP scenario over REF, as illustrated in the figure below.

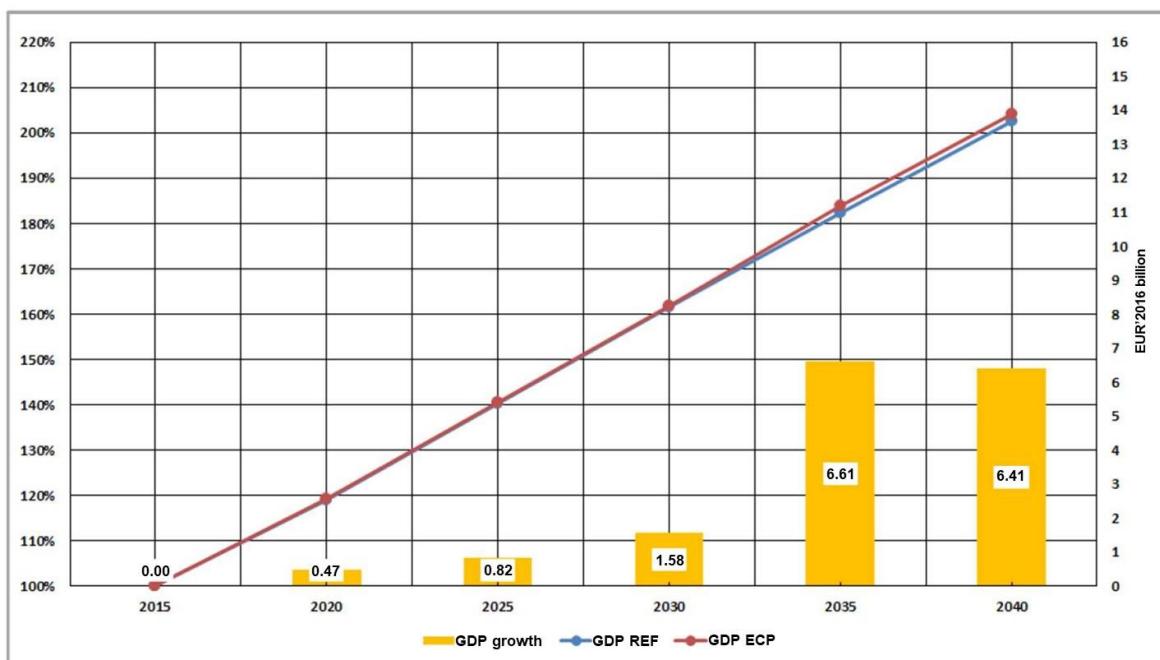


Figure 46. Comparison of GDP dynamics in the ECP and REF scenarios (distribution of revenues from the sale of allowances only in the ECP scenario)

In both scenarios, the **foreign trade balance** (FTB), i.e. exports minus imports, follows a similar path, which is illustrated in the figure below.

In 2020, the reduced FTB in both scenarios is caused by the need to increase imports of natural gas by about 20%. In later years, the volatility of the FTB depends on the difference between the growth in the needs for imports (including for fuels) and the possibilities of increasing exports, which determine the relationship between domestic and global prices of products across the economic sectors. In the ECP scenario, the needs for natural gas imports are so high that in 2020 and 2030 the FTB turns out to be negative. In 2030, with the assumptions regarding world inflation adopted (identical for both scenarios), the relations between domestic and import prices slow the growth of exports down to a rate lower than the increase in import needs, which depends, *inter alia*, on the economic growth rate. Despite a similar course of changes, it can be observed that in the 2030 horizon, the ECP scenario is characterised by worse foreign trade performance. After 2030, this tendency clearly changes in favour of the ECP scenario, which is associated with the need for technological adjustments in many manufacturing industries and clearly reduced demand for fuels and energy in the household sector as a result of efficiency schemes.

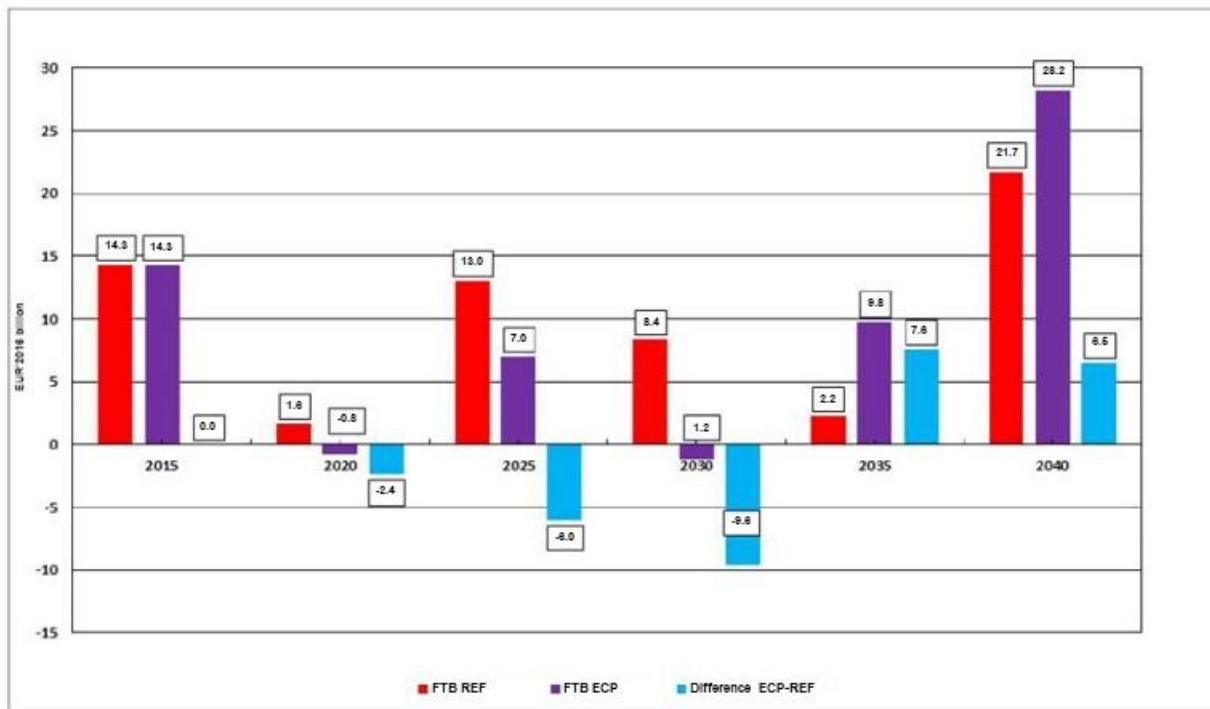


Figure 47. Comparison of foreign trade balances between the ECP and REF scenarios

Unlike the above-discussed differences in GDP in both scenarios, the results for evolution in energy productivity clearly indicate a strong advantage of productivity in ECP over REF, which is illustrated by the chart below.

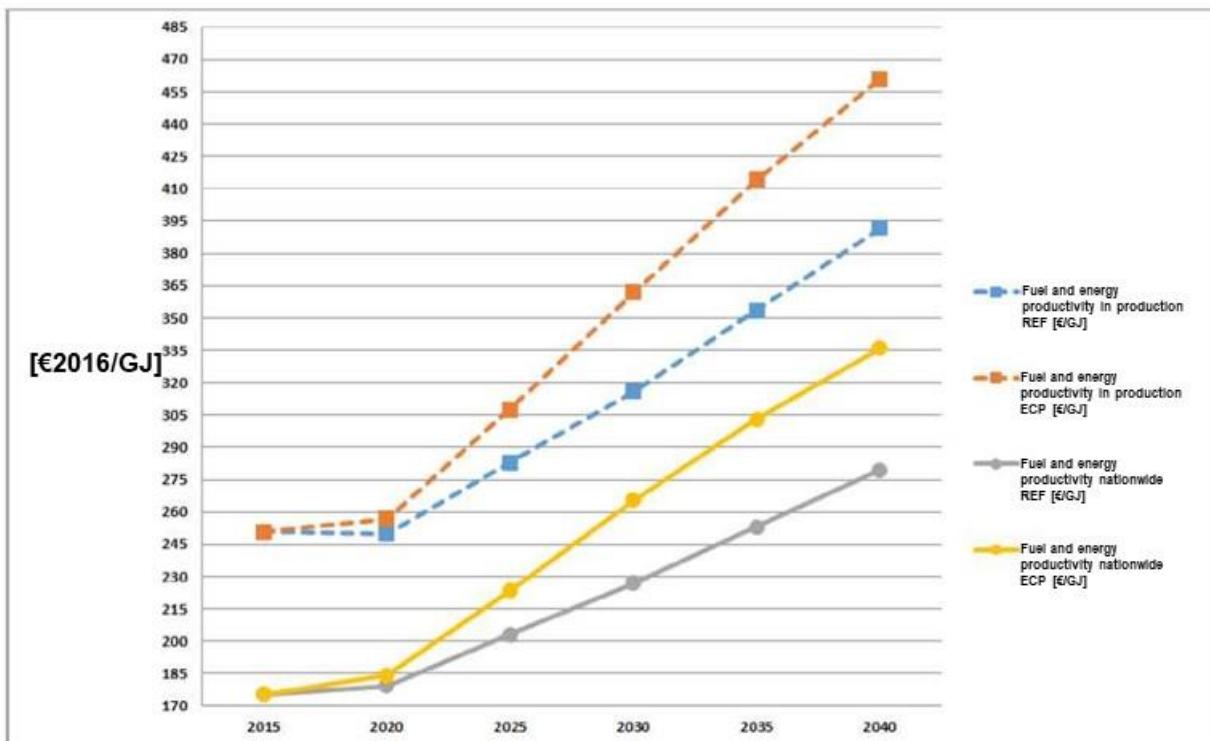


Figure 48. Comparison of changes in energy productivity for final energy and overall in the REF and ECP scenarios

The study compares the change trends in the two categories of productivity of final energy in the production sphere, which is formed by all economic sectors that generate added value and, as a result, GDP. In the

analysis, use is made of a simplified approach in which energy consumption in the housing sector (Hh) is subtracted from inland energy consumption. Thereby the production consumption is better linked to the production activity of the production and service sectors. In the figure, this productivity is illustrated by dashed lines.

The effects described above stem both from energy-savings measures in the sectors of the national economy and from the improvement of energy productivity through a number of modernisation and retrofitting activities, in combination with the substitution of fuel and energy carriers, notably the much higher use of electricity in the increasingly modern production processes (products and services).

The figure shows that in ECP, energy productivity increases very quickly – by 2030, it grows by 50% (the base effect and result of intervention measures with a high energy-savings potential) to slow down slightly in the following years and reach close to 85% in 2040 relative to 2015. The assumptions in the REF scenario are more conservative – in 2040, productivity is approx. 55-60% higher than in 2015. In relative terms, final energy productivity in the ECP scenario is approx. 20-30 pp above the REF value in 2040.

It is worth emphasising that the changes will highly contribute to nearly all climate and energy policy objectives, i.e. strengthen the security of fuel and energy supply, reduce environmental pressure, and improve the competitiveness of the production of goods and services. The last of the benefits is particularly important because it will considerably improve stability by highly reducing exposure to external risks, including, for example, fluctuations in fuel and energy prices on international markets. **A comparison of the results for the ECP and REF scenarios demonstrates that a much higher qualitative leap and stabilisation can be achieved through consistent pursuit of the assumptions adopted in the ECP scenario.**

5.2.2.2. Sectoral assessment of macroeconomic impacts – manufacturing industries

The table below and the two graphs that follow summarise the trends in **gross profitability indicators of sold production** in both scenarios – REF and ECP.

Similarly, to employment and GDP levels, the differences in the profitability of manufacturing industries between the two scenarios are inconsiderable and reveal a slight advantage of REF over the ECP scenario. The deterioration of profitability in the ECP variant is not strong enough to deepen considerably the general downward profitability trend across the manufacturing industry as a result of the strong impulse from the increase in energy and fuel prices and the only slightly less intense impulse from the increase in real wages. These two factors, together with the required strong increase in capital expenditures, decrease sales profitability ratios, which means that a number of other innovative actions need to be taken, including organisational ones, so as to give domestic manufacturers a better competitive position on international markets. Undoubtedly, the policy measures assumed in the ECP scenario improve and stabilise the competitive position of domestic manufacturers.

It is worth mentioning that the high convergence between the scenarios is attributable to the assumed capital and labour productivity trends, which are the same in the analysed scenarios. This is a fairly common practice in economic modelling, which allows assessing the impact of a single key factor (here: energy) on the economy with the assumption of no change (conservative approach) in other factors (here: capital and labour). With this in mind, it can be concluded that, if well-designed and effectively implemented, the public policies envisaged can contribute to the creation of more favourable economic conditions such as to strengthen the path of sustainable development according the ECP scenario.

Table 93. Summary of changes in gross profitability in the manufacturing industry in the REF and ECP scenarios [%]

Model category	scenario	2015	2020	2025	2030	2035	2040
Gross profitability in the food industry	REF	4.7	4.6	4.4	4.3	3.3	2.7
	ECP	4.7	4.6	4.4	4.4	3.4	2.7
Gross profitability in the light industry	REF	6.8	7.3	6.8	6.9	5.6	3.3
	ECP	6.8	7.3	6.8	6.4	5.5	3.0
Gross profitability in the paper industry	REF	8.4	8.1	7.4	7.3	6.2	5.1
	ECP	8.4	8.0	7.2	7.1	6.1	5.0
Gross profitability in the chemical industry	REF	7.9	7.9	7.2	7.1	5.8	4.6
	ECP	7.9	7.9	7.3	7.2	6.0	4.9

Gross profitability in the mineral industry	REF	9.0	9.7	8.9	8.9	8.1	6.8
	ECP	9.0	9.3	8.3	8.3	7.6	6.5
Gross profitability in metallurgy	REF	5.7	5.9	5.2	4.9	4.0	2.7
	ECP	5.7	5.7	5.0	4.8	3.8	2.7
Gross profitability in the machinery industry	REF	4.5	4.5	4.9	5.2	5.0	4.5
	ECP	4.5	4.3	4.4	4.8	5.0	4.5
Gross profitability in other industries	REF	6.9	6.0	5.1	4.4	3.2	2.4
	ECP	6.9	5.9	4.9	4.3	3.2	2.6

Source: *EnergSys's own study, CGE-PL model, and Mezzo-Impact module*

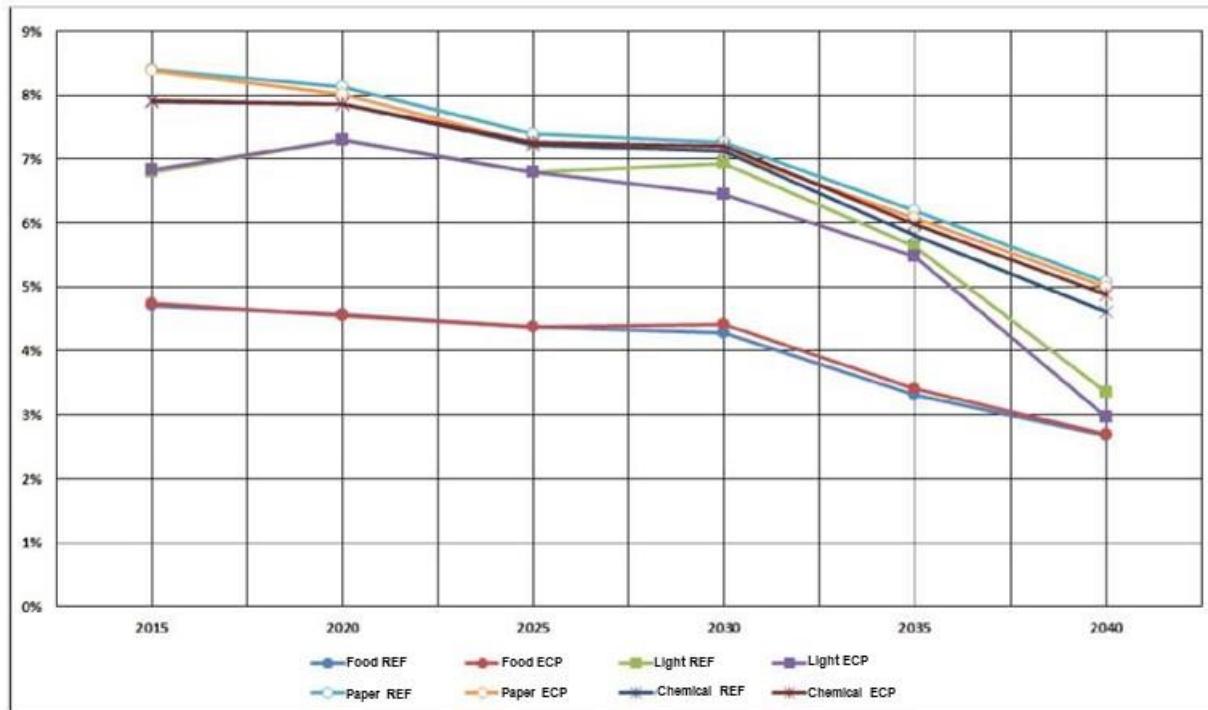


Figure 49. Changes in gross production profitability in the food, light, paper and chemical industries in the REF and ECP scenarios

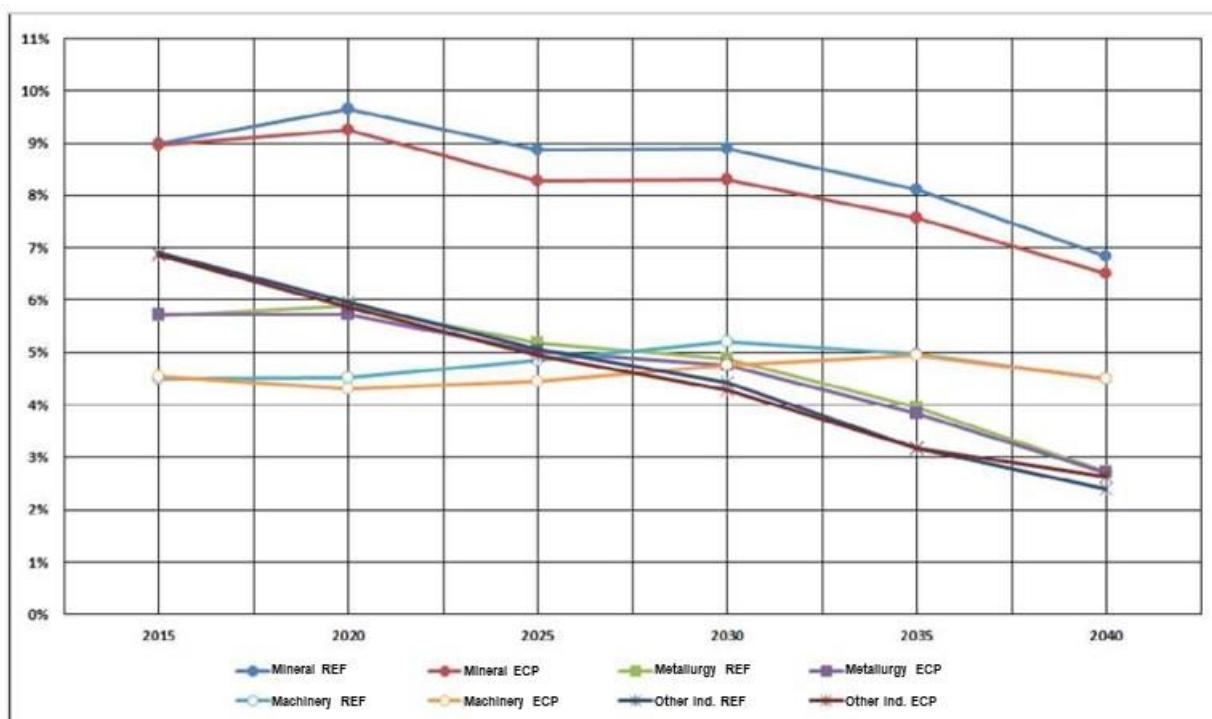


Figure 50. Changes in gross production profitability in the mineral, metallurgical, machine and other industries in the REF and ECP scenarios

5.2.2.3. Social impact assessment

The implementation of the ECP scenario requires a number of changes in the fuel and energy economy both in the electricity sectors (full supply chain) and in energy-using sectors. This involves thorough remodelling of the approach to development investments in the energy sector, and far-reaching modifications at final consumers, including the housing sector, where the use of fuels and energy in households inhabiting multi-dwelling buildings and single-family houses comes to the fore.

The analysis of the social impacts of the ECP scenario on selected parameters (indicators) of social and/or energy well-being presented in previous sections indicate that the **approach to the delivery of the climate and energy policies set out in the ECP scenario should not worsen the situation of households compared to the REF scenario in the medium and long term, and may even improve it. Unfortunately, in the short term, in which high expenditure on efficiency and health-oriented measures will be necessary, households – as fuel and electricity consumers – may experience some disturbances, partly mitigated by an increase in real wages, and partly by public policies, which are to be addressed to the poorer part of society, though.** As is shown by the calculations, reasonable public support should be channelled to the lower three Hh income quintiles (1-3), which correspond to 60% of the Hh that are currently in need of public support in Poland.

The macroeconomic categories presented in the table below are used in the comparative assessment of social impacts. The analysis includes both the Hh income side, which looks fairly optimistic, and the expenditure side, i.e. the share of Hh expenditure on fuels and energy of the 20% poorest Hh (quintile 1) and the 20% most affluent Hh. Meanwhile, all the Hh income groups are presented in the two graphs that follow.

Changes in relationships between macroeconomic categories are noteworthy. For example, the dynamics of nominal disposable income of Hh in both scenarios increases 2.5 times, and by slightly more in ECP. Meanwhile, the growth of nominal wages (the product of real wages and the annual inflation rate) increases slightly less, by about 2.2 times. The difference between these categories is attributable to the fact that a portion of growth in Hh incomes comes also from capital incomes (investments in funds, bank deposits, or stocks and shares, and the surplus of income from self-employment).

Table 94. Key macroeconomic categories relevant for social impact assessment – REF and ECP

Model category	Unit	Scenario	2015	2020	2025	2030	2035	2040
Direct consumption of fuels and energy in households	PJ	REF	792	866	898	926	947	962
		ECP	792	845	793	751	751	757
Real disposable Hh income dynamics	2015 = 100	REF	100	119	139	156	175	193
		ECP	100	118	138	154	178	193
Real wage dynamics		REF	100	114	135	143	158	173
		ECP	100	114	134	142	160	172
Nominal wage dynamics		REF	100	122	156	169	199	229
		ECP	100	122	156	169	201	228
Share of first-quintile Hh expenditure on fuels and energy	%o	REF	151	121	119	120	113	110
		ECP	151	120	108	100	90	87
Share of fifth-quintile Hh expenditure on fuels and energy		REF	66	71	73	76	74	73
		ECP	66	71	68	66	60	60

Source: EnergSys own study, CGE-PL and Mezzo-Impact models, Hh module

However, **the declining trend in the share of expenditure on fuels and energy in households is the key indicator for assessing social impact in 2015-2040** in both scenarios, with the trend being highly positive as from 2030 in the ECP scenario, which is demonstrated by the growing disparities in the Hh expenditure dynamics between the ECP and REF scenarios. However, it must be emphasised that in quintile 1 (20% group of the poorest Hh), the expenditure may exceed the ‘defined’ energy poverty threshold (10% share of expenditure on fuels and energy in income) by around 2030 in ECP and by 2040 in REF. This is indicative of the importance of an effective housing stock thermomodernisation policy combined with other measures for the development and implementation of low-emission sources.

The results reflect the complexity of the current economic situation of the poorer Hh, as well as the need for public support targeted at the poorest Hh in order to reduce expenditure below the ‘defined’ energy poverty line.

The two charts below present the evolution in Hh expenditure on various groups of fuels and energy for all income quintiles in both scenarios. The red line marks the Hh energy poverty line ‘defined’.

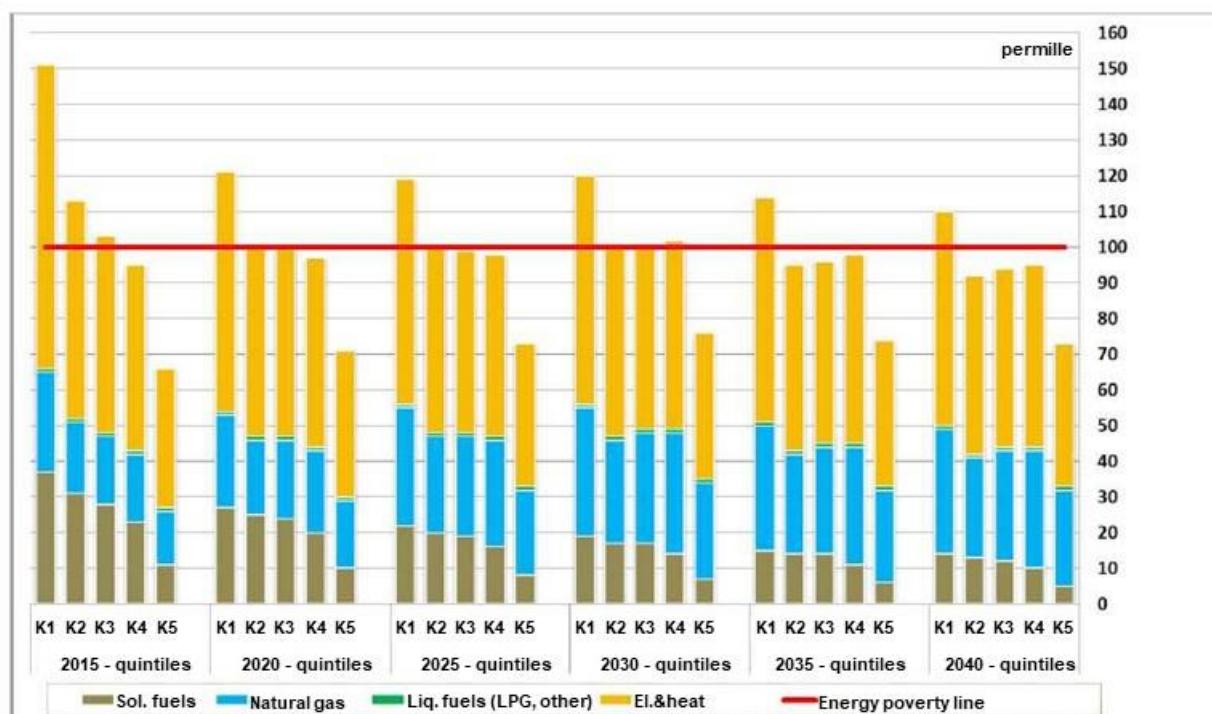


Figure 51. Changes in the share of expenditure on fuels and energy in household budgets by quintiles – REF

A comparison of these two graphs clearly shows that the implementation of the climate and energy policy assumptions of the ECP scenario should highly contribute to reducing the share of energy costs in the income across the Hh quintiles, thereby mitigating the energy poverty 'defined'.

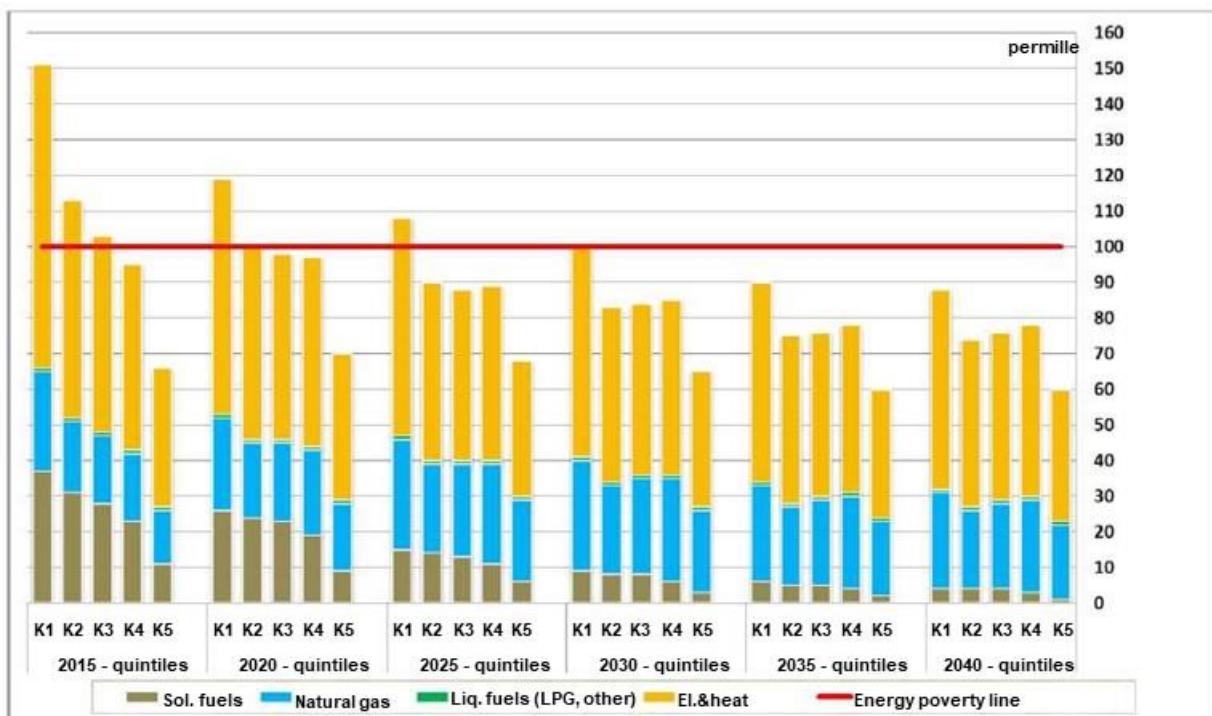


Figure 52. Changes in the share of expenditure on fuels and energy in household budgets by quintiles – ECP

It is also worth remembering that a significant reduction in the share of energy expenditure in the Hh spending basket may produce a rebound effect, i.e. re-increase in Hh expenditure on energy, mainly as a result of faster saturation of households with equipment that consumes energy, mainly electricity (e.g. household appliances, electronics, etc.). In some situations, it may also take the form of no reduction or even increased consumption of fuels for heating when a Hh chooses to increase the thermal comfort in the house/dwelling or to use more rooms in a previously underheated building. This must be borne in mind when designing the intervention policy instruments in each of the scenarios.

5.2.2.4. Summary and conclusions on macroeconomic and social impacts

The report presents all the essential elements of macroeconomic and sectoral analysis necessary to assess the macroeconomic and social impacts and the cost-effectiveness of the planned policies and measures (interventions) foreseen in two, qualitatively different, visions of the country's development over the period 2015–2030, with an outlook for 2040. To this end, use is made of an approach based on two development scenarios:

- Reference Scenario (REF) – which assumes completing the development policies and programmes that stem from Polish and EU legislation effective at the end of 2017.
- the Energy and Climate Policy scenario (ECP) – the effect of the policies and measures that indicate how the objectives in the five dimensions of the Energy Union will be achieved takes into account the provisions of the Clean Energy for All Europeans package.

Importantly, the assumptions of the scenarios in the analysis are prepared in such a way that the elements that differentiate them concern areas that may be affected by changes in the energy and climate policy. The calculations assume that the country's development potential associated with the availability of workforce and capital and their increasing productivity will be identical in both scenarios. The values of these development determinants (resource and productivity) are determined through the calibration of CGE-PL macroeconomic model based on the REF scenario assumptions.

The REF and ECP scenarios analysed differ in several important respects:

- different volume and structure of the demand and supply balance of fuels and energy in the country,
- different volume and structure of the demand for fuels and energy in households,
- different fuel and energy productivities in the production sphere (value of sales per unit of energy consumed),
- different volumes and distribution of overall capital expenditures in the national economy, including expenditure in the fuel and energy supply sector and energy end-use sectors,
- different allocation of revenues from the sale of CO₂ emission allowances; in the REF scenario, they are fully allotted to the state budget, while in ECP, the proceeds are distributed between the budget, sectors of the economy, and support for Hh (in the first calculation loop),
However, both scenarios assume the same rules for the allocation of revenues from the sale of CO₂ emission allowances, namely distribution of revenues between the budget, economic sectors and support for Hh (in the second calculation loop).

The results of model calculations for both scenarios are compared in the following three main areas of impact:

- (a) in the national economy – changes in the rate of GDP growth are compared,
- (b) in industry – changes in the profitability of the manufacturing industries are compared,
- (c) in the social area – the dynamics of disposable income of households and changes in the share of expenditure on energy in household budgets are compared, with 5 income groups distinguished (five quintiles – Nos 1 and 2 comprise the 40% poorest Hh, quintile No 3 comprises middle-income earners – 20% of Hh, while No 4 and 5 include the wealthiest 40% of Hh, according to the GUS criteria adopted for 2015).

The results obtained in all the examined areas reveals a greater number of macroeconomic and social benefits in the ECP scenario, which envisages the adoption of new requirements, including mechanisms for the implementation of the climate and energy policy, in comparison to the REF scenario (delivery of currently applicable policy instruments, including national and EU legislation).

The main benefits of the ECP scenario include, *inter alia*: slightly higher GDP volume and higher employment, including in manufacturing industries, a slower decline in gross profitability ratios in industries, much higher energy productivity in sectors of the national economy, mainly industry and services, and a much faster rate and a larger percentage of households that make it out of the 'defined' energy poverty.

Selected conclusions regarding the country's macroeconomic development

- An assessment of the ECP scenario indicates that a climate and energy policy leading to a major reduction in domestic CO₂ emissions without adverse effects on the economic growth rate is possible, provided that the efficiency of fuel and energy use in the economy is improved quickly and effectively (better energy productivity means increased cost-efficiency and highly mitigated exposure to the risk posed by fuel and energy price fluctuations on international markets). In addition, the effects of fuel and energy savings in manufacturing and consumption may vitally contribute to reducing production costs, fostering the competitiveness of Polish products and producers in international trade.
- Disturbances to the long-term development of the country (maintaining the conditions of general equilibrium as the main characteristic of the CGE-PL model) caused by the excessively rapid remodelling of the production potential of the fuel and energy sectors can only be avoided by **allocating substantial resources for supporting energy savings and energy efficiency improvement processes in all energy use areas, i.e. manufacturing, services and households.**
- The macroeconomic (and social) impact assessment carried out in the report proves that **developing an effective set of instruments for supporting energy efficiency measures targeted at final consumers** will be a key success factor for energy transition. To this end, use should be made of financial instruments

and funds, e.g. from the sale of CO₂ emission allowances, support funds, including energy efficiency, thermomodernisation funds, etc. The instruments should be systemic in nature, with built-in self-correction mechanisms that respond, within specific bounds, to developments in energy markets, including the dynamically growing markets for energy and multi-energy services.

Conclusions for manufacturing

- The rapid increase in fuel and energy prices, which is inevitable in the situation of accelerated modernisation or even technological remodelling of part of the domestic energy sector, reduces the profitability of the Polish manufacturing industry. Despite this, given the relatively high profitability of the manufacturing industries, including the energy-intensive ones that benefit from geographical premium and strong internal demand (investments), the decrease in profitability by 2030 will not lead to a clear deterioration of their operating conditions. The model results reveal that after 2030 downward trends in profitability of the industries that export a large proportion of their production may prove dangerous for their sustainability. However, this is a fairly distant perspective (> 12 years), over which many of the conditions taken into account in the model may change, which means that a series of subsequent calculations will be needed to correct the current assumptions.
- The conditions set out in the ECP scenario only slightly mitigate the downward trend in the loss of gross profitability of industries resulting from the strong increase in the prices of fuels and energy available on the Polish market – from domestic resources. The strong price increase is a consequence of the growth in fuel prices on international markets, but also the increase in domestic production costs. In addition, the rise in prices of fossil fuels, mainly coal, is amplified by the steep upward CO₂ emission allowance trend. Given the next steps in the area of climate protection and the increasing integration of energy and climate issues, it seems that choosing a development path consistent with the ECP scenario will highly mitigate the economic risk, and at the same time reduce the social nuisance of choosing the scenario and strategy for the development of the Polish energy sector.

Conclusions concerning the social area

- The elimination of energy poverty (according to Eurostat data, in 2015, about 80% of households were affected) is possible, *inter alia*, by reducing the income gap between the Hh quintiles and urgent but prudent investments in energy efficiency, including rational thermomodernisation of residential and commercial buildings, as well as the upgrading of supply sources and networks.
- The results of the analysis and assessment show that a considerable portion of public support for improving energy efficiency should be allocated for the poorest groups of Hh (quintiles 1-2 and 3). This will speed up eliminating energy poverty and will considerably curb 'low-stack' emissions in Poland. The results of the model analysis confirm the reasonableness of the adopted framework criteria for providing public support through the Clean Air programme.

General conclusion

After analysing and assessing the results of calculations for both macroeconomic development scenarios, i.e. REF and ECP, it can be concluded that the choice of the ECP scenario is a better option for the Polish economy as a whole, including households and other target groups, although in many cases the numerical differences are relatively small. The rationale for choosing ECP is well documented by the results of both scenarios and – just as importantly – it is consistent with global energy developments.

5.2.3. Environmental and health impact assessment

The assessment of the environmental and health impacts resulting from the implementation of the ECP scenario is based on the following assumptions:

- **the environmental and health impacts** are determined as environmental and health losses related to air pollutant and greenhouse gas emissions, respectively, as expressed in monetary terms;
- **the environmental and health losses** are calculated for those sectors of the economy for which the implementation of the ECP scenario causes a significant reduction in emissions (fuel combustion – electricity and heat production, fuel combustion – manufacturing and construction, fuel combustion – road

transport, fuel combustion – other sectors)

- **the impact of greenhouse gas and air pollutant emissions on human health and the environment** is determined on the basis of available models and external unit cost indicators.

The environmental and health benefits resulting from the implementation of the ECP scenario relative to the REF scenario are expressed as avoided environmental and health losses from emissions of air pollutants and greenhouse gases (expressed in monetary values), respectively. They are captured as the absolute difference in environmental and health losses determined for the REF and ECP scenarios for the key sectors of the economy mentioned above.

It should be noted that a number of conclusions in this context are provided by section 5.1.2 ‘Decarbonisation’. The methodology for calculating environmental and health impacts is described below.

The following types of air pollution are included in the analysis of the **environmental and health impacts of air pollution emissions:**

- nitrogen oxides (as NO₂);
- non-methane volatile organic compounds (NMVOC);
- sulphur oxides (as SO₂);
- ammonia (NH₃);
- PM_{2.5};
- the portion of PM₁₀ with the grain diameter between 2.5 and 10 µm (PM_{CO} = PM₁₀-PM_{2.5}).

The environmental and health impacts of the ECP and REF scenarios and the environmental and health benefits resulting from the implementation of the REF scenario are assessed on the basis of data on the projected pollutant emissions presented in Tables 26 and 27 respectively (subsection 5.1.2.1.2). **For the energy production sector** (electricity and heat production) and the industry sector (manufacturing and construction), the unit indicators of external costs of air pollution are adopted on the basis of the NEEDS research report²⁹.

For the transport sector (road transport), the unit indicators of external costs adopted are based on a EC handbook³⁰.

For the fuel combustion sector (other sectors), the unit external cost indicators consist of the average values determined for the other sectors.

The analysis of the **environmental and health impacts of greenhouse gas emissions** for human health and the state of ecosystems takes into account such climate change phenomena as:

- heat waves and their implications for health (e.g. heart disease) and the environment (droughts),
- the direct and indirect consequence of extreme weather events (hurricanes, floods),
- increased risk of cancer due to increased exposure to UV radiation,
- increased concentration of allergic pollen in the air due to longer growing season.

This impact is usually expressed by the **integrated indicator of unit damage costs** per tonne of carbon dioxide equivalent (CO₂eq). Given the global nature of the impact of greenhouse gases, the indicator involves much greater uncertainty than analogous indicators for air pollution, and takes different values in various specialist studies, depending on the assumptions regarding, *inter alia*, the extent of impact and macroeconomic parameters. For the purpose of the forecast of the environmental benefits resulting from the implementation of the ECP scenario, use is made of a **variable unit damage cost indicator** based on a World Bank study³¹ in two variants – high and low (in 2017, it amounts to 37 and 75 USD/tCO₂eq, respectively).

The tables below present the environmental and health impacts of pollutant and greenhouse gas emissions for

²⁹ NEEDS. New Energy Externalities Developments for Sustainability. Deliverable 6.1-RS1a; FP6. 2009.

³⁰ Handbook on the external costs of transport, EC, 2019

https://ec.europa.eu/transport/themes/sustainable/studies/sustainable_en

³¹ “Guidance note on shadow price of carbon in economic analysis”, World Bank, 2017,

<http://documents.worldbank.org/curated/en/621721519940107694/pdf/2017-Shadow-Price-of-Carbon-Guidance-Note.pdf>

the ECP and REF scenarios, as well as the environmental and health benefits resulting from the implementation of the ECP scenario in relation to the REF scenario, expressed in monetary terms, as calculated using the above methodologies.

Table 95. Environmental and health impacts of air pollutant and greenhouse gas emissions from the key sectors for the ECP and REF scenarios – low and high unit damage cost values

	AIR POLLUTANT EMISSION IMPACTS – low variant				GREENHOUSE GAS EMISSION IMPACTS	
	HEALTH IMPACTS [EUR million]		ENVIRONMENTAL IMPACTS [EUR million]		TOTAL [EUR million]	
YEAR	REF	ECP	REF	ECP	REF	ECP
2020	13 444	12 234	1 355	1 239	10 897	10 304
2025	13 194	10 768	1 329	1 093	13 056	11 266
2030	13 177	9 589	1 332	980	15 038	11 710
2035	12 562	8 528	1 263	868	15 171	11 043
2040	11 869	7 773	1 186	790	14 624	10 867

	AIR POLLUTANT EMISSION IMPACTS – high variant				GREENHOUSE GAS EMISSION IMPACTS	
	HEALTH IMPACTS [EUR million]		ENVIRONMENTAL IMPACTS [EUR million]		TOTAL [EUR million]	
YEAR	REF	ECP	REF	ECP	REF	ECP
2020	13 444	12 234	1 355	1 239	22 089	20 886
2025	13 194	10 768	1 329	1 093	26 464	22 836
2030	13 177	9 589	1 332	980	30 483	23 737
2035	12 562	8 528	1 263	868	30 752	22 385
2040	11 869	7 773	1 186	790	29 643	22 028

Source: ATMOTERM S.A. own study

Table 96. Environmental and health benefits resulting from the implementation of the ECP scenario in relation to the REF scenario – low and high unit damage cost values

	BENEFITS OF REDUCED EMISSIONS OF – low variant			
	AIR POLLUTIONS [EUR million]		GREENHOUSE GASES [EUR million]	TOTAL [million EUR]
YEAR	HEALTH	ENVIRONMENT		
2020	1 209	116	594	1 918
2025	2 426	236	1 790	4 452
2030	3 588	352	3 328	7 268
2035	4 034	396	4 128	8 557
2040	4 097	395	3 757	8 248

	BENEFITS OF REDUCED EMISSIONS OF – high variant			
	AIR POLLUTIONS [EUR million]		GREENHOUSE GASES [EUR million]	TOTAL [million EUR]
YEAR	HEALTH	ENVIRONMENT		
2020	1 209	116	1 203	2 528
2025	2 426	236	3 628	6 291
2030	3 588	352	6 746	10 686
2035	4 034	396	8 367	12 796
2040	4 097	395	7 615	12 107

Source: ATMOTERM S.A. own study

It follows from the above that the **environmental and health benefits** resulting from the implementation of the ECP scenario in relation to the REF scenario for the forecast years amount to EUR 1.918 billion in 2020 to EUR 8.248 billion in 2040 – for the low variant, and from EUR 2.528 billion in 2020 to EUR 12.107 billion in 2040 –

for the high variant.

Notably, the projections reveal differences between the scenarios, which are bound to deepen in favour of the ECP scenario with each five-year period – in both dimensions, both as regards the impacts of air pollutant emissions and greenhouse gas emissions.

The spreads between the above figures prove that estimating these costs is difficult. Nevertheless, the summary of their scale and air pollutant and GHG emission reductions achieved, as presented in section 5.1.2, imply a highly positive impact of the PaMs set out in the NECP. One particularly noteworthy development is the improvement of air quality resulting from the ECP, which, in addition to having a real effect on reducing the impacts on human health (e.g. chronic or fatal diseases), will improve people's quality of life by reducing nuisance associated with temporary breathing problems, headaches, or depressed mood.

5.3. Overview of investment needs

5.3.1. Existing investment flows and forward investment assumptions with regard to the planned policies and measures

This subsection presents estimates of expected capex on the delivery of the ECP scenario with relevant comparisons with the REF scenario. The table below summarises energy-related capex in the national economy, by capex in the fuel and energy sector and energy-related capex in non-energy sectors as from 2016. These two categories of capex are disaggregated in the subsections below. As is shown by the estimates, nearly half of the expenditure covers non-energy sectors, which shows how deep and widespread the impact of the NECP will be.

Table 97. Projected energy-related capital expenditure in the entire economy in 2016-2040 [EUR'2016 million]

	2016-2020	2021-2025	2025-2030	2031-2035	2036-2040	2016-2040
energy-related capex in the national economy	94 973	100 251	95 528	86 561	74 369	451 682
capital expenditures in the entire fuel and energy sector	53 618	45 178	45 810	52 712	48 174	245 492
energy-related capex in non-energy sectors (industry, Hh, services, transport and agriculture)	41 355	55 073	49 718	33 850	26 195	206 190

Source: own study by ARE S.A.

5.3.1.1. Capex in the fuel and energy sector

Capex on the development of the fuel and energy sector include investments in the electricity, heating, gas, mining and liquid fuels sectors. In the case of the **electricity sector**, both spending on construction and modernisation of the generation sector (power plants and cogeneration plants), and on transmission and distribution network development, including connection of new generation capacities and promotion of electromobility are taken into account. Costs of the installation of meters in 80% of households until 2026 are included, too. Estimates for transmission and distribution networks are based on operators' plans. In the **district heating sector**, in addition to new production capacities, the modernisation and expansion of heating networks is taken into account. In the **gas sector**, the projections include outlays on the development of the distribution network as a result of the gasification of successive Polish regions, as well as the planned investments in the area of transmission network development based on expansion plans for gas companies. Outlays in the **liquid fuels** sector are determined, *inter alia*, by shifts in Poland's energy mix as a result of the development of alternative fuels and increased use of electricity and biocomponents (including advanced biofuels) in transport. The development of storage infrastructure and actions to increase the capacity at existing refineries are also included. Outlays in **mining** are based on Poland's coal²⁹ and lignite³⁰ programmes and own estimates for the periods that go beyond the timeframes of the programmes. The table below presents estimated energy-related capex in the fuel and energy sector in 2016-2040.

²⁹ Program dla rozwoju sektora górnictwa węgla kamiennego w Polsce na lata 2016-2030 (Programme for the development of the coal mining sector in Poland in 2016-2020), adopted by Resolution of the Council of Ministers of 23 January 2018.

³⁰ Program dla sektora górnictwa węgla brunatnego w Polsce (Programme for the Polish lignite mining sector for 2016-2020), adopted by the Council of Ministers of 30 May 2018.

Table 98. Projected capex in the fuel and energy sector for the two scenarios [EUR'2016 billion]

Table 98

	2016-2020	2021-2025	2025-2030	2031-2035	2036-2040	2016-2040
ECP	53.6	45.2	45.8	52.7	48.2	245.5
REF	46.2	38.4	37.6	46.3	51.1	219.5

Source: own study by ARE S.A.

The total planned capital expenditures in the domestic fuel and energy sector in the 2040 perspective amount to approx. EUR'2016 246 billion. It is estimated that nearly 60% of these outlays will be incurred in 2016-2030 (EUR'2016 144.6 billion). Post 2030, the increase in capex is associated with planned investments in nuclear energy – in the long run, this would be less noticeable since the investment is expected to provide energy production for 60-80 years. These expenditures are lower than in the REF scenario since the construction of one nuclear unit is put forward beyond 2040 in the ECP scenario.

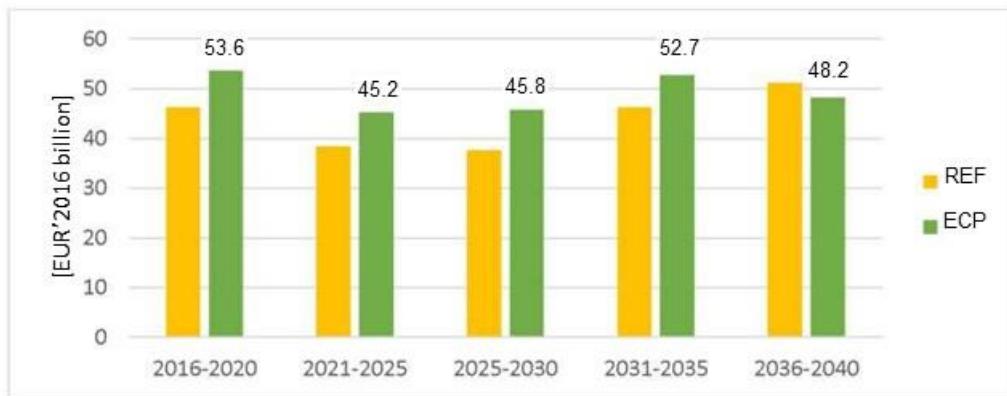


Figure 53. Comparison of capital expenditures in the ECP and REF scenarios in the fuel and energy sector in 2016-2040

The table below presents capex trends in the individual fuel and energy subsectors in the two scenarios along with differences between these sums. In most cases, expenditures in the ECP scenario are higher, with a declining trend in mining.

Table 99. Forecast capex in the energy sector by subsectors [EUR'2016 million]

Sectors:				Comments:
Electricity generation				
	REF	ECP	difference	
2016-2020	15 169	20 407	5 238	Capex on the modernisation and expansion of the electricity generation sector (power plants and cogeneration plants, energy storage, DSR, costs of adaptation to IED/BREF).
2021-2025	7 026	11 706	4 680	
2026-2030	6 348	12 229	5 881	
2031-2035	17 929	23 879	5 949	
2036-2040	24 580	22 880	-1 700	
2016-2020			20 049	
Transmission and distribution of electricity				
	REF	ECP	difference	
2016-2020	8 395	8 501	105	
2021-2025	8 841	10 020	1 180	
2026-2030	9 109	10 535	1 425	
2031-2035	9 392	9 772	381	
2036-2040	9 149	9 487	337	
2016-2040	44 886	47 140	3 429	
District heating				
	REF	ECP	difference	
2016-2020	2 476	2 202	-274	Capex on the retrofitting and construction of new district heating plants (excluding industrial plants that produce heat for the needs of their parent plants).
2021-2025	2 455	2 758	303	
2026-2030	2 563	3 192	629	
2031-2035	1 978	2 267	289	
2036-2040	582	1 238	656	
2016-2020	10 054	10 110	1 603	

Distribution of district heat				Capex on the development and modernisation of district heating networks.
	REF	ECP	difference	
2016-2020	1 204	1 265	61	
2021-2025	1 363	1 486	123	
2026-2030	1 060	1 158	99	
2031-2035	847	960	113	
2036-2040	685	804	119	
2016-2020	5 159	5 680	515	

Gas industry				Capex on investments in the sector as planned by gas companies.
	REF	ECP	difference	
2016-2020	7 121	9 529	2 408	
2021-2025	6 053	6 291	238	
2026-2030	6 053	6 291	238	
2031-2035	5 146	4 154	-992	
2036-2040	5 146	4 154	-992	
2016-2020	29 519	30 418	899	

Liquid fuels				Capex on the expansion of the Oil Terminal in Gdańsk, building of the second leg of the Pomeranian Pipeline, construction of approx. 350 thousand m ³ of new fuel storage capacities and 200 thousand m ³ of oil storage capacities, and extension of the fuel pipeline from Boronów to Trzebinia. The costs of the Brody-Adamów oil pipeline are included. The capex associated with the maintenance, modernisation and development of infrastructure in the liquid fuels sector are assumed on the basis of data reported by fuel and logistics companies operating on the Polish market.
	REF	ECP	difference	
2016-2020	9 832	9 739	-93	
2021-2025	9 926	10 623	697	
2026-2030	9 998	11 010	1 011	
2031-2035	10 057	9 830	-227	
2036-2040	10 106	9 472	-634	
2016-2020	49 919	50 673	754	

Mining of coal and lignite				Capex related to the implementation of the January 2018 Programme for the hard coal mining sector in Poland and the May 2018 Programme for the lignite mining sector in Poland.
	REF	ECP	difference	
2016-2020	1 976	1 976	0	
2021-2025	2 758	2 293	-465	
2026-2030	2 438	1 395	-1 043	
2031-2035	912	1 850	938	
2036-2040	806	140	-666	
2016-2020	8 890	7 655	-1 236	

Source: own study by ARE S.A.

The costs in the electricity and heating sectors are disaggregated.

In the **electricity sector** (generation, transmission and distribution), capex in the 2016-2030 period is EUR'2016 73.4 billion for the ECP scenario and **EUR'2016 139.4 billion for the period 2016-2040**. The steep increase in 2031-2040 is explained by the assumed construction of three nuclear units with a total capacity of 3 900 MW. Notably, in the approach adopted, the expenditure is 'made' in the year when the unit is commissioned. This is a simplification, but adds transparency to the data analysis and eliminates the problem of a depreciation-based approach, which goes beyond the scope of the analysis, i.e. 2040. Outlays on RES are also noteworthy. The detailed scope of capex planned in the generation, transmission and distribution sector is presented in the two tables below, as well as in the graph – for generation.

Table 100. Projected capex in the electricity transmission and distribution sector [EUR'2016 million]

	2016-2020	2021-2025	2025-2030	2031-2035	2036-2040	2016-2040
transmission network	1 393	1 740	2 897	2 375	2 402	10 807

distribution network	7 108	8 280	7 638	7 397	7 085	35 597
total	8 501	10 020	10 535	9 772	9 487	46 404

Source: own study by ARE S.A.

Table 101. Projected capex in the electricity generation sector [EUR'2016 million]

	2016-2020	2021-2025	2025-2030	2031-2035	2036-2040	2016-2040
by type						
power plants	14 858	8 008	9 246	21 459	19 445	73 016
combined heat and power plants	3 824	3 234	2 784	1 981	2 874	14 697
DSR/energy storage	25	64	199	439	561	1 288
adaptation to IED/BREF	1 700	400	0	0	0	2 100
by fuel						
coal	9 222	2 237	0	287	446	12 192
gas	1 709	2 511	591	1 802	1 298	7 911
nuclear	0	0	0	11 700	5 850	17 550
other	694	539	446	689	1 061	3 430
renewable	8 782	6 419	11 192	9 401	14 225	50 019
hydro	110	317	120	120	120	787
wind	5 966	1 842	7 467	5 504	10 025	30 804
solar	2 004	2 156	1 659	2 819	2 838	11 475
biomass	407	1 318	1 109	93	278	3 206
biogas	294	786	837	865	964	3 747
total expenditures on electricity generation capacities	20 407	11 706	12 229	23 879	22 880	91 101

Source: own study by ARE S.A.

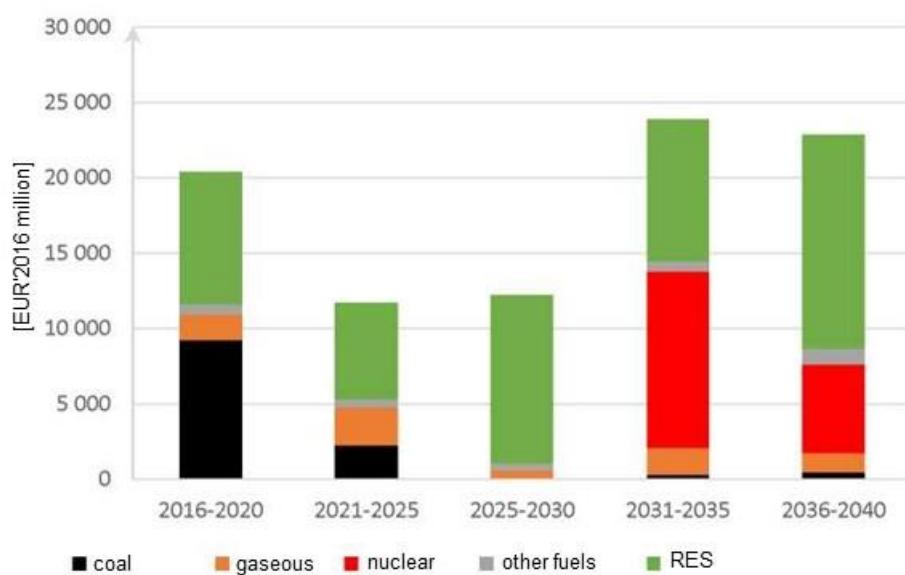


Figure 54. Projected capex in manufacturing in 2016-2040 [EUR'2016 million]

In the **district heating sector** (generation and distribution), for the ECP scenario, capex in the 2016-2030 period is EUR'2016 12.0 billion and **EUR'2016 17.3 billion in 2016-2040**. In the sector, the replacement of old coal-fired boilers for biomass- and natural gas-fired boilers will require high sums, as will the retrofitting of boilers and the process of adaptation to environmental requirements. The modernisation and development of district heating systems is another crucial cost factor, which – as the presented assumptions show – is expected to consume around EUR'2016 4 billion in 2016-2030 and nearly EUR'2016 6 billion in 2016-2040. The table below

presents estimated capital expenditures on the completion of the ECP scenario in district heating.

Table 102. Projected capex in the district heat generation and distribution sector (excluding industrial heating plants) [EUR'2016 million]

	2016-2020	2021-2025	2025-2030	2031-2035	2036-2040	2016-2040
district heating boilers	292	1 254	2 349	241	733	4 868
energy storage	13	28	0	7	0	47
upgrading	1 898	1 476	843	2 020	505	6 742
total generation	2 202	2 758	3 192	2 267	1 238	11 657
total district heat distribution	1 265	1 486	1 158	960	804	5 680

Source: own study by ARE S.A.

5.3.1.2. Energy-related capex in other sectors

The table below summarises the estimated energy-related capex in other sectors of the national economy, i.e. industry, services, transport, households and agriculture. The expenditures are shown in the table below, and their detailed breakdown by sectors is presented in the following table. Notably, in each case capex in the ECP scenario is higher than in REF.

Table 103. Projected energy-related capex in other sectors for both scenarios [EUR'2016 billion]

	2016-2020	2021-2025	2025-2030	2031-2035	2036-2040	2016-2040
ECP	41.4	55.1	49.7	33.8	26.2	206.2
REF	36.7	39.3	35.7	27.6	22.9	162.3

Source: own study by ARE S.A.

Table 104. Projected energy-related capex in other sectors [EUR'2016 billion]

Sectors:				Comments:
Industry				
	REF	ECP	difference	Replacement of technologies that supply process heat (process furnaces and ovens and industrial heating plants). Replacement and upgrading of electric drives and light sources, energy efficiency improvement measures.
2016-2020	3 215	3 990	774	
2021-2025	3 681	5 636	1 955	
2026-2030	3 047	4 575	1 528	
2031-2035	2 523	3 722	1 199	
2036-2040	2 070	3 040	970	
2016-2020	14 536	20 092	6 427	
Transport				Capex on rail infrastructure (tracks, stations, rolling stock), development of intermodal transport, development of recharging/refuelling infrastructure for vehicles powered by electricity/CNG respectively, expansion of airports and seaports, river regulation, replacement of public transport fleet/rolling stock.
	REF	ECP	difference	
2016-2020	17 165	17 738	574	
2021-2025	19 857	25 470	5 612	
2026-2030	17 551	22 894	5 343	
2031-2035	11 418	14 370	2 952	
2036-2040	9 721	11 553	1 832	
2016-2020	75 713	92 025	16 312	
Households				Capex on thermomodernisation, retrofitting and replacement of heat sources (CH, WSW), replacement of light sources with energy-efficient ones, replacement of electric devices for low-energy ones, purchase of new energy-efficient appliances.
	REF	ECP	difference	
2016-2020	9 970	12 071	2 102	
2021-2025	9 734	15 867	6 133	
2026-2030	9 696	14 543	4 847	
2031-2035	8 714	9 478	764	
2036-2040	6 697	6 772	75	
2016-2020	44 811	58 732	13 921	

Services				Capex on thermomodernisation, retrofitting and replacement of heat sources (CH, WSW), replacement of light sources with energy-efficient ones in commercial premises, upgrade of street lamps, replacement of electric devices for low-energy ones, purchase of new energy-efficient appliances.
	REF	ECP	difference	
2016-2020	1 304	2 446	1 142	
2021-2025	1 329	3 251	1 921	
2026-2030	1 181	3 145	1 965	
2031-2035	1 042	2 057	1 015	
2036-2040	925	966	41	
2016-2020	5 781	11 865	6 084	

Agriculture				Capex on thermomodernisation, retrofitting and replacement of heat sources (CH, WSW), replacement of light sources with energy-efficient ones, replacement and purchase of agricultural tractors and machines for less energy-intensive ones.
	REF	ECP	difference	
2016-2020	5 076	5 110	34	
2021-2025	4 680	4 849	169	
2026-2030	4 254	4 560	306	
2031-2035	3 872	4 223	350	
2036-2040	3 532	3 863	332	
2016-2020	24 414	22 606	1 192	

The table below presents the estimates on capex required to complete the thermomodernisation of buildings assumed in the ECP scenario, which are based on the assumption that by 2030, 70% of residential buildings will have been fully or partially insulated. In the service sector, it is assumed that by 2030, approx. 78% of the total useful floor area of public healthcare, administration and education buildings, and 70-75% of the area of hotels, offices, workshops, and warehouses that provide non-commercial services will have been insulated.

Table 105. Projected capex on thermomodernisation of buildings [EUR'2016 billion]

	2016-2020	2021-2025	2025-2030	2031-2035	2036-2040	2016-2040
ECP	3 111	7 372	7 532	4 619	1 518	24 151
REF	1 689	1 839	1 865	1 889	1 905	9 186

Source: own study by ARE S.A.

5.3.2. Sector or market risk factors or barriers in the national and regional context

5.3.2.1. Electricity sector – sectoral risks

The electricity sector is exposed to risks and threats arising from the specificities of its operations and functioning in a certain market and regulatory environment.

In the power sector, both investment processes and payback periods are long. Therefore, the strategic documents, legislation, and state ownership policies formulated by international organisations, in particular the European Union, and by the Polish state are very important and have a crucial impact on both the investment decisions of energy companies and their implications.

Regulatory risk

The factors that have an impact on the development and performance of the Polish energy sector include the EU's Climate and Energy Package, which sets the 2030 GHG emission reduction target, and the clean energy for all Europeans package, which works towards the realisation of the Energy Union in legal terms. A number of risks arise from the tightening of emission standards and the rules for the functioning of the CO₂ emission allowance-trading scheme (EU ETS). The main problem related to carbon prices lies in the uncertainty inherent in their trends, which means that power undertakings do not know what technology to invest in so they prefer to put investment decisions off.

A threat to the development of the energy sector is also posed by other EU regulations adopted within the framework of the environmental policy and related to the reduction of pollutant emissions. They include the IED and best available techniques (BAT) conclusions for large combustion plants provided for by Directive 2010/75/EU (BAT conclusions for LCP). Given the uncertainty as to their final wording (this applies, in particular, to the BAT/BREF revision), they are a potentially significant risk factor likely to translate into a change in the

level of expenditures in the sector, their directions, or even the profitability of construction projects, which may prove non-conducive to energy transition after several years from their commencement.

A similar threat is posed by Regulation on the internal electricity market (EMR) and Directive on common rules for the internal market in electricity (EMD), which aim to create a new framework for the single energy market, *inter alia*, by introducing many pro-consumer solutions and making the market more flexible, as well as by interfering in the structure of mechanisms.

With a sufficiently high capacity of interconnections, a substantial portion of domestic demand for electricity can be satisfied by foreign producers. An investor examining the feasibility of an investment project must, in fact, take into account the potential risk, as well as strategies and prices of electricity offered by producers located outside of Poland. A major barrier is also created by unregulated legal status of property, which gives rise to difficulties in acquiring or accessing land as part of new investments (especially in the distribution segment).

Market risk

A serious market risk is posed by uncertainty regarding future prices of electricity and related products, e.g. property ownership or CO₂ emission allowances, as well as that concerning the volume of electricity sold (resulting from the uncertainty of electricity and heat demand determinants). The actual occurrence of market risk factors may have an adverse effect on the entity's financial result, *inter alia*, by reducing its revenues, driving up its costs, or undermining the margin.

The large share of near-end-of-life, high-emission coal- and lignite-fired power plants, which will be gradually decommissioned in the next several years, *inter alia* due to non-compliance with emission standards, plays a role, too. This hinders new investments, especially with the insufficient funds available in the economy. There is also pressure on the operating results of Polish energy companies, caused by competition from the free EU energy market, which will limit their investing potential.

The risk resulting from banks' reluctance to finance investments in conventional energy or in other non-renewable sources should be highlighted, too. This may cause power shortages in the system, causing interruptions to continuous energy supplies for the economy.

Risk arising from sustainable finance

In accordance with the sustainable finance concept proposed by the High-Level Expert Group (HLEG), economic activities are to be classified in environmental terms. The criteria for determining whether a given activity is sustainable include the phasing out of anthropogenic greenhouse gas emissions, including those from sources based on fossil fuels. It can be assumed that in the case of activities that will be classified as unsustainable, incentives will be created to divert capital available on financial markets towards other activities, e.g. through greater prudential requirements for securing loans for such investments, or a lower rating. This means that obtaining private capital for investments in activities considered unsustainable will be more difficult than at present.

Therefore, institutions dealing with asset and investment management are to be put under an obligation to integrate sustainable finance factors (Economic, Social & Governance – “ESG”) into their core activity, which means adaptation of their processes, internal procedures, risk management rules and sale policy to European Commission proposals. If a project is not aligned with the climate objectives and the 2030 Agenda, getting a loan or insurance may be difficult. Currently, a large proportion of financial market actors (including investment funds, insurance companies, and banks) have already been put under an obligation to inform customers of the availability of an ESG-based solution.

Technology risk

In addition to the huge benefits, the decarbonisation of the energy sector also produces risks. A large proportion of investments in generation capacity is channelled to renewable but unstable energy sources, with insufficient focus on technologies serving better integration of renewable energy sources with the power system, in particular dispatchable sources producing energy at competitive prices, and above all the development of energy storage technologies, including use of hydrogen.

Notably, in Poland, there are few actors that can compete with international suppliers of energy technologies,

both due to less extensive experience and the prevailing economic conditions. Therefore, the Polish energy sector may be in a disadvantaged position in terms of investments and their subsequent servicing.

Poland undertakes R&D challenges in the energy sector, but struggles, in particular, with much more difficult access to capital than in richer economies. This may hinder acquisition of new technologies, but efforts are being made towards international cooperation or raising foreign capital.

Transmission and distribution risks

Transmission and distribution system operators seem to be in a slightly more advantaged position. Although new legislation places a number of tasks on them, the investment risk incurred by transmission and distribution system operators is much lower, mainly on account of the stable regulations to which these subsectors are subject, i.e. specific return on investment which is ensured by the regulator in the form of transmission and distribution tariffs. Despite this, the transmission subsector is facing the problem of long-term project planning. Plans to build new capacities evolve and change over the years, e.g. in terms of parameters or the choice of technology. The network is built in a multi-year process, so it is difficult to keep up with market developments that take place in the meantime. The construction of the transmission network is strongly linked to the pace and extent of the construction of new generation units, which follows from the fact that the TSO is required to provide capacity and integrate these units into the common network.

In addition, the lack of understanding from the public of the need to build new networks is a major obstacle to forecasting the development of both transmission and distribution networks.

5.3.2.2. Heating sector – sector risks

In the years to come, the heating sector faces many challenges related to new regulations. The key legislative acts affecting the functioning of the heating sector on the local market include the Renewable Energy Directive, the Energy Efficiency Directive, and Directive on energy performance of buildings. In Poland, district heating is strongly affected by the implementation of a capacity market and a new cogeneration support scheme.

Currently, the heating sector is characterised by a very high dependence on coal for heat generation and high level of wear of the legacy heat generation units and transmission networks.

There is also the ‘cost trap’ of heat generation technology modernisation projects resulting from the fact that, on the one hand, technology upgrades typically require the replacement of coal by other conventional fuels, which are much more expensive, and on the other hand, from the capital weakness of most heating companies, which forces them to entrust retrofitting projects to ‘third funding parties’, i.e. specialised ESCOs, which seek to achieve a high margin and return on investment in the short run;

There is also the ‘price trap’ of environmental investing which stems from the existence of mechanisms encouraging heating enterprises to pursue projects that reduce pollution and simultaneous difficulties with access to cheap funding instruments for these projects, which in turn contributes to direct and high rises in heat prices as a result of the completion of environmental projects.

Ownership risk

In Poland, most district heating systems are owned by municipalities, which means that they do not have high financial resources readily available for investments. As regards large corporate groups, the cash flows they generate are high enough to finance individual investments. Smaller district heating companies do not have such an easy access to the financial market as large players present on a larger, more reliable market. The sole option that remains, namely commercial loans, are not always easily available since funding institutions are reluctant to extend loans to entities that are facing stricter standards, rising environmental costs, and restrictive tariffs. Schemes of financial support from energy efficiency or renewable energy development funds are an opportunity.

Regulatory risk

The sector will be affected by the BAT standards for large combustion plants (LCP), which were adopted in April 2017 and which introduce strict requirements, in particular as regards pollutant emission limit values. They will apply from 2021, imposing strict criteria for the emission of nitrogen and sulphur compounds and PM for all large

combustion units with a capacity of more than 50 MW. Small and medium-sized units from 1 to 50 MW are required to comply with equally stringent requirements, imposed by Directive on the limitation of emissions of certain pollutants into the air from medium combustion plants (MCP Directive).

Another major risk to investments in district heating development is posed by EU and domestic regulations preventing inefficient heating systems³² from obtaining public financial support. This causes network investments to be unprofitable as business ventures since the payback period is usually several-decade long. However, such investments are pursued to increase the security of heat supply and connect new consumers. Currently, practically only 20 per cent of district heating networks within the Polish heating system are efficient, i.e. such that are environmentally friendly and can have a real contribution to the fight against smog and cause local fuels to be used in a better way.

In the coming decade, deep modernisation of heating systems should be carried out, which, in many cities, especially smaller ones, will minimise the risk of losing existing sources of heat supply and air quality deterioration and will prevent the liquidation of some companies due to the lack of sufficient own funds for investments. A certain threat and risk to investments in district heating is also posed by the current regulation model, which should be more flexible and give heat companies the opportunity to obtain a fair return on capital so that they are able to raise funds for investments necessary to meet applicable emission requirements. Currently, heating companies have limited opportunities of raising capital for retrofitting their generation assets (not to mention complete replacement of the generation technology) and development of the network. It is necessary to revise the current tariff policy, so that it better contributes to the development of the sector and ensures that more funds are allocated to system development in order to provide better quality services.

The inability to expand the network due to the lack of spatial planning legislation is another important risk factor that affects district heating development. District heating, like many other network businesses, faces serious difficulties caused by spatial planning issues and the resultant problems with access to land. The delineation and construction of new heating networks and obtaining the formal consents from plot owners is very time consuming and expensive. This forms an additional barrier to the development of district heating, which runs the risk of being constrained to the urban areas where district heating is already available.

In many cases, district heat will not be an attractive option for developers. This results from Directive 2010/31/EU of 19 May 2010 on the energy performance of buildings, which requires investors using coal-based district heat to raise the building's energy standard (i.e. reduce the building's energy intensity or add a renewable energy source). This means that investors may find installing individual gas- or pellet-fired boilers cheaper than connecting buildings to district heating systems.

Market risk

Some heating companies are wound up because they do not have enough own funds for investments. They are not in the position to raise capital on market terms and cannot apply for public aid because they are 'inefficient systems' and are unable to make their way into the category of 'energy-efficient systems'.

Another problem for the sector is posed by the decrease in heat demand as a result of the thermomodernisation of buildings already connected to the network. New buildings are often out of the network because it is more profitable for investors to supply them with heat from individual sources. There is also an increased risk of other enterprises going bankrupt due to falling demand and emission abatement costs. The risk stems from the fact that new environmental investments mean rising unit prices of heat sold, which in turn reduces the demand for heating services and drives the spiral of prices.

The cogeneration support scheme introduced in 2019 can create stable conditions for investing in cogeneration and can be a strong impulse for building new CHP units, especially at the sites of existing heating plants. However, the current poor condition of the heating sector limits the possibility of converting some heat-only boilers into cogeneration units. Still, the potential is considerable.

From the perspective of cogeneration support, a serious risk to investors will be posed by optimal selection of

³² Directive 2012/27/EU on energy efficiency defines 'efficient heating (cooling) systems' – efficient district heating and cooling means a district heating or cooling system using at least 50% renewable energy, 50% waste heat, 75% cogenerated heat or 50% of a combination of such energy and heat.

fuel, which is made on the basis of projected price trends for individual fuels and CO₂ emission allowances, which are burdened with a high margin of error. This follows from the fact that these parameters are crucially important for the entire economics of implemented projects.

5.3.2.3. Gas sector – sector risks

The development of gas infrastructure in Poland is primarily determined by the need to ensure diversified sources of gas supply and by the development of interconnections to ensure integration with European markets. Ensuring gas supplies alternative to current sourcing directions is of utmost importance. Historically, the NTS was being developed so as to handle exclusively the transport of Russian gas from east to west, which caused Poland to be fully dependent on one direction. In recent years, in order to eliminate barriers to access to neighbouring foreign gas markets, the transmission system operator has completed a number of activities aimed at diversifying the directions and sources of natural gas supplies, striving to minimise the risk of dependency on the historically dominant supplier (Russia).

The activities integrating Poland with regional gas markets continued by the TSO (GAZ-SYSTEM S.A.) include the building of interconnections and continued expansion of the national transmission system so as to handle gas supplies from any direction and clear existing bottlenecks within the transmission system. This has removed the successive barriers, which improves the diversification of gas supply sources and boosts the technical potential for accessing alternative, competitive Western markets.

Regulatory risk

From the investor's point of view, the key barriers and risks to investment projects include the long process of incorporating pipeline investments into local plans, difficulties with acquisition of legal titles to land, no immediate enforceability of administrative decisions, and long timeframes for filing objections, appeals and complaints, which results in increased project costs. The protracted permit issuing process, the lengthy appeal procedure, and the repeatability of issued administrative decisions considerably extend investment delivery times, and may result in the abandonment or postponement of key investment decisions. Issues related to obtaining consents from property owners, which extend the investment process, also remain a major problem. This renders projects that teeter on the edge of profitability unprofitable.

Market risk

In the gas sector, the operator of transmission pipelines responds to increased demand for natural gas signalled by the market and conducts a number of infrastructural investments. The difficulties encountered by the TSO are specific to the entire construction sector and relate to limited availability of contractors and designers. There is an observable increase in prices of contractor services as a result of limited resources on the market. In addition, in some tendering procedures, the prices bid exceed the estimated value of the awarding entity's budget. Large tenders for the construction of gas pipelines may entail inflated bids and increase the risk of the contractor failing to meet the completion deadline.

One key challenge for the contractor is to accumulate the necessary resources and materials in the initial period of the contract, and another is the high diversity of preparatory work in terms of the disciplines involved, including several areas that go beyond gas work as such. Often, contractors have such work completed by third-parties, which complicates the entire process because of the need to obtain specialised equipment and qualified staff or engage subcontractors. The problems that the construction industry struggles with mainly relate to limited contracting and design potential.

5.3.2.4. Liquid fuels sector – sector risks

Given the limited access to domestic crude oil resources, it is essential that Poland aims towards diversifying supplies and ensuring security of crude oil and liquid fuels supply. Further diversification of crude oil imports requires, above all, well-developed and reliable inland infrastructure to reduce supply barriers and ensure the possibility of increasing imports by sea. In order to provide technical possibilities to diversify sources of oil supplies to domestic refineries, investments are also necessary to increase aboveground storage infrastructures.

Market risk

The Polish fuel market is supplied from two sources: domestic producers (PKN Orlen S.A. and Grupa LOTOS S.A.) and importers. The main market risks to which the liquid fuels sector is exposed in its operations include the commodity risk, which is associated with changes in refinery and petrochemical margins achievable on product sales, the Brent/Ural price differential, crude oil and petroleum product prices, and prices of CO₂ emission allowances.

The overall economic situation is crucial for fuel consumption, determining the level of sales, prices of products in the liquid fuels sector and its financial standing, and consequently the potential for further development. The fuel market is also exposed to the risk resulting from what is referred to as the ‘grey market’, which mainly involves illegal trade in fuels with no taxes paid. Companies from the liquid fuels sector are exposed to oil processing disturbances caused by the unavailability of pipeline logistics services and instability in oil-producing countries. Change to the parameters of supplied oil and the resultant lower yields of ‘white products’, as well as maintenance shutdowns of production installations, have a major impact, too. For example, the expansion of existing and construction of new refineries in Russia may decrease the volumes of Russian crude oil allocated for export, and consequently, decrease the availability of crude oil for European buyers, including Polish companies.

The predominant activity in the liquid fuels sector is represented by the downstream segment, i.e. the processing of crude oil into petroleum products, including fuels, and the sale of these products to customers. The upstream segment is the production sector, which includes prospecting for potential underground or underwater oil and gas fields, drilling exploratory wells, and operation of the wells that recover and bring crude oil or raw natural gas to the surface. Extraction projects are exposed to a number of geological and operational risks that may make achieving the expected profits difficult. The implementation of such projects may be delayed or may fail, chiefly due to the associated high exploration risk, cost overruns, lower oil and gas prices than assumed, higher tax burdens than anticipated, unfavourable legislative developments in the sector, equipment and qualified staff shortages, difficult weather conditions, or difficulties in finding partners to share project risks and costs. Often, such projects may also require using new, state-of-the-art technologies that are expensive to develop, acquire and implement, and may not function as expected.

Notably, the sector is exposed to the risk associated with the need to pursue the goal of increasing the share of renewable energy in transport. Entities encounter technological difficulties in blending methyl esters and bioethanol and in meeting the requirements for the types of biocomponents to reach the target. The costs incurred may also affect the competitiveness of these entities.

5.3.3. Analysis of additional public financial support to avoid identified risks

A large proportion of the risks cannot be avoided since they result from market developments which have occurred or will occur as a result of the implementation of EU legislation. A number of risks will be eliminated as a result of the implementation of the PaMs envisaged by the NECP, and whose financing is described in Part 2 (Policies and measures) of this document.

Technological development, which can be of key importance for each of the sectors, will certainly play a role.

5.4. Impacts of planned PaMs on regional cooperation and other Member States

5.4.1. Impacts on the energy system in neighbouring and other Member States in the region

5.4.1.1. Power systems

The efficient use of interconnections in Europe is crucial for future energy security. To this end, Poland intends to continue active cooperation with neighbouring countries.

The construction of the ‘power bridge’ between Poland and Lithuania is one of the most vital investments completed in recent years by PSE S.A. The main element of the project was the construction of a connection between the Elk Bis station and the Alytus station in Lithuania, which can handle cross-border exchange of up to 500 MW.

Currently, the ‘LitPol Link’ is the only interconnector between the Baltic states and the system of Continental Europe, which has made it possible for Lithuania, Latvia and Estonia to trade with Continental Europe. The interconnector is the first step towards the desynchronisation of the Baltic states’ system from the IPS/UPS. The

next stage will involve the construction of the Harmony Link, a high-voltage direct current cable connection. The deadline for completing the synchronisation of the Baltic States with Continental Europe is scheduled for 2025.

By 2030, PSE S.A. plans to expand its domestic network in the west of the country. The investments are known as the “GerPol Improvements” and “GerPol Power Bridge I” projects. Analyses carried out by the operator indicate that the expansion of the transmission network in the area of the Krajnik and Mikułowa stations will generate comparable effects in terms of the possibility of increasing power imports as would the construction of a new interconnector with Germany, but it requires lower capital expenditures. The expansion of the domestic network also improves the certainty of the evacuation of power from domestic power sources. The expansion of the domestic transmission network will produce 2 000 MW of import capacity with no need to build a third interconnection with Germany.

- Joint determination of transmission capacity

The division of Europe into CCRs (Capacity Calculation Regions), which has been decided on by ACER, aims to ensure stability of interconnections between the region of western and eastern Europe in the coming years. In the individual CCRs, transmission network operators will jointly determine transmission capacities at the borders between the regions. The borders of the Polish bidding zone are assigned to three independent CCRs (Hansa, CORE, Baltic).

The goal of TSO’s cooperation under the CORE CCR is to combine Eastern (CEE) and Western (CWE) energy markets into a single system (CORE). Within its framework, Poland is interconnected with Germany, the Czech Republic, and Slovakia.

Until 2025, the FBA (flow-based allocation) methodology is to be employed in CORE as the mandatory method of determining transmission capacity. The FBA approach relies on physical flows in determining the transmission capacity, with the calculation of available capacity based on power transfer distribution factors, subject to safety margins.

The currently used capacity factor is calculated as the ratio of the transmission capacity made available to the installed capacity of power units in the respective Member State. It does not take into account the structural conditions in power systems, which may lead to erroneous conclusions as regards the need to build new interconnections. Poland will increase its cross-border transmission capacities by 2030, *inter alia* through projects of common interest to PCI (which are listed in the second part of the document – Policies and measures). Based on the results of the Expert Group’s work, the European Commission has proposed a set of new thresholds to launch urgent measures to provide the necessary infrastructure to help achieve the “interconnectivity” goal for 2030. These new thresholds to help achieve the “interconnectivity” goal are provided for by Regulation on the Governance of the Energy Union (Regulation 2018/1999/EU (*inter alia* Annex I, Part 1, Section A, paragraph 2.4.1)).

Detailed information on the development of interconnections is provided by subsections 5.1.5.1. and 5.1.5.2.

5.4.1.2. Gas systems

Poland has planned a series of activities to achieve real diversification of energy supplies. This will be accomplished by investing in the Baltic Pipe, increasing the capacity of the LNG terminal in Świnoujście, building a Floating Storage Regasification Unit in the Gulf of Gdańsk, and creation/expansion of the interconnections with Slovakia and Lithuania. Investments in cooperation with the Czech Republic and Ukraine are also possible. These projects constitute the Polish contribution to the Three Seas initiative, which aims to deepen the integration of the Baltic, Adriatic and Black Seas and EU’s priority countries – the north-south gas corridor for the CEE countries, and add to the planned energy integration of Baltic States.

In addition, expanding gas interconnectors will allow countries in the region to foster commercial use of natural gas storage. Ukraine has the largest natural gas storage capacity in Europe (over 30 billion m³), Slovakia has a storage capacity of almost 4 billion m³, the Czech Republic over 3 billion m³, and Lithuania 3.2 billion m³. The increased cross-border gas transmission capacity will therefore create the possibility of making storage capacities available on a commercial basis.

It is in the common interest of all countries in the region interconnectivity so as to enhance the diversification of natural gas supplies for the needs of the national economies in the region of Central and South-East Europe.

Such activities will increase energy security in the region and will stabilise energy carrier prices.

Detailed information is provided in subsections 5.1.5.3. and 5.1.5.4.

5.4.1.3. Nuclear power

Given the need to replace ageing generation capacities in the national power system from 2030 and increasing demand for electricity, it is necessary to invest in new sources. The construction of nuclear power plant units in Poland will mainly produce benefits in terms of energy security, diversification, and mitigation of impacts of the power sector on the environment. In addition, it will drive the development of the energy market, both for Poland and neighbouring countries. The investment is expected to slow down the growth of energy prices and, in the long run, to stabilise them. Nuclear power plants ensure predictability and stability of operation. Enhancing the country's production potential will improve the possibilities of exporting electricity to the neighbouring countries that are interconnected with Poland, and will add to the creation of an internal regional energy market. Given the lower unit cost of production compared to other power generation technologies, which is attributable to the small share of fuel costs in the total costs of electricity production, nuclear power plants will contribute to the stabilisation of wholesale electricity prices.

5.4.1.4. Capacity market

A capacity market has been launched in Poland pursuant to the Capacity Market Act of 8 December 2017. In addition to domestic entities, capacity market auctions are open to foreign physical generation units and demand reduction units located in the EU Member States whose power systems are interconnected with the Polish system, i.e. the Czech Republic, Germany, Lithuania, Slovakia, and Sweden. Foreign units must take part in a preliminary auction, which will be held for the first time in 2019, and therefore, for the first time, the units will participate in the main auction for 2024. For the periods 2021-2023, foreign units may participate only in additional auctions. The Act delimits three geographical zones for which the maximum volumes of capacity obligations that can be offered by the units of these zones will be determined each time. The preliminarily assumed level is around 1 GW.

The capacity market is to provide an investment impulse to ensure stability of electricity supply. Given the substantial decommissioning of existing units within the system, enhancing production capacities is crucially important for ensuring reliability of supply and satisfying the increased demand. Disruptions to the operation of the Polish power system could also have implications on the neighbouring countries interconnected with the National Power System. The capacity market mechanism is designed to prevent such disruptions. Supporting transboundary capacities is one of the foundations of the integration of EU energy markets.

Ensuring security of supply is based on maintaining a balanced system, continuity and reliability of supplies, as well as on transparency and competitiveness of the wholesale market. The creation of new and modernisation of existing units will undoubtedly improve the technical infrastructure and will help maintain the required power levels. Additionally, it will stabilise energy prices on the wholesale market. As a result of the introduction of the capacity market, reserve capacities will increase, which will reduce capacity shortage times during the year, thereby mitigating the risk of shortage of electricity supply. Maintaining a secure and required level of capacity in the system will contribute to building a stable European energy market.

By definition, the supply of electricity within the interconnected European energy markets supports the building of an energy union. Exploiting the production potential of generation units made available by neighbouring countries and transboundary trade may produce benefits for all the countries involved, such as improved technological competitiveness and the resultant reduction of production costs. Efficient use of production capacities is only possible with no disruptions to cross-border trade, expanded transmission networks, and upgraded distribution systems. In order to coordinate physical flows in a better way and enhance the potential for trade between the interconnected systems, cooperation with operators of neighbouring countries is necessary. It is necessary to eliminate the risk of failure to deliver the contracted capacity in situations where the neighbouring country is also struggling with difficulties in balancing its power system. Allowing foreign units to participate in the capacity market contributes to the creation of an internal European market.

Poland has opened the mechanism up to all kinds of capacity providers, including foreign ones, and has ensured the regularity and competitiveness of the auctions. In addition, during the notification process, Poland undertook to reform the electricity market. The capacity market mechanism has been approved by the European Commission, which clearly demonstrates that it does not threaten the integration of the Polish energy market

with neighbours' markets. It contributes to the security of energy supply, while safeguarding competition in the single market, and does not impede cross-border flows of electricity in the EU.

5.4.2. Impacts on energy prices, utilities and energy market integration

5.4.2.1. Impacts on energy prices

Actions taken in the area of gas systems will largely affect the structure of the gas market. Increased diversity of supply directions in the region will improve the competitiveness and stability of gas prices. The investment burden that must be borne by gas transmission companies in Poland and neighbouring countries will be partly relieved by support from EU funds, in particular for PCIs. The support will allow partial cost mitigation in order to rationalise the increase in gas prices for final consumers.

Currently, natural gas prices for non-industrial customers in the region vary widely. According to the Eurostat, in the last three years average natural gas prices (excluding taxes) have varied twice in extreme cases. With the exception of the Czech Republic (where the price of gas for the largest non-industrial customers is around EUR 12/GJ), gas prices in the region are lower than the European average. The lowest gas prices (around EUR 5/GJ) were recorded in Ukraine. For several years, gas prices in Lithuania have been falling (to EUR 6/GJ in the first half of 2018), similarly to Slovakia (to EUR 9.6/GJ). As regards industrial customers, natural gas prices are much more similar and, unlike previously, higher than the EU average. Prices in the region range from EUR 6.3/GJ in Ukraine to EUR 7.3/GJ in Lithuania. Deliveries of gas from the Norwegian continental shelf will allow the wholesale gas prices in the region to be equalised.

Regarding electricity, attention should be drawn, in the first place, to positive effects for neighbouring countries, which will be able to import some energy, especially during spells of adverse weather conditions (weak wind, low sunlight). The effects will be produced by the construction of nuclear power units and partly by the capacity market, which will stimulate the construction of stable sources able to offer extra export capacity in addition to the fulfilment of the capacity obligation.

- Energy market integration

Regulation 2017/2195 (guidelines on balancing) contains a number of recommendations regarding the balancing of electricity within the interconnected European system created. Cooperation in this dimension will reduce the balancing costs and increase the security of the NPS. At present, TSO-TSO balancing service exchange platforms are being created. In this solution, the service provider is required to provide services to its TSO (transmission system operator) for it to be able to provide the same to another requesting TSO. Currently, the following projects are being implemented under the Regulation:

- PICASSO (Platform for the International Coordination of Automated Frequency Restoration and Stable System Operation) platform for the exchange of balancing energy from frequency restoration reserves with automatic (secondary automatic) activation – aFRR. The project is carried out by the TSOs that have joined the initiative. PICASSO is designed and delivered as a joint European platform for activating automatic secondary regulation taking into account economic aspects leading to service cost optimisation.
- MARI (Manual Activated Reserve Initiative) is a platform for the exchange of balancing energy from frequency restoration reserves with non-automatic (secondary manual) activation – mFRR. The project is carried out by the TSOs which have joined the initiative. MARI is designed and implemented as an initiative of a joint European platform for the exchange of balancing energy between control areas. Electricity comes from units contracted to provide the manually activated secondary reserve service.
- TERRE (Trans European Replacement Reserves Exchange), i.e. a platform for the exchange of balancing energy from replacement reserves. The project includes the individual TSOs that have joined the initiative. TERRE is designed and implemented as an initiative of a joint European platform for the exchange of balancing energy between control areas. Electricity comes from units contracted to provide the manually activated tertiary reserve service.
- IGCC (International Grid Control Cooperation) is a project implementing an imbalance netting process between TSOs of two or more LFC Areas (Load-Frequency Control Areas). Activities are carried out within one or several synchronous areas to prevent the activation of balancing energy from the secondary frequency recovery reserve in opposite directions and to correct controllers within the LFC Areas of specific

TSOs.

5.4.3. Impacts on regional cooperation

Paris Agreement

Developed countries have committed themselves to providing USD 100 billion a year until 2020 to developing countries for investments in energy efficiency and combatting harmful emissions. Poland is among the group of developed countries and has declared a contribution of USD 8 million at the conference. Countries have undertaken to verify the targets in 5-year cycles. Poland actively cooperates with all the countries that have ratified the Agreement, pursuing actions to reduce greenhouse gas emissions, while taking into account the socio-economic specificities of the country. It also actively organises and hosts climate summits (Poznań, Warsaw, Katowice), which aim to achieve progress in creating the principles and obligations of implementing the Agreement.

Statistical transfer

As part of international cooperation between Poland and EU countries (as well as Switzerland and EFTA members), a certain amount of electricity generated in RES installations can be transferred in a given year. The arrangement takes the form of what is referred to as 'statistical transfer', which is effected on the basis of international agreements or civil law agreements. Countries can benefit from a transfer if their national target for the share of energy from renewable sources in gross final consumption is not met. It is assumed that until 2030 Poland will rely on its own resources to fulfil the target set, taking into account the required levels of cooperation with other countries. At the same time, Poland does not envisage surplus production of energy from renewable sources which could be transferred to other Member States in order for them to achieve their national contributions.

SET PLAN

Poland is currently an active member of two teams of Temporary Working Groups of the Strategic Energy Technology (SET) Plan. They are TWG Action 6 'Energy efficiency in industry' and TWG Action 10 'Nuclear'. Active participation in the work of other TWGs depends on the definition of Poland's energy priorities in line with the priorities of the SET Plan. This means that Poland's priority areas in the SET-Plan will be selected on the basis of its energy policy and will be implemented at a later date. After the areas are determined, national representatives will be designated to selected TWGs (the Ministry of Science and Higher Education will be able to invite the National Centre for Research and Development to join in and appoint experts to TWGs).

Baltic Energy Market Interconnection Plan

The activities carried out continuously over the entire period covered by the Plan should include the above-mentioned monitoring activities as regards diversification of gas supply sources. In addition, Poland envisages further cooperation at European level under the Baltic Energy Market Interconnection Plan (BEMIP). The investment projects listed above will allow the strategic assumptions of the Plan to be put into practice. To this end, continuous communication will be maintained between participants in this initiative. The expected effects will include closer regional cooperation in the field of energy and free trade in energy carriers and electricity.

Nuclear energy

The National Atomic Energy Agency (*Państwowa Agencja Atomistyki*) is the state authority appointed to ensure nuclear safety and radiation protection in Poland. This body participates in the creation of international standards and legislative acts by exchanging information on nuclear safety with neighbouring countries. Given the operation of nuclear power plants in close proximity to Poland's borders, as well as the planned investment in Poland, there is a need for cooperation with nuclear regulatory bodies of neighbouring countries, which should be pursued on the basis of intergovernmental agreements on early notification of nuclear accidents and cooperation in the field of nuclear safety and radiation protection. The National Atomic Energy Agency has concluded agreements with all countries bordering Poland, as well as with Austria, Denmark and Norway.

In addition, the National Atomic Energy Agency is engaged in international cooperation to enhance competence and implement good practices by exchanging knowledge and experience with foreign partners while participating in the work of international organisations and associations. Poland is an active member of

communities, groups and associations, such as the European Atomic Energy Community (Euratom), the International Atomic Energy Agency (IAEA), the Nuclear Energy Agency of the Organization for Economic Cooperation and Development (NEA OECD), the Heads of the European Radiological Regulatory Authorities (HERCA), the Western European Association Nuclear Regulators' Association (WENRA), the Council of the Baltic Sea States (CBSS), the European Nuclear Security Regulators Association (ENSRA), and the European Safeguards Research And Development Association (ESARDA). Poland declares its continued willingness to participate and act in the above-mentioned groups within the framework of international and regional joint efforts.

Open international cooperation in improving the safety of nuclear power plants because of the potential global impacts of nuclear accidents is a useful means of gaining knowledge and experience from other countries and disseminating good practices. Poland believes that international cooperation and the learning process provide an opportunity for quick and effective implementation of the best solutions in nuclear power plants. Poland plans to further develop cooperation with partners that have extensive experience in overseeing large nuclear installations and to continuously develop the R&D potential for nuclear power.

Within the European Union, Poland participates in the work of the Joint Working Party on Research/Atomic Questions, which discusses legislative and non-legislative documents for the EWEA. Poland participates in the coalition of pro-nuclear countries and submits positions in support of the development of nuclear energy in the EU, improvement of investment conditions in the sector, and an increase in funds for nuclear R&D. It also monitors and if necessary makes intervention during work of other working groups of the EU Council on matters relevant to the development of nuclear energy, e.g. environmental issues. Poland is also a member of working parties dedicated to Task 10 of the SET Plan, which is the technological pillar of the European Climate and Energy Policy, ensuring the visibility of, and access to, funding for Polish high-technology research projects, nuclear safety, and radioactive waste management.

The Visegrad Group (V4)

In the area of energy, Poland also cooperates within the Visegrad Group. Joint initiatives are being undertaken to create a regional gas market. In order to ensure diversification of gas supplies for the region, the members of the Group are cooperating with the aim of sourcing liquefied gas from the US. In addition, the North-South Gas Corridor project will include the construction of the following gas interconnectors: Poland-Slovakia, Poland-Czech Republic, and Slovakia-Hungary. All V4 countries have a unified position on the use of nuclear energy and cooperate in the field of electricity. These activities are conducive to developing the energy security and independence of the V4 countries. Setting objectives in a consistent way and implementing them in a unified manner contributes to the integration of the European Union and the harmonisation of its development level.

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