Ministry
Of Climate and

VERSION
PRELIMINARY

Annex 1 to the EPCIP
Transition scenario
in market and technical conditions

(with existing measures)

Warsaw 2024

Contents

Introduction

This document contains the results of analyses and projections **in *the WEM scenario*, which is understood as the baseline scenario of market-technical transformation**. The WEM scenario is an assessment of the situation with implemented and[1] planned policies and measures, the effects of which will affect the level of the 2030 climate and energy targets. The low projections presented are realistic in technical, organisational, economic terms in the short term, i.e. until 2030.

The report contains a set of statistical and foresight data corresponding to the list provided in Section B (Analytical Basis) of Annex 1 to Regulation (EU) 2018/1999 on the Governance of the Energy Union and Climate Action – General framework for the integrated national energy and climate plans. The information and figures produced as part of the work on the document relate to the current situation in the national fuel and energy system and its development forecasts.

The analyses and forecasts were carried out at the request of the Ministry of Climate and the Environment by the Consortium, which comprised: Institute for Environmental Protection – National Research Institute (IOŚ-PIB) and Energy Market Agency S.A. (ARE SA). The study provides a detailed description of the calculation methods and assumptions used for the work, which have a key impact on the results obtained. The statistics and aggregations used describing the state of play and prospects for the development of the fuel and energy sector are based on the EUROSTAT methodology (in accordance with the Commission's recommendations on the preparation of national plans). Data shall be presented on a five-year basis.

The text presents an analysis and assessment of the current situation and outlook for the development of the fuel and energy sector with existing policies and measures within the five main dimensions of the Energy Union – *energy security, internal energy market, energy efficiency, decarbonisation, and research, innovation and competitiveness*. The document also presents key assumptions and describes the projected gradual evolution of the main external factors affecting the development of the energy system and greenhouse gas emissions.

1 The WEM scenario shall take into account the actions and policies in place at the stage of preparation of the report or those for which a political decision has already been taken. The policies implemented have been adopted, in accordance with the guidelines set out in EU Regulation 2018/1999, for which one or more of the following criteria apply: directly applicable Union or national legislation, one or more voluntary agreements, financial allocations or human resources have been mobilised.

1. Foresight assumptions

Information on the projected evolution of the main external factors affecting developments in the energy system and greenhouse gas emissions is presented below.

1.1. Population

For the purposes of work, the population projection in Poland was used on the basis of the EC guidelines, adjusted slightly upwards to reflect immigration processes.

Table 2.1. Population [million]

	2005	2010	2015	2020	2025	2030
Total	38,1	38,1	38,0	38,0	38,0	37,9
City	23,4	23,1	22,9	22,7	22,7	22,6
Village	14,7	14,9	15,1	15,3	15,3	15,3

Source: Are S.A. on the basis of the Commission guidelines, Central Statistical Office's forecasts

The demographic projection presented assumes a decline in the population. At the same time, it should be noted that the population in urban agglomerations is affected by a gradual increase in the population living in rural areas. This is mainly due to the movement of people from towns to villages since approximately 2000, most often to suburban municipalities around large cities. The population projections used for model calculations are higher than those presented by the Central Statistical Office – the estimates of the Polish Metropolises Union Analysis Centre have been taken into account2, which indicate higher values than those reported in official statistics.

1.2. Gross Domestic Product (GDP)

The macroeconomic scenario on which the projection of energy demand in Poland was based was based on the Commission's guidelines (assumptions for the PRIMES2020 Reference Scenario3). Poland's projection of GDP growth in absolute terms used for model calculations is presented in the table below (Table 2.2), while the projections for annual average growth in the following table (Table 2.3). The projections show an average annual growth rate of 1.8 % of GDP in Poland over the period considered.

2021-2025	2026-2030

Table 2.2. Gross Domestic Product [million EUR'2020]

	2005	2010	2015	2020	2025	2030
GDP	286 657	361 804	419 955	475 755	561 399	632 335

Source: Eurostat, PRIMES2020 Reference scenario

Table 2.3. GDP growth dynamics in 2021–2030 (medium)

2 https://metropolie.pl/artykul/34-million-ukrainians-in-poland-new-report-by-the-union-of-polish-Metropolises

3E3-Modelling: Prof. P. Capros, A. De Vita, A. Florou. Energy, transport and GHG emissions – Trends to 2050. PRIMES2020 Reference Scenario. Brussels/Athens, July 2021

GDP	103,6	102,4

Source: Eurostat, PRIMES2020 Reference scenario

1.3. Gross sectoral value added

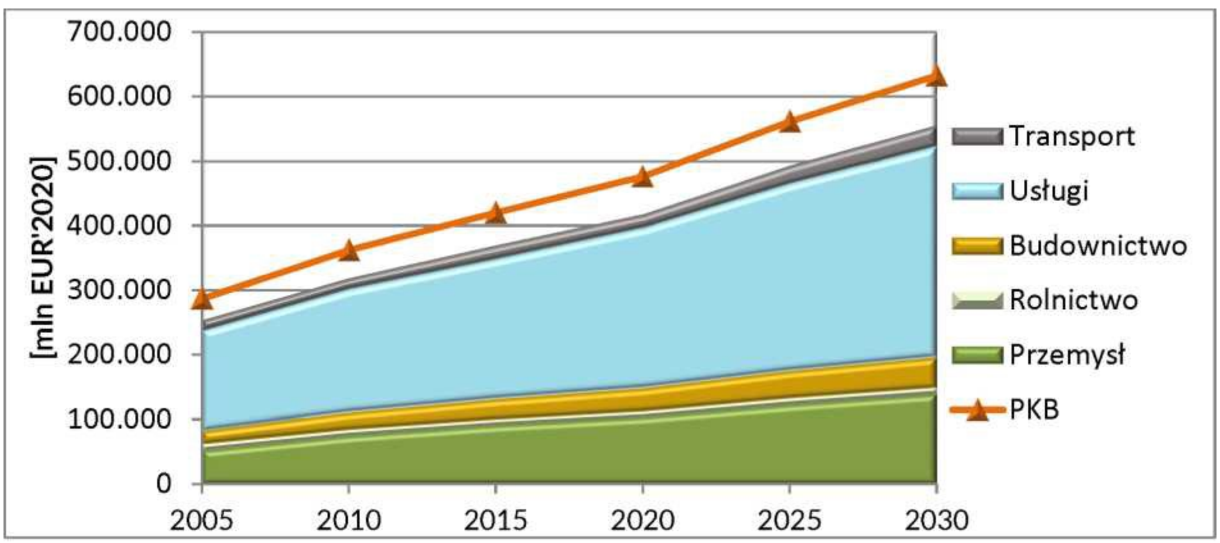
The structure of gross value added creation is based on the macroeconomic path towards PRIMES2020 model (Reference scenario). This projection was slightly revised in the initial projection period in order to align them with 2020 statistics (Table 2.4).

Table 2.4. Sectoral gross value added [million EUR'2020]

	2005	2010	2015	2020	2025	2030
Value added, gross	253 404	318 290	369 495	417 356	492 952	555 333
Industry	52 112	74 580	90 851	103 547	123 007	139 249
Agriculture	9 312	9 284	8 624	8 958	9 447	9 961
Transportation	16 527	16 831	21 386	20 554	27 768	32 094
Construction	20 772	27 023	32 431	36 001	43 006	47 285
Services	154 681	190 572	216 203	248 296	289 724	326 744

Source: Eurostat, PRIMES Ref2020, ARE SA

According to the scenario of sector-specific value added growth, the fastest growing economic sector will be services (Figure 2.1). Next to services, industry is the second sector that drives the economy.



Rysunek 2.1. PKB i struktura tworzenia wartości dodanej brutto w Polsce

1.4. Number and size of households

On the basis of the projected population in the country, projections for the number of households (Table 2.5) and the average number of people living in one household (Table 2.6) have been drawn up. The estimates were based on an analysis of the historical trend and comparisons with the latest projections prepared by CSO4. The table shows that there will be a gradual improvement in housing conditions in Poland, with a decrease in the number of people per household. In 2020, there were an average of 2.5 people per household. This indicator is expected to improve over the relevant time horizon to around. 2.4 in 2030

Table 2.5. Number of households

4Population forecast for 2023-2060. Central Statistical Office, Warsaw 2023

	2005	2010	2015	2020	2025	2030
Total	12 776	13 471	13 962	15 016	15 694	16 088
City	8 580	9 088	9 398	10 154	10 598	10 793
Village	4 196	4 383	4 564	4 862	5 096	5 295

Source: GUS, ARE SA

Table 2.6. Number of persons per household

	2005	2010	2015	2020	2025	2030
Total	3,0	2,8	2,7	2,5	2,4	2,4
City	2,7	2,5	2,4	2,2	2,1	2,1
Village	3,5	3,4	3,3	3,1	3,0	2,9

Source: GUS, ARE SA

1.5. Disposable income of households

According to the methodology adopted by EUROSTAT and implemented in Polish statistics,*household's available income*is the sum of the gross annual monetary income of all members of the household, less prepayments of income tax, taxes on property income, social security and health contributions, cash transfers transferred to other households and settlements with the Tax Office. In other words, they are money that households can spend on consumption, investment or savings. This indicator makes it possible to assess the real purchasing power of households. For work purposes, the data presented in the CSO publication on5 the level of average monthly disposable income per person was used. The forecast for this indicator (Table 2.7) is based on assumed projections for GDP growth in the country and the average number of people per household.

Table 2.7. Household disposable income projection [EUR'2020]

	2005	2010	2015	2020	2025	2030
Total country	6 769	10 204	10 819	13 125	15 502	17 464

Source: GUS, ARE SA

According to the presented projection, households' disposable income increases by approximately between 2020 and 2030. 33 %. The increase in this indicator reflects an improvement in the material situation of society and will, among other things, determine the future increase in energy demand in the country. Households' disposable income will be adjusted in subsequent calculation loops using the CGE economic model.

1.6. Passenger transport work

The demand for transport labour is a key driver of fuel and energy demand and, consequently, the level of emissions in the transport sector. Forecasts of this demand are based on data from 2005-2020 and have been compared with the assumptions in this area in the PRIMES2020[8] reference scenario and the figures from the "Transport Development Strategy..."6. They are the result of a 'bottom-up' approach in a predictive model, which uses the following general calculation method:

*transport work of the mode [pskm] = number of vehicles of the type [unit] * average annual mileage [km] * number of passengers carried*

According to the projection used for the calculations, the number of registered passenger cars in the country will increase from 25.1 million units in 2020 to 29.8 million units in 2030. 7 million) from the number of vehicles actually used (in the fuel consumption forecasts, this fact was taken into account and the number of passenger cars was reduced according to estimates of the 7AMP). Average mileage forecasts were drawn up on the basis of expert

5"Household budgets" – Central Statistical Office, Warsaw

6Resolution of the Council of Ministers of 24 September 2019 on the Transport Development Strategy to 2030 (with a perspective to 2030) – Monitor Poland, Warsaw, 14 February 2013.

7 Polish Automotive Industry Association. https://fleet.com.pl/wiadomosci/cykl-zycia-samochodu

analyses based on data from the Central Register of Vehicles and Drivers (CEPiK). A detailed description of the methodology used to analyse the transport sector in Poland is provided in the chapter below. The results obtained in respect of transport work were verified using a top-down approach, using the relationship between the level of economic activity as measured by the GDP/Ma indicator and the level of transport activity.

Table 2.8. Passenger transport work [billion pskm]

	2005	2010	2015	2020	2025	2030
Passenger cars (indust.)	b.d.	289,2	344,1	443	531	567
Motorcycles (industry)	b.d.	5,1	6,7	8	10	13
Scooters, mopeds, bicycles	b.d.	1,5	1,7	1,9	2,2	2,4
Buses (city)	b.d.	11,7	11,9	12	13	14
Buses (non-urban)	21,6	21,5	21,8	20	23	24
Railways (publish)	18,2	17,9	17,4	25	26	40
Aeroplanes	8,5	8,3	13,5	13	18	20
Vessels (inland navigation)	b.d.	0,02	0,03	0,03	0,04	0,04
Railway vehicles (trams, trolleybuses, metro)	b.d.	3,2	3,5	4	5	7
Total	b.d.	358	420	527	630	687

Source: Are SA, on the basis of: PRIMES Ver. 6 Energy Model. National Technical University of Athens, 2021, Transport – Performance – Central Statistical Office. Warsaw, 'Strategy for the development of transport up to 2030 (with a view to 2040)' – Monitor Poland. Warsaw, 2019

Synthetically, demand for passenger transport labour increases from 527 billion Psk in 2020 to 687 billion psk in 2030, i.e. by around. 30 %. In the industry, the largest share of demand is concentrated on individual car transport, which increases from 443 billion pskm in 2020 to 567 billion pskm in 2030. Rail transport (which is linked to the improvement of the quality of services provided and the development of high-speed rail) and domestic air transport (as a result of the increasing availability and popularity of this mode of transport) also shows a significant increase in demand.

[8] E3-Modelling: Prof. P. Capros, A. De Vita, A. Florou. Energy, transport and GHG emissions – Trends to 2050. PRIMES2020 Reference Scenario. Brussels/Athens, July 2021.

1.7. Freight transport work

In addition to economic growth measured by a series of macroeconomic indicators, the main drivers of demand for freight transport are changes in the transport intensity rates of economic activity (which tend to decrease with the share of highly processed goods and services), the size of Polish foreign trade, changes in modal relations in transport and the cyclical situation in international transport markets. The projections for freight transport labour demand implemented in energy projections are derived directly from a model based on the following calculation algorithm:

transport work of the means of transport [tkm] = mass of freight carried [tonne] average distance of 1 tonne of freight [km].*

Forecasts of the average freight distance by the means of transport in question have been drawn up on the basis of an analysis of historical trends. The table (Table 2.9) summarises the freight transport work projections resulting from model calculations and assumptions.

Table 2.9. Freight transport work [bill tkm]

	2005	2010	2015	2020	2025	2030
Rail transport	50,0	48,9	50,7	54,0	70,2	87,1
Road transport	119,7	214,2	273,1	354,9	351,3	364,4
Pipeline transport	25,4	24,2	21,8	23,0	18,3	18,6
Inland waterway transport	1,3	1,0	2,2	0,9	1,6	1,9
Maritime transport	b.d.	112,0	158,0	178,0	206,0	235,0

Air transport	0,1	0,1	0,4	0,6	1,6	2,1
Total	b.d.	400	506	611	649	709

Source: Are SA on the basis of: PRIMES Ver. 6 Energy Model. National Technical University of Athens, 2021, Transport – Performance – Central Statistical Office. Warsaw, 'Strategy for the development of transport up to 2030 (with a view to 2040)' – Monitor Poland. Warsaw, 2019

According to the results presented, demand for freight transport labour increases from 611 billion tkm in 2020 to 709 billion tkm in 2030. In the industry sector, the bulk of demand for freight transport is driven by car transport, which accounts for about. 58 % in 2020 and gradually decrease to 51 % in 2030.

1.8. International fuel import prices

The projections for fuel prices for imports into the European Union used for model calculations, presented in the table (Table 2.10) and in the figure (Figure 2.2) were adopted on the basis of the Commission guidelines. In the first years, the projections for hard coal and natural gas were revised to reflect the increase in the prices of these raw materials due to the departure of EU countries from imports from the Russian Federation. The projections presented below served as a basis for determining fuel prices on the domestic market.

Table 2.10. Fuel prices for imports into the EU [EUR'2020/GJ (NCV)]

	2005	2010	2015	2020	2025	2030
Natural gas	6,0	7,4	7,8	9,4	13,9	11,9
Hard coal	2,5	3,1	2,3	3,3	5,4	3,3

Source: Are SA on the basis of the Commission Guidelines for updating the NECPs

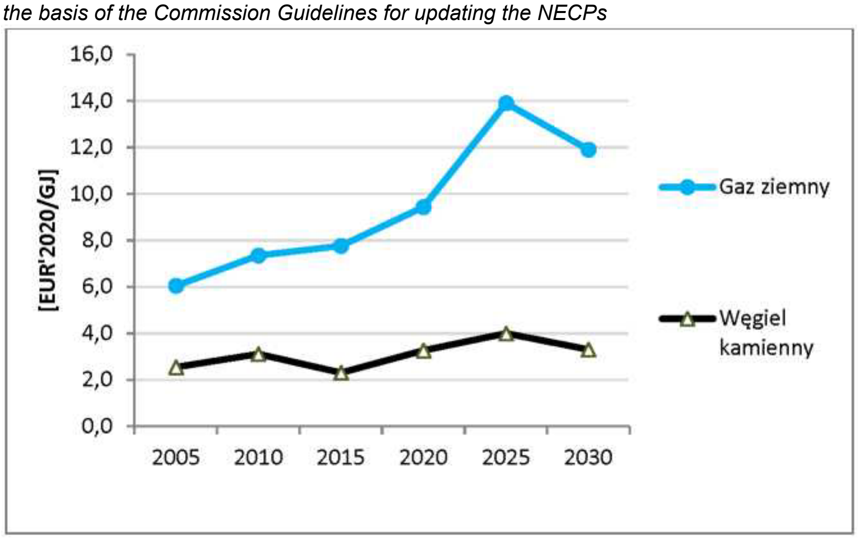


Figure 2.2 Fuel prices for imports into the EU

1.9. EU ETS CO2 allowance prices

The EU ETS CO2 price projections used inthe analysis are presented in a table (Table 2.11). These prices were calculated on the basis of the Commission guidelines with upward adjustment for 2025 and 2030 (for which the Commission's recommendations indicated EUR 80'2020/tCO_2), taking into account price increases in 2023. In the periods between coastline years, a linear increase in the cost of CO2 allowances was assumed.

Table 2.11. EU ETS CO2allowance price [EUR'2020/tCO_2]

	2005	2010	2015	2020	2025	2030
Price for 1 allowance	0	14	9	25	90	100

Source: EC guidelines to the NECPs

It was assumed that the price of CO2 allowancesin the EU ETS would gradually increase to EUR 100'2020/t CO_2 in 2030. A stabilisation reserve (MSR) mechanism will be one of the key mechanisms influencing the way in which the CO2 pricewill evolve in the future. The biggest impact on the reduction of supply and the increase in the price of EUA allowances in the EU ETS towards 2030 will be the increase of the linear reduction factor (LRF) from 2.2 % to 4.3 % in 2024-2027 and 4.4 % in 2028-2030, introduced in the EU ETS Directive in May 2023, together with a one-off adjustment of the allowance limit (so-called 'rebasing')8. The extension of the 24 % intake rate until 2030 will also result in a significantly faster reduction of the supply of allowances in the market by increasing EUAs' transfers to the MSR. Combined with a reinforced LRF and a rebasing in 2024, this will mean a tight supply already in 2025. After 2030, a further significant reduction in the supply of allowances in the system is expected.

1.10. Exchange rates

The EUR/PLN exchange rates were adopted according to the latest projections of the Ministry of Finance9. They assume an exchange rate of 4.450 PLN/EUR. The calculation uses a USD/EUR exchange rate of 1.1. Historical data for 2005-2 020 are derived from the NBP's archives.

Table 2.12. Exchange rates

	2005	2010	2015	2020	2025	2030
USD/EUR	1,245	1,328	1,120	1,140	1,100	1,100
PLN/EUR	4,023	3,995	4,184	4,440	4,450	4,450

Source: NBP, MF

1.11. Number of heating and cooling degree days

The assumptions concerning the number of heating degree days in view of the forecast were adopted on the basis of the European Commission's recommendation on the preparation of the NECPs10. Historical data for 2005-2 020 are taken from EUROSTAT databases. The projected number of heating and cooling degree days assumes a gradual warming of the climate in the climate zone in which Poland is located.

Table 2.13. Number of HDD degree days

	2005	2010	2015	2020	2025	2030
HDD	3 547	3 881	3 113	3 442	3 430	3 418

Source: Eurostat, EC Guidelines for NECPs 2021-2030

Table 2.14. Number of CDD cooling degree days

	2005	2010	2015	2020	2025	2030
CDD	216	197	220	223	226	229

Source: Eurostat, EC Guidelines for NECPs 2021-2030

1.12. Technology cost assumptions used in modelling for main relevant technologies

The parameters of the new generation units presented in the table (Table 2.15) are based on the latest available publications of renowned research centres. The modelling studies assume that only electricity and heat generation technologies currently in commercial offers will be available.

8Centre for Climate and Energy Analysis (CAKE). "Finalise negotiations on key elements of the EU ETS in the framework of the "Fit for 55" package. Warsaw, January 2023

9Ministry of Finance. Guidelines on the use of uniform macroeconomic indicators as a basis for estimating the financial impact of draft laws. Updated October 2023

10Notice on the Guidance to Member States for the update of the 2021-2030 national energy and climate plans (2022/C 495/02) Official Journal of the European Union 29.12.2022

Table 2.15. Technical and economic parameters of generation and transmission technologies

Fuel/Technology	Activation period	Investment expenditure. OVN EUR	Costs Permanent EUR 1000/MWnet	Variables EUR/MWhnet	Efficiency electr /total %	Technical lifespan Years	Indicate net emissions kg/GJ
1.1 Brown coal – PL	2020-2050	2000	53	3,8	44	40	110
1.2 Brown coal – PL+CCS	2030-2050	3600	80	9.5**	38	40	14*
1.3 Brown coal – FBC	2020-2050	2275	56	3,8	40	40	106
2.1 Coal – MS	2020-2050	1850	49	3,6	46	40	94
2.2 Coal – IGCC	2025-2050	2500	64	7,8	48	40	94
2.3 Coal – IGCC+CCS	2030-2050	3650	87	11.3**	40	40	12*
2.4 Coal – CHP	2020-2050	2500	53	3,6	30/80	40	94
2.5 Coal – CHP+CCS	2030-2050	3885	84	13,3	22/75	40	12
3.1 Natural gas/hydrogen# – CCGT	2020-2050	835	20	2	58-62	30	56
Natural gas – CCGT+CCS	2030-2050	1500	42	4.4**	50-52	30	6 *
3.3 Natural gas/hydrogen# – CHP CCGT	2020-2050	1055	22	2,2	52-56	30	56
Natural gas///hydrogen# – TG	2025-2050	500	18	6,7	40	30	56
3.5 Gas Mikro CHP	2020-2050	2610	108	— —	20/90	25	56
Nuclear – PWR	2030-2050	4750	115	3	36	60	0
4.2 Small Nuclear Reactors_ SMR	2030-2050	6500,5250	88	4	40	60	0
5.1 Onshore Wire	2020-2050	1500 UNION1150	56	— —	— –	25	0
5.2 Wire at sea	2020-2030	3050 GOC2450	100	— —	— –	25	0
5.3 Welcome at sea	2031-2050	2450 GOC1850	100	— —	— –	25	0
5.4 Large water	2020-2050	3100	39	— —	— –	60	0
5.5 Small aquatic	2020-2050	2850	83	— —	— –	60	0
5.6 Geothermal	2020-2050	7780 GOC6650	178	— —	12	30	0
5.8 Photovoltaic cells	2020-2050	840STAN DARD610	18	— —	— –	25	0
5.9 Photovoltaic roof cells	2020-2050	1100 GOC780	22	— —	— –	25	0
5.10 Agricultural biogas – CHP	2020-2050	3650-3050	244	— —	36/85	25	0
5.11 Biogas from waste water treatment plant – CHP	2020-2050	3900	150	— —	34/85	25	0
5.12 Landfill biogas – CHP	2020-2050	2000	89	— —	40/85	25	0
5.13 Solid biomass – CHP	2020-2050	3250H3000	133	— —	30/80	30	0
6.1 Water pumps	2020-2050	1350	44	— —	80	60	0
6.1 battery storage systems en.electr.	2025-2050	555H225 [EUR/kWh]	22	— —	90	15	0
7.1 electrolysers	2020-2050	550H285	30 UNION25	— —	68≠75	30	0
8.1 Coal Heat Plant	2020-2050	350	1,5	1,4	90	30	94
8.2 Natural gas heating plant	2020-2050	150	1,3	0,4	96	30	56
8.3 Heating heating plant	2020-2050	200	1,4	0,5	95	30	74
8.4 Biomasa Heat Plant	2020-2050	500	1,5	1,4	90	30	0
8.5 Biogaz Hemicycle plant	2020-2050	150	1,3	0,4	95	30	0
8.6 Electrode boiler heater/El radiators.	2020-2050	450	1,1	0,5	99	30	0
8.7 geothermal heater	2020-2050	2850 GOC2500	26	4,4	10	30	0
8.8 Heat pump plant	2020-2050	950H850	2	1,8	300	25	0
Connection to/reinforce the network							
9.1 System Power Plants	2020-2050	250					
9.2 Onshore wind power plants	2020-2050	350					

Fuel/Technology	Activation period	Investment expenditure. OVN EUR	Costs Permanent EUR 1000/MWnet	 Variables EUR/MWhnet	Net efficiency of the electr. /total %	Technical lifetime Years	Please select. emissions kg/GJ
9.3 Offshore wind power plants	2020-2050	750					
9.4 Other el. And combined heat and power plants	2020-2050	50-250					

 # Fit for hydrogen combustion or burning only hydrogen

** Ratio related to the fuel input. Lower values of this indicator take into account CO_2 capture installation **Incl. CO_2transport and storage*

Sources:

- *International Energy Agency (2022), Global Energy and Climate Model Documentation 2022, IEA, Paris*
- *National Renewable Energy Laboratory, 2022 Annual Technology Baseline, Golden, 2022*
- *Aurora Energy Research, CO_2-free flexibility options for the Duch energy system, October 2021*
- *European Commission JRC (Joint Research Centre), Power generation technology assumptions, Oct 2019*
- *Danish Energy Agency, Technology Data Catalogue for Electricity and district heating production – Updated February 2023*
- *Asset (Advanced System Studies for Energy Transition) EU funded project, Technology pathways in decarbonisation scenarios, 2018*
- *O. Schmidt, A. Hawkes, A. Gambhir & I. Staffell. The future cost of electrial energy storage based on experience rates. NAT. Energy 2, 17110 (2017)*

The table (Table 2.16) shows the technical and economic parameters of the CO and CWU technologies used in households and small service enterprises for the model calculations. This data comes from a wide variety of sources, including official parties of manufacturers and distributors of equipment in Poland.

Table 2.16. Technical and economic parameters of CO and CWU technologies

	Purchase cost 2020-2050 [EUR'2020/kW]	Cost of purchasing additional installations 2020-2050 [EUR'2020/kW]	Description of additional installations	Efficiency [%]
electric furnaces or radiators – Installed	24	absence	not applicable	100
electric furnaces or radiators – mobile	12	absence	not applicable	100
electric floor heating	143	48	control and automation	100
electric water heater (boiler, temperature)	17	absence	not applicable	100
central heating boiler for natural gas	48	179	water heaters + connector	90-97
natural gas water heater (boiler, temperature)	18	60	connector	90
two-function boiler (co + cw) for natural gas	72	179	water heaters + connector	90-97
central heating boiler for liquid gas (propane – butane)	48	239	water heaters + tanker	90-97
liquid gas water heater (propane – butane)	18	2	cylinder	90
two-function boiler (co + cw) for liquid gas (propane – butane)	72	239	water heaters + tanker	90-97
central heating oil boiler	48	131	water heaters + tanker	90-95
two-function boiler (co + cw) fuel oil	72	131	water heaters + tanker	90-95
central heating boiler using solid fuels	48	119	water heaters	60-80
water heater (boiler, temperature) for solid fuels	18	48	solid fuel furnace	60-80
two-function boiler (co + cw) for solid fuels	66	119	water heaters	60-80
indoor solid fuel furnaces	24	absence	not applicable	40-80
solid fuel fireplace with open chimney cartridge	24	72	enclosure	40-80

	Purchase cost 2020-2050 [EUR'2020/kW]	Cost of purchasing additional installations 2020-2050 [EUR’2020/kW]	Description of additional installations	Efficiency [%]
solid fuel fireplace with closed chimney cartridge	24	72	enclosure	50-80
solid fuel fireplace with water jacket	96	191	enclosure+water heaters	60-80
cookery for solid fuels	24	absence	not applicable	30-80
dual-purpose heat node	70	absence	Node+connection	70
heat pump	717	119	water heaters	3,5-5,4*

**COP – coefficient of performance*
Source: Are SA based on data collected from equipment manufacturers and distributors

Table 2.17. Technical and economic parameters of industrial technologies

Technology	Fuel	Direction of use	Purchase costs 2020 [EUR'2020/kW]	Purchase costs 2030 [EUR'2020/kW]	Costs operational O&M [EUR'2020/GJ]	Technical lifespan	Indicator emissions [kg/GJ]
Industrial furnaces/boilers for process heat production	Blast furnace gas	Heat high-temperature	1200	1200	0,3	25	260
Industrial furnaces/boilers for process heat production	Coke oven gas	Heat high-temperature	1650	1650	0,4	25	44
Industrial furnaces/boilers for process heat production	Coke	Heat high-temperature	500	500	0,12	25	107
Industrial furnaces/boilers for process heat production	Electricity	Heat high-temperature	1200	1200	0,3	25	0
Industrial furnaces/boilers for process heat production	Coal	Heat high-temperature	1650	1650	0,4	25	94
Industrial furnaces/boilers for process heat production	Heavy fuel oil	Heat high-temperature	1600	1600	0,4	25	77
Industrial furnaces/boilers for process heat production	Light fuel oil	Heat high-temperature	1600	1600	0,4	25	77
Industrial furnaces/boilers for process heat production	LPG	Heat high-temperature	1200	1200	0,3	25	63
Industrial furnaces/boilers for process heat production	Natural gas	Heat high-temperature	1200	1200	0,3	25	56
Large-scale electric motors	Electricity	Electric drives	300	250	0,18	10	0
Small-scale electric motors	Electricity	Electric drives	500	450	0,18	10	0

Source: Are SA based on an analysis of available literature sources and equipment suppliers' data

Table 2.18. Technical and economic parameters of transport technologies

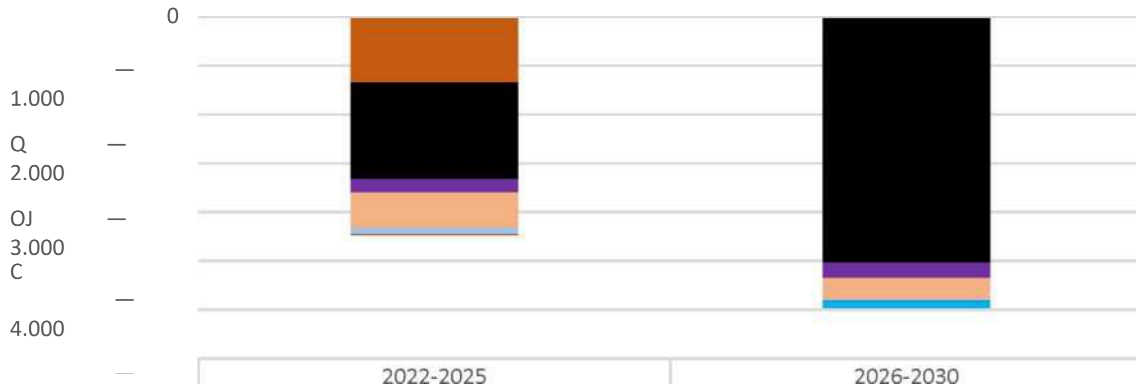
	Cost of purchasing new vehicles [EUR'2020/vehicle]	**Specific fuel/energy consumption [l/100km] 2020⟶2040**
Cars (petrol & 1399 cm^3)	9 500	5,4 0 3,6
Cars (petrol 1400-1 900 cm^3)	12 200	6,6 0 4,3
Cars (petrol > 1 900 cm^3)	14 900	8,5 0 5,5
Cars (On &199 cm^3)	13 600	4,6 0 3,0
Cars (On 1400-1 900 cm^3)	17 600	5,9 0 3,8
Cars (On > 1 900 cm^3)	20 250	6,9 0 4,5
Cars (LPG <1399 cm^3)	10 250	6,4 0 4,3
Cars (LPG 1400-1 900 cm^3)	13 000	8,1 0 7,0
Cars (LPG > 1 900 cm^3)	15 650	10,7 0 7,1
Cars (hybrid)	20 000 0 14 000	3,8 0 2,8
	[EUR'2020/vehicle]	**[^{m}3/100km]**
Cars (CNG)	19 000	7,1 0 6,5
Lorries up to 3.5 t (CNG)	36 000	11,9-> 10.5
	[EUR'2020/vehicle]	**[kWh/100km]**
Cars (elect)	50 000 0 20 000	23,0 0 21,0
Trucks up to 3.5 tonnes (electric)	90 000 0 70 000	33,0 0 28,0
	[EUR'2020/vehicle]	**l/100km**
Lorries up to 3.5 t (petrol)	27 600	12,008,5
Trucks up to 3.5 tonnes (ON)	35 650	9,60 7,0
Trucks up to 3.5 tonnes (LPG)	33 350	12,1010,6
Lorries up to 3.5 t (CNG)	35 650	11,908,7
Trucks weighing 3.5 t (ON)	108 100	45,0 0 34,0
	[EUR'2020/vehicle]	**[toe/year]**
Agricultural tractors	46 000	1,15 0 1,02
Siloso-combine	155 250	4,5 0 3,96
Combine harvester-threshers	73 000	1,42 0 1,25

Source: Are SA based on data from producers and trade organisations

1.13. Other key parameters affecting the development of the fuel and energy sector

1.13.1. Timetable for the decommissioning of electricity generation capacity

The timetable for the decommissioning of existing generation units and the modernisation plans were based on information held by MKiŚ, surveys carried out among energy companies, data from the annual reports of energy companies and press releases. The results of the analyses are presented in the graph below (Figure 2.3) showing all determined and assumed permanent withdrawals of generation units11 in the NES between 2022 and 2030. The largest amount of permanent abandonment concerns coal units. According to the timetable presented, more than 8 GW of power plants and coal-fired power plants will be shut down in 2022-2030 (further waiving beyond 2030). The scale of these exemptions is important and represents a major challenge for the National Energy System, especially as it concerns units with a high level of availability. The withdrawals of these generation units must be covered in a way that ensures continuity of supply in the future.



	2022-2025	2026-2030
Magaziny en.	0	0
Photovoltaic	0	0
EL_Vitor	0	—121
EC_Biogaz	—11	—28
EL and	0	—1
EC_Gaz	—144	—35
EC_WK	—720	—429
EC_Industry	—275	—311
EL_Gaz	0	0
EL_WK	—1.982	—5.034
EL_WB	—1.340	0

Figure 2.3 Schedule of permanent withdrawals of generation units 2022-2030

Source: Own study by ARE SA

The table (Table 2.19) summarises the cumulative withdrawals of existing units implemented for the calculation.

According to the data provided, more than 10 GW of generation capacity will be permanently decommissioned by 2030, including more than 8.3 GW of existing JWCDs. Of the professional combined heat and power plants included in the nJWCD group, approx. will be decommissioned by 2030. 1.3 GW.

Table 2.19. Cumulative withdrawals in 2022-2030 [MWnet]

Year	2022-2025	2026-2030
Cumulative withdrawals of generation capacity	— 4 472	—5 959
Year	**2022-2025**	**2026-2030**
— of which: Thermal JWCD	—3 322	—5 034
— nJWCD from the professional EC group	—864	—464

Source: Own study by ARE SA

11Figure 4.3 shows a large number of wind and photovoltaic power plants that are decommissioned after 2035, as it is assumed that existing units will be replaced by new ones once they reach the expected lifespan, although some permeable part through deep modernisation will extend the lifetime beyond the 25-year lifespan.

1.13.2. Main assumptions on capacity and technology included in the projections

One of the key assumptions used in the analysis of the development of the electricity system is the availability of capacity and new technologies. The modelling calculations, taking into account long-term forecasting:

- current capacity resources in the national electricity system (NCS),
- expansion of resources in existing technologies in the NES,
- building capacity in technologies that do not exist in the Polish system but are used globally;
- the potential of technologies and solutions whose development on the international scene has not reached technical maturity, but the high level of commitment to these areas allows for a positive assessment of their applicability in Poland in the next decade.

Forecasts have been made for so-called normal climatic and weather conditions and assume the development of power generation technologies presented in this document. Detailed assumptions per technology and solution are set out below.

Coal capacity

In 2022, approx. were installed in the NES. GW of capacity in coal-fired power plants and around GW in combined heat and power plants[12]. Taking into account the operation of generation units, the need to decarbonise the sector, as well as the fiscal burden (purchase of CO2 emission allowances, fuel costs) and regulatory (pollution limits), it is assumed that no new conventional coal power plants will be created, which does not exclude investments in clean coal technologies, such as the construction of a gas-steam unit with integrated gasification of coal fuel. IGCC) or construction of a CO_2 capture and storage/treatment facility CCS/CCUS).

Capacity for lignite

In 2022, the capacity installed in lignite-fired power plants was 8.9 GW[13]. Similarly to coal units, no new lignite capacity or launching new opencasts are foreseen, although strategic resources should be secured. The costs of generating electricity in such power plants are relatively low given the cost of fuel alone, but with rising costs of purchasing CO2 emission allowances,this capacity will be phased out from the system. Additional factors contributing to the need to limit the production of electricity from lignite include: limiting the negative impact of the sector on the environment, age and technical condition of generation units, depletion of lignite reserves in existing opencast mines. Therefore, a decrease in the share of lignite in electricity generation and in the power balance is inevitable.

Capacity for natural gas

In 2022, the capacity installed in power plants and combined heat and power plants was around. 4 GW. The main role of gas capacity is to increase the stability of the operation of the NES in a context of intense increases in the capacity installed in zero-emission sources, but dependent on atmospheric conditions. Gas capacity is considered as transitional sources in the transition process. Thus, the increment of installed capacity may not be higher than necessary and be temporary until it is possible to ensure the stability of system operation using zero-emission technologies and solutions. The projected significant role of gas in NSEs' balancing is mainly due to the inclusion of units currently under construction and those with a high degree of maturity in the investment process.

Nuclear capacity

There are currently no nuclear power plants in Poland, but the first large-scale nuclear power plant is planned for 2033. The projection took into account the construction of 6 units under the Government's Polish Nuclear Energy Programme adopted in the version updated by the Council of Ministers in 2020. It also took into account the possibility of building two nuclear units in Korean technology APR1400 with a total capacity of 2800 MWe as part of a business initiative (PGE, PAK in cooperation with the KHNP), with a total capacity of 2800 MWe, with the first unit of the power plant being put into operation by 2034. As a private initiative, this project will be implemented

12Statistical information on electricity, table. 3 and 4. Are S.A December 2022
13Ibid

in parallel to the actions foreseen under the PINC. At the same time, the construction of small modular reactors (SMRs) is included in the modelling calculations. Although SMRs are currently not widely used in the global energy sector, they are of broad market interest due to a number of advantages, the most important being: zero emission, availability, modularity. The industry is considering more than 20 locations, identifying the approximate potential of more than 25 reactors in the 1930s. By working on a base of electricity system load and regulatory features, they can provide valuable complements to large-scale blocks. In addition, SMR technology can contribute to covering heat demand in district heating and provide energy for the production of alternative fuels (including hydrogen), as well as large reactors. However, it is important to highlight the high uncertainty and real possibilities for deploying this technology in Poland with a view to 2040. To date, the SMR licensing process in SMR supplier countries has not yet been completed and there is no reliable information on the costs of these investments. Despite the existing uncertainties, this technology has been taken into account in the long-term analyses, but a precautionary approach has been taken and forecasts may be updated as individual projects become more aware. The values of installed capacity and production from SMR should not be considered as limit values, especially since the capacity of this technology may also be used by large energy-intensive companies to cover their own needs.

The analyses take into account the so-called childhood age of newly created nuclear units, which is why in the first years of operation the power utilisation rate deviates from the full capacity to load these units.

Offshore wind farms (offshore lifts)

Analyses carried out on the development of the electricity sector assume that the first offshore production volumes from offshore wind power plants will appear in 2027 (i.e. after synchronisation of the work of the units in the NES; the first installed capacity is planned for 2026) In view of the advantages of this RES technology, in particular the relatively high capacity utilisation rate and the high market interest, a number of investments in offshore wind are foreseen. The forecasts use market information for projects for which documentation is at a high level of maturity. Projections assume a maximum offshore wind capacity of 5.9 GW in 2030 (and around in the longer term. 18 GW in 2040).

Onshore wind farms (onshore lifts)

At the end of 2022, the installed capacity of onshore wind farms was close to 8.3 GW. Analyses of the development of the electricity system take into account the results of the auctions of RES auctions conducted so far and the further increase in wind capacity in the following years. It is also envisaged to build capacity outside support schemes, including those linked to the flexibilisation of the so-called 10 H rule, which may accelerate the development of onshore wind energy.

Solar energy (PV)

At the end of 2022, the installed capacity of solar power plants was around. 12.2 GW. The majority were prosumer installations, which have recently grown very dynamically. The projections take into account the further development of solar energy, both in view of the implementation of projects resulting from the RES auctions and the further development of prosumer energy, also in the light of the implementation of REPowerUE. Network constraints are partly inhibiting the growth of photovoltaic installations. For this reason, a significant part of the funds foreseen in the RRP for the energy transition will be devoted to the modernisation and expansion of the grid in order to adapt it to the increasing share of volatile RES sources. The solution, which is expected to improve the situation for major projects, is the amendment to the RES Act adopted by the Senat at the end of July 2023, with an amendment allowing several renewable energy sources to be included in the grid on a single connection so-called cable pool. The newly introduced legislation is likely to unlock at national level the potential of several additional green gigawatts – mainly photovoltaic, located alongside existing wind farms.

Capacity for biomass and biogas

Biomass and biogas capacities are stable sources of energy, but currently, due to high operating costs and the availability of raw materials, they do not represent a high share of the capacity structure in the NES – in 2022 the installed capacity was around. 1.25 GW. The obligation to use sustainable biomass in units above 20 MW for solid fuels and above 2 MW for gaseous fuels and its limited availability, as well as the insufficiently developed biogas market in the coming years, may have an impact on the relatively low rate of development of biomass and biogas capacities.

The forecast takes into account the expected investments in relation to the existing RES support schemes.

Programmes financed by EU and national funds, such as the 'Energy for Rural' programme, will also be used to stimulate investment, which may lead to a higher real increase in this capacity, also in view of the increasingly assessed potential of biomethane, the development of which may result in a reduction in natural gas imports into Poland. It was assumed that the development of biomass energy should be carried out in a sustainable manner that does not endanger Poland's food security. Harnessing the potential of agricultural biogas plants will reduce the environmental impact and the nuisance of agricultural production, including livestock production, for the inhabitants of rural areas.

Hydropower

In 2022, the installed capacity of flow-through hydropower plants was close to 1 GW. Poland has a relatively low water potential, which determines the low share of flow hydropower in the energy mix. The development of this technology is foreseen in the country, although the intensity of new capacity is limited by objective natural capacities. Pumping/storage power plants are a separate category as described below. Such hydropower plants are not counted as renewable energy sources.

Storage, pumped storage and demand management (DSR)

In recent years, energy storage technologies have become a growing interest for investors due to their role in efficiently managing and balancing RES production, as well as in strengthening security of supply. Given that research into storage and the development of these technologies is a global trend, it can be concluded that technology will develop to such an extent in the coming decades to ensure better use of RES capacity and system management and to influence the security of energy supply and the building of energy independence for both households and economic operators. The development of both battery storage facilities and other solutions to efficiently store energy is expected. The National Renewable Energy Laboratory (NREL) was assumed to have an average efficiency of 88 %. For large-scale battery storage facilities, 4 hours a day and 2 hours a day for prosumer installations.

Pumped storage plants play an important role as energy storage facilities. As a result of the planned projects, the capacity of this type of technology could increase from the current 1.4 GW to 4.8 GW in 2040, including as a result of the Młoty, Tolkmicko, Rożnów power plants.

The projections take into account the possibility of demand side response (DSR), but were intended to be able to cover physical capacity. DSR analyses have a positive impact on the results of the power adequacy analysis in the available DSR analyses. 'Demand-side management' solutions may, inter alia, increase the flexibility of the operation of the NES and reduce peak demand for electricity during periods of critical load in the electricity system and thus have a positive impact on strengthening energy security. The national potential of DSRs (both centralised and distributed) is promising, but technical possibilities and costs remain constrained in the coming years.

Hydrogen

According to Poland's Hydrogen Strategy for 2030 with a view to 2040, installed electrolyser capacity could be 2 GW by 2030 and could be around. 5300 h/year, i.e. 61 % of the hours per year. Further actions – including those aimed at developing the hydrogen market, the need to meet the objectives of EU regulation on the use of hydrogen in specific economic sectors and the potential to use hydrogen for energy storage – will lead to the expansion of transmission networks and increased efficiency in the use of these capacities, in particular through cooperation of electrolysers with RES sources.

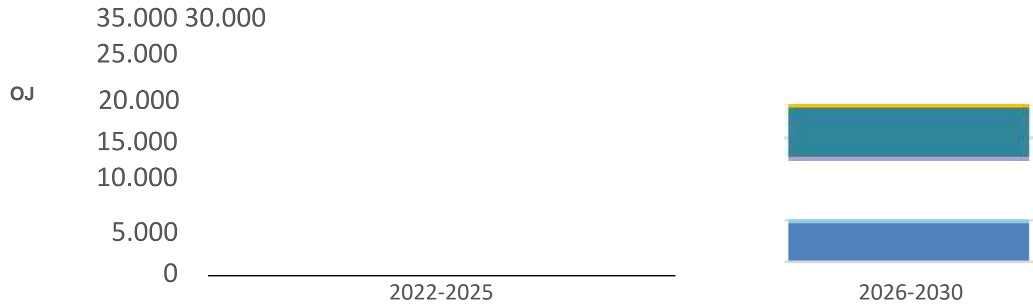
1.13.3. New generation capacity determined

The figure below illustrates the timeline for the deployment of new capacity in the period 2022-2030. When determining the future energy mix as units determined in the analysis, the following were adopted:

- the gas blocks under construction and the winners of the capacity auction,
- for RES, account was taken of the existing and announced auctions for the purchase of electricity from RES, the relaxation of the distance law for onshore wind farms and the implementation of the Act of 17 December 2020 on the promotion of electricity generation in offshore wind farms. The forecast includes

5.9 GW of offshore wind power capacity in 2030, with full production of the first units in 2027;

- for DSR units, the available volume of capacity was assumed to be 1 000 MW in 2 025.1650 MW in 2030, with DSR mechanisms being assumed to exist only during periods of critical load of the electricity system;
- the selection of the remaining new power units was determined by the optimisation process carried out in the MESSAGE model.



	2022-2025	2026-2030
Magaziny en.	48	710
El_hydrogen*	0	0
Photovoltaic	12.560	9.290
EL_Witr_ Sea	0	5.927
EL_Wiatr_Land	3.965	4.867
EC_Biogaz	100	156
EL and	81	315
EL_Pumped	0	740
EL_Water	17	110
EC_Industrial	377	314
EC_Gaz	283	1.591
EL_Gaz	1.332	4.625

Figure 2.4 Schedule for the deployment of generation units in 2022-2030
Source: Own study by ARE SA and MKiŚ

The table below summarises the cumulative activation rates of new generation units defined in the MESSAGE calculation process. According to the data provided, almost 48 GW will be deployed between 2022 and 2030, mainly RES (onshore and offshore wind and photovoltaic installations).

Table 2.20. Cumulative power activations 2022-2030 [MW_{net}]

Year	2022-2025	2026-2030
Cumulative activations of generation capacity	16 513	26 150

Source: Own study by ARE SA

1.13.4. Assumptions for the required reserve capacity in the system

The Resource Adequacy Standard adopted by the operator of the National Electricity System in Poland for annual planning was assumed to determine in the IRiESP the[14] degree of reserve capacity at 18 % of the average monthly peak demand for working days. In addition, at the time of peak load, the total available capacity of onshore wind farms was assumed to be 12.5 % of their available capacity, while offshore wind farms would be 15 %.

1.13.5. Cross-border exchanges

For forecasting purposes, the import balance (import-export) is assumed to be zero. This does not mean excluding cross-system exchanges, but is intended to demonstrate that the balance sheet presented is sufficient to cover the electricity demand from its own generation sources. Poland is not responsible for the availability of energy from other countries, therefore analyses cannot base security of energy supply on potential imports. The above assumption also addresses the objectives set out in the Guidelines for updating Poland's Energy Policy until 2040

[14] Instructions for the operation and operation of the transmission network

(PEP2040) – Strengthening energy security and independence with regard to building energy independence.

1.13.6. Transmission and distribution networks

The transition process requires adapting the grid to the functioning of a diversified energy mix, ensuring high flexibility for the operation of the NSE, bidirectional energy transmission, capacity to handle both large-scale and distributed generation sources and modern digital services for electricity end-users (including through smart metering). In addition, networks need to maintain an adequate level of security in the operational, physical and cyber domains, adapted to current threats. Meeting the new challenges necessitates the expansion, upgrade and modernisation of network infrastructure, which requires a multi-annual and multi-directional investment process of unprecedented scale.

The planned development of the network and the timelines for the commissioning of new network elements must take into account the main four factors that will determine the pace of transformation of transmission and distribution networks:

I. Dynamic development of new power, including zero-emission capacity in electricity,
II. Electrification of transport,
III. Electrification of heating, and
IV. Changing the direction of network flows – in the transmission network, the dominant flow from north to south, and in the distribution network, the flow of electricity from prosumer to the grid is increasing.

1.13.7. Assumptions on the development of electromobility and heat pumps

The development of electro-mobility in Poland was adopted in a rather optimistic option, according to which around 2030 is expected. 0.87 million electric passenger cars. Based on estimates from the Ministry of Climate and the Environment (MKiŚ), the number of electric buses for urban transport can be around. 3.400 in 2030. The WEM scenario also saw the emergence of hydrogen passenger cars, the number of which is not very significant and is the result of a cost analysis without support for such vehicles. The values used for the analyses are not targets in the area of electro-mobility, but the development of electric vehicles is assumed to be the "motor" for the decarbonisation of the transport sector. The inclusion of a very ambitious scenario aims, among other things, to reduce the risk of underestimating the needs related to electrification of the economy.

Table 2.21. Accepted number of electric vehicles [thousands]*

Year	2025	2030
Electric cars	~243	~870
Hydrogen passenger cars	~3.9	~14.6
Public transport buses	'~1.9	~3,4
Hydrogen buses for urban transport	~0,1	~0,5

** The values used for analysis are not targets in the area of electromobility.*

Source: Estimates of MKiŚ and ARE S.A.; estimates for passenger cars based on: Polish EV Outlook 2020, Polish Alternative Fuels Association (pSPA).

The energy demand projections take into account the development of different types of heat pumps. It was assumed that in 2025, residential buildings in Poland could operate around. 1 million installations (mostly air-to-water) and this value could double in 2030. The values used for analyses are not targets for the development of heat pumps.

2. Decarbonisation dimension

2.1. Emissions and removals of greenhouse gases and emissions of other substances

2.1.1. Trends in current greenhouse gas emissions and removals in the EU ETS and non-ETS and LULUCF sectors, as well as in various energy sectors

Trends in greenhouse gas emissions and removals have been identified on the basis of the National Inventory Report 2023; Inventory of greenhouse gas emissions and removals in Poland for the period 1988-2021, carried out as part of the reporting obligations under the United Nations Framework Convention on Climate Change' 15.

This report presents trends in greenhouse gas emissions and removals, in line with the UNFCCC reporting methodology and IPCC classification and using global warming potentials (so-called: GWP) from the *IPCC's Fifth Climate Change Assessment Report (so* -called: AR5) over a 100-year time horizon16.

National greenhouse gas emissions are on the whole downward trend, with a very mild rate since 2000, including years with modest increases in emissions. The shares of individual gases, net of LULUCF emissions and removals, are illustrated in the figure (Figure 2.5).

15KOBiSE – National Centre for Emissions Balancing and Management
16 https://www.ipcc.ch/report/ar5/wg1/ Appendix 8.A, p. 731

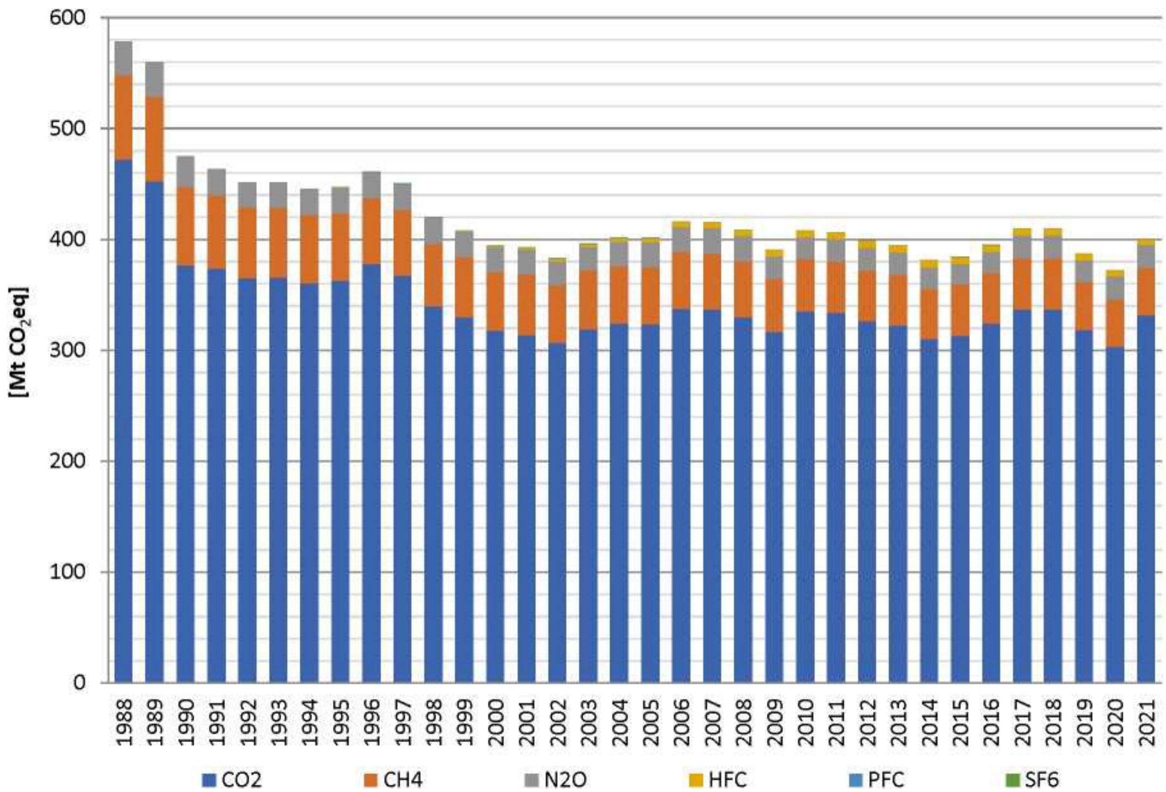


Figure 2.5.GHG emissions 1988-2021 (including indirect CO2 emissionsand excluding LULUCF emissions and removals) by gases

Source: KOBISE, IOŚ-PIB

Carbon plays a dominant role in domestic emissions, accounting for 82.9 % in 2021. The share of methane and nitrous oxide is significantly lower and is respectively: 10.7 % and 5.2 %. Fluorinated manufactured gases (so-called: F-gases) account for a small share of national greenhouse gas emissions (ca. 1.3 %), with no NF_3 emissions in Poland.

The greenhouse gas emissions for the period 1988-2021 by sector are shown in the table (Table 2.22).

Table 2.22. Greenhouse gas emissions, 1988-2021 by sector [Mt CO_2eq]

Sector	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
1. Energy	479.48	458.97	385.15	383.02	375.13	376.60	369.48	370.53	386.53	375.14	346.58	337.95	324.34	325.63	318.37	329.72	333.98
2. Industrial processes and product use	29.87	28.94	21.97	19.27	18.55	18.53	20.75	22.15	21.31	22.21	20.61	19.63	22.22	20.80	19.46	22.28	23.94
3. Agriculture	50.06	52.76	49.29	42.51	38.64	37.21	36.92	36.72	35.76	36.56	36.46	34.99	33.21	32.62	31.66	31.19	31.25
4. Land use, land use change and forestry	—17.59	—22.07	—28.49	—21.43	—0.21	—7.92	—7.47	—17.72	—35.13	—35.02	—40.73	—37.94	—34.57	—26.81	—35.49	—37.47	—48.69
5. Waste	18.26	18.48	18.14	18.38	18.54	18.59	17.67	17.33	16.79	16.10	15.74	14.96	14.23	13.48	12.81	12.35	11.63
Indirect CO2emissions	0.62	0.58	0.28	0.32	0.35	0.39	0.42	0.40	0.42	0.42	0.42	0.42	0.48	0.48	0.51	0.50	0.58
Total (in accordance with LULUCF)*	**560.70**	**537.66**	**446.34**	**442.07**	**451.00**	**443.40**	**437.78**	**429.41**	**425.67**	**415.41**	**379.08**	**370.01**	**359.91**	**366.20**	**347.32**	**358.57**	**352.69**
Total (without LULUCF)*	**578.29**	**559.73**	**474.84**	**463.50**	**451.21**	**451.32**	**445.25**	**447.13**	**460.80**	**450.43**	**419.81**	**407.95**	**394.47**	**393.00**	**382.81**	**396.04**	**401.38**

** including indirect CO2emissions*

Sector	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
1. Energy	334.32	346.97	343.73	338.73	327.24	344.42	340.82	334.73	331.30	317.59	321.73	332.45	345.20	344.37	323.53	307.99	336.17
2. Industrial processes and product use	23.73	26.01	28.40	27.12	21.73	22.88	25.63	24.63	23.62	25.10	24.35	24.55	25.07	25.56	25.08	24.52	24.56
3. Agriculture	31.66	32.15	32.84	32.94	32.26	31.66	31.99	31.83	32.46	32.36	31.71	32.07	33.36	33.69	32.60	34.05	34.04
4. Land use, land use change and forestry	—48.02	—42.11	—35.24	—34.83	—34.75	—32.96	—38.42	—38.80	—40.96	—33.48	—29.14	—36.40	—37.39	—36.75	—18.29	—18.96	—20.09
5. Waste	11.00	10.21	9.68	9.07	8.60	8.28	7.36	6.72	6.50	6.00	5.61	5.24	5.38	5.38	5.18	4.75	4.67
Indirect CO2emissions	0.56	0.66	0.66	0.73	0.66	0.57	0.59	0.54	0.46	0.50	0.55	0.54	0.54	0.49	0.48	0.58	0.50
Total (in accordance with LULUCF)*	353.26	373.90	380.08	373.75	355.74	374.84	367.97	359.64	353.38	348.08	354.80	358.46	372.15	372.75	368.58	352.94	379.84
Total (without LULUCF)*	401.27	416.00	415.31	408.59	390.49	407.80	406.39	398.44	394.35	381.57	383.94	394.86	409.54	409.49	386.87	371.89	399.94

** including indirect CO2emissions Source: KOBISE, IOŚ-PIB*

In 2021, Poland's total greenhouse gas emissions (including indirect CO2 emissionsand excluding greenhouse gas emissions and removals from LULUCF – land use, land use change and forestry), converted to CO2 equivalent, were 399.94 Mt CO_2eq and were 30.8 % lower than the base year 1988 emissions. Emissions including LULUCF in 2021 were 379 842.88 Mt CO 2eqandwere 32.25 % lower than the base year.

Emissions decreased in all source categories compared to 1988. The largest decrease in GHG emissions was recorded in terms of: 5. *Waste*, 3. *Agriculture* and 1. *Energy* (74.4 %, 32.0 % and 29.9 % respectively). In sector 5, this was due to the development of landfill technologies and legislation (as a result of which 58 % of the weight of waste was disposed of in 2021 compared to 1988) and the development of other waste treatment methods, including recycling and thermal treatment of waste. In agriculture, such a significant decrease in emissions was caused by structural and economic changes after 1989, including reductions in livestock and crop production (e.g. there was a decline in cattle numbers in the 19 882 021 years from more than 10 million to around. 6 million sheep from more than 4 million to approx. 270 thousand). In turn, emission reductions in category 1. *Energy* was mainly linked to the transformation of heavy industry and the decline in coal consumption and extraction, as well as energy efficiency measures. For sector 4. *Land use, land use change and forestry*, 2021 is another consecutive year in which the level of carbon accumulation in Polish forests did not reach the level recorded in the years preceding the collapse of this accumulation trend in 2019 (Table 2.22).

Detailed GHG emissions in sector 1A *Combustion of fuels* are presented in the table (Table 2.23). The predominant share of GHG emissions is sub-category 1A1. *Energy industries* and in particular the combustion of fuels under 1A1a. It should be stressed that between 1988 and 2021, GHG emissions associated with the production of commercial electricity and heat (in category 1A1a) fell significantly by almost 39 % (from 249 to 152 Mtco2eq). The reason for this was a reduction in fuel consumption by approx. 30 %, in particular a reduction in the use of solid fuels – hard coal (approx. 46 %) and brown (by almost 24 %). A significant share of GHG emissions, reaching more than 20 % in recent years, is category 1A3. *Transport*. GHG emissions from transport show an increasing trend. A slight decrease in these emissions was observed only in 2020, due to the COVID-19 pandemic and the reduction in road transport. In the next GHG emission category 1A2. *The manufacturing and construction* industries show a marked decrease in greenhouse gas emissions between 1988 and 1992 due to major changes in the Polish economy, particularly in heavy industry. This situation was the result of an initial political transition and a shift from a centrally-controlled to a free market economy. This was followed by an increase in GHG emissions between 1993 and 1996 as a result of economic growth. In the following period, emissions fell, with slight fluctuations, until 2009, when a noticeable lower value of greenhouse gas emissions was linked, among other things, to the global economic recession. In the following years, GHG emissions under Category 1A2 were stabilised as much as possible. Among stationary fuel combustion sources (categories 1A1, 1A2, 1A4), fuel combustion in 1A4b also accounts for several percentage points in GHG emissions. *Households*. GHG emissions have also been significantly reduced in this category compared to 1988 (by almost 50 %). This is mainly due to a reduction in fuel consumption by more than 17 %, most of which is hard coal (nearly 63 %), with natural gas consumption increasing by more than 86 % and more than 5 times the consumption of solid biomass.

Table 2.23. Greenhouse gas emissions in sector 1A. Combustion of fuels [Mt CO_2eq]

Sector	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
1A Combustion of fuels	**447,31**	**427,37**	**355,99**	**358,50**	**350,53**	**353,13**	**346,53**	**346,60**	**363,05**	**350,74**	**323,66**	**314,49**	**300,63**	**299,60**	**293,43**	**303,74**	**308,61**
1A1 Energy industries	**257,93**	**253,88**	**235,23**	**229,35**	**221,04**	**207,87**	**206,14**	**191,21**	**198,51**	**191,84**	**184,70**	**178,92**	**176,59**	**177,99**	**171,89**	**180,49**	**179,84**
1A1a Electricity and heat production	248,97	245,55	228,19	224,03	215,38	200,66	195,12	178,45	184,90	179,52	173,04	168,78	166,91	169,07	164,42	172,72	171,60
1A1ai Electricity generation	—	—	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	— —	9,97
1A1aii CHP	205,39	202,88	186,89	181,57	176,46	174,90	173,09	154,73	157,95	155,98	152,42	150,37	150,80	151,30	148,46	157,10	147,94
1A1aiii Heat plants	43,58	42,68	41,30	42,46	38,92	25,76	22,04	23,71	26,95	23,55	20,62	18,41	16,10	17,76	15,96	15,62	13,69
1A1b Rafineries	2,92	2,84	2,18	1,40	1,91	1,65	1,68	3,73	4,03	3,49	3,48	3,22	3,54	3,62	3,59	3,60	3,80
1A1c Manufacture of solid fuels and other energy industries.	6,04	5,49	4,85	3,92	3,75	5,55	9,34	9,04	9,58	8,83	8,18	6,92	6,14	5,30	3,88	4,16	4,44
1A2 Manufacturing and construction	**55,22**	**52,17**	**42,83**	**39,66**	**36,72**	**47,73**	**48,76**	**63,32**	**67,87**	**64,05**	**53,79**	**45,92**	**45,96**	**40,62**	**38,47**	**37,59**	**38,28**
1A3 Transport	**24,55**	**24,35**	**20,74**	**21,80**	**22,23**	**21,79**	**22,95**	**23,80**	**26,98**	**28,57**	**30,13**	**32,89**	**29,00**	**28,79**	**27,78**	**29,86**	**33,77**
1A4 Other sectors	**109,61**	**96,98**	**57,19**	**67,69**	**70,54**	**75,73**	**68,68**	**68,26**	**69,69**	**66,28**	**55,03**	**56,77**	**49,08**	**52,20**	**55,29**	**55,80**	**56,72**
1A4a Trade/Services/Institutions	30,28	24,95	9,78	9,64	10,12	9,34	7,12	7,09	6,50	6,76	5,38	5,73	5,63	6,09	8,06	8,46	8,21
1A4b Households	69,65	62,65	38,15	46,95	48,21	51,97	45,95	46,06	47,41	43,16	34,92	35,86	29,27	32,06	34,05	34,03	34,83
1A4c Agriculture/forestry/fisheries	9,68	9,38	9,25	11,10	12,21	14,42	15,60	15,12	15,79	16,35	14,73	15,19	14,19	14,05	13,18	13,31	13,68

Sector	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
1A Combustion of fuels	**308,13**	**320,35**	**318,02**	**313,00**	**303,26**	**320,24**	**316,32**	**309,96**	**305,45**	**291,78**	**294,80**	**305,68**	**318,52**	**318,01**	**299,84**	**284,56**	**313,10**
1A1 Energy industries	**178,36**	**184,11**	**180,32**	**174,79**	**167,26**	**173,53**	**174,85**	**169,75**	**170,34**	**160,94**	**163,70**	**163,53**	**165,25**	**163,30**	**150,55**	**139,60**	**160,22**
1A1a Electricity and heat production	171,01	176,80	171,27	166,07	159,90	165,73	166,66	161,94	163,22	154,07	155,62	155,78	157,51	155,81	142,58	131,81	152,23
1A1ai Electricity generation	9,91	10,01	9,90	11,25	4,40	4,77	7,17	11,35	11,68	8,45	2,38	2,00	2,53	2,36	2,33	3,49	3,73
1A1aii CHP	148,03	153,83	149,41	143,03	143,07	146,79	147,99	138,23	139,73	134,88	143,10	142,99	144,44	143,12	130,34	118,39	137,40
1A1aiii Heat plants	13,06	12,96	11,96	11,79	12,44	14,17	11,49	12,37	11,82	10,75	10,14	10,79	10,54	10,33	9,91	9,94	11,10
1A1b Rafineries	3,57	3,58	4,32	4,31	4,20	4,79	5,03	5,05	4,28	4,00	4,44	4,51	4,66	4,36	4,61	4,59	4,41
1A1c Manufacture of solid fuels and other energy industries.	3,78	3,72	4,73	4,40	3,16	3,01	3,16	2,76	2,83	2,87	3,65	3,24	3,08	3,14	3,36	3,20	3,58
1A2 Manufacturing and construction	**33,87**	**33,80**	**36,09**	**31,96**	**28,03**	**29,62**	**30,56**	**29,47**	**29,29**	**29,42**	**27,95**	**28,65**	**31,03**	**31,55**	**31,19**	**28,91**	**30,11**
1A3 Transport	**36,25**	**40,12**	**44,26**	**46,25**	**46,85**	**49,37**	**49,97**	**48,02**	**45,17**	**45,54**	**48,04**	**54,74**	**63,22**	**65,04**	**66,04**	**63,08**	**68,35**
1A4 Other sectors	**59,64**	**62,32**	**57,35**	**60,01**	**61,12**	**67,72**	**60,95**	**62,72**	**60,65**	**55,87**	**55,11**	**58,75**	**59,02**	**58,11**	**52,07**	**52,97**	**54,42**
1A4a Trade/Services/Institutions	7,80	8,69	8,37	8,94	9,35	10,61	9,75	9,43	8,73	7,78	7,94	8,61	7,48	7,02	6,43	6,03	7,74
1A4b Households	37,62	41,43	37,89	39,51	40,35	45,25	39,83	41,73	40,64	37,28	36,82	39,16	39,40	38,85	33,83	34,98	35,25
1A4c Agriculture/forestry/fisheries	14,22	12,20	11,09	11,56	11,42	11,86	11,36	11,56	11,28	10,81	10,35	10,98	12,14	12,24	11,81	11,96	11,44

Source: KOBISE, IOŚ-PIB

Greenhouse gas emissions from sources covered by the EU Emissions Trading System (EU ETS) come from energy and heating, as well as part of industrial plants. Emissions reported by installations covered by the EU ETS mainly concern CO_2 but also N_2O, mainly from nitric acid production.

The share of emissions from installations covered by the EU ETS in the total national emissions in Poland in the period 2005-2020 was approx. 50 %, decreasing from 52.5 % in 2013 to 45.6 % in 2020. In 2021, emissions in the EU ETS amounted to 192.0 Mt CO_2eq, representing 48 % of national emissions.

Poland, like other EU countries, does not have a national reduction target for 2021-2030 on emissions from sources covered by the EU ETS, as the cap on these emissions is imposed at the level of the EU system as a whole and emissions within this limit are accounted for directly by operators.

In accordance with Decision 2009/406/EC of the European Parliament and of the Council on the effort of Member States to reduce their greenhouse gas emissions to meet the Community's greenhouse gas emission reduction commitments up to 2020 (the so-called ESD Decision), Poland was required to limit the increase in greenhouse gas emissions to 14 % below 2005 levels. Taking into account the whole period 2013-2020, Poland met its reduction target in the non-ETS sectors with a small surplus of 0.545 Mt_{CO2}eq. (Table 2.24).

Table 2.24. Comparison of emissions in the non-ETS sectors with annual emission credits (AEAs) allocated in 2013(emissions expressed in kt CO_2eq converted according to GWP with AR4)

Parameter	2013	2014	2015	2016
Non-ETS emissions	186 095	181 543	186 772	198 665
AEAs	193 643	194 886	196 128	197 371
Difference (AEA – non-ETS)	7 548	13 343	9 356	—1 294
Accumulated AEA surplus	□ □	20 890	30 246	28 952
Parameter	2017	2018	2019	2020
Non-ETS emissions	211 507	213 033	209 085	205 093
AEAs	199 974	201 710	203 446	205 181
Difference (AEA – non-ETS)	—11 532	—11 323	—5 639	88
Accumulated AEA surplus	17 420	6 097	457	545

Source: KOBISE, IOŚ-PIB

As part of EU regulation, Poland was required to achieve a 17.7 % reduction by 2030 compared to 2 005 in the non-ETS sectors. A comparison of the estimated emissions for the non-ETS sectors in 2021 with the allowance allocated to Poland for that year shows that the emissions are below the limit by more than 7 Mt CO_2eq (Table 2.25).

Table 2.25. Calculation of emissions in the non-ETS sector in 2021 and comparison with annual emission allocations (recalculated according to GWP with AR5)

Breakdown		Emissions [kt CO_2eq]
A	National greenhouse gas emissions (with indirect CO_2 emissions, no LULUCF)	399 938
B	Verified GHG emissions in the EU ETS	192 033
C	Emissions from national aviation (1.A.3.a)	54
D	Non-ETS emissions (= A-B-C)	207 851
E	Annual emission allocation (AEA) for Poland in non-ETS	215 005
F	Difference between AEAs and non-ETS emissions (= E-D)	7 154

Source: KOBISE, IOŚ-PIB

The LULUCF sector takes into account greenhouse gas emissions and removals from land use, land use change and forestry. Breakdown of greenhouse gas emission and removals balances for years

1988-2021, for the aggregated LULUCF source categories (forest land, cropland, grassland, wetlands, settlements, harvested wood products), see Figure 2.6.

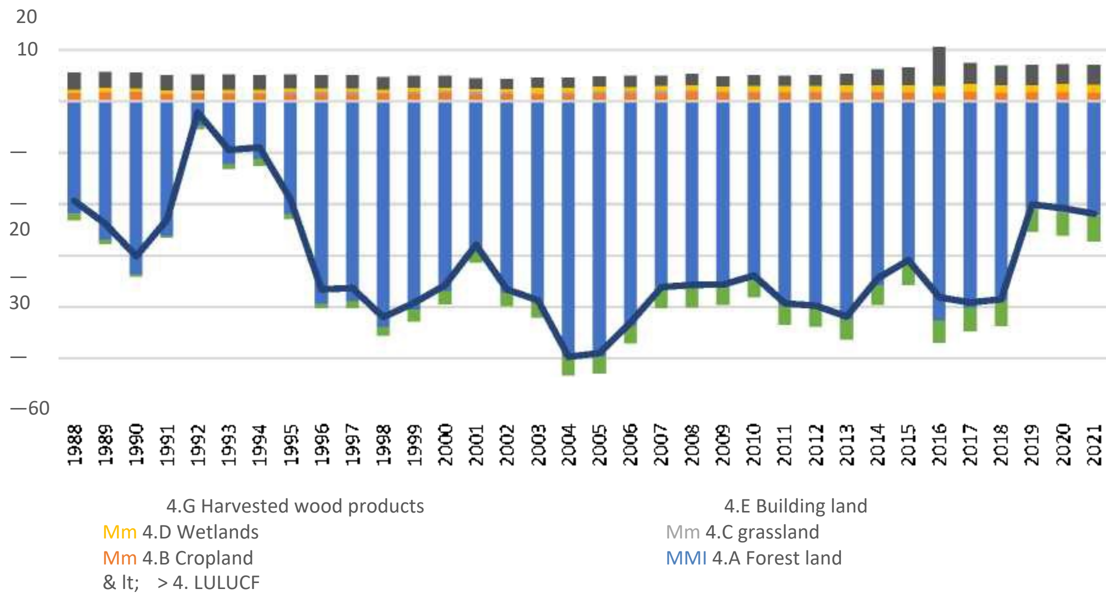


Figure 2.6 Aggregated balance of LULUCF GHG emissions 1988-2021 by source category
Source: KOBISE, IOŚ-PIB

It should be noted that the aggregated value of the balance of greenhouse gas emissions and removals for all LULUCF categories, over the period analysed (1988-2021), is negative, meaning that the combined 'capture' of CO_2 exceeded the total sectoral GHG emissions, expressed in CO2 equivalent. The highest values for the balance of greenhouse gas emissions and removals from the LULUCF sector were recorded between 2004 and 2005. In the following years, removals decreased, in particular in recent years (2019-2021). 2021 is another year in a row, assuming that the accumulation of carbon (CO2 absorption)in Polish forests does not reach the level observed over historical years.

The main reasons for the significant decline in removals (in the form of a collapse in the growth of wood stocks) in forests since 2 019 are, inter alia, the long-term effects of natural disasters (droughts since 2014, winds (and associated winds) in 2017, which are the direct cause of changes in the estimated standing timber stock, the ageing of stands affecting the reported level of current annual growth, and □ importantly – σιγνιφιχαντ changes in the dynamics and characteristics of dead wood.

Net removals (i.e. negative balance of emissions and removals) in the LULUCF sector increased by around 6.0 % in 2021 compared to 2020. Among the main sectoral sources of greenhouse gas streams are greenhouse gas streams on forest land, the carbon substitution effect of harvested wood products and greenhouse gas (GHG) streams in built-up land, with an absolute percentage of the estimated level of greenhouse gas streams in the LULUCF sector, respectively: 64.2 % (- 22 085 kt $CO\ 2_{eq}$); 14.2 % (- 4 877 kt $CO\ 2_{eq}$); and 11.2 % (3 851 kt $CO\ 2_{eq}$). For forest land, wood products and built-up land, the estimated GHG emission and removal balances for 2021 increased by 3.1 % respectively; 9.1 % and 4.4 %.

Detailed data on greenhouse gas emission and removal balances for the period 1988-2021, for aggregated source categories, are presented in the table (Table 2.26).

Table 2.26. National inventory of greenhouse gas emissions and removals in the LULUCF sector, 1988-2021 by source category [kt CO2eq]

IPCC Category	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
4.A Forest land	—21 807	—26 881	—33 650	—26 232	—4 778	—12 204	—11 330	—21 996	—39 363	—38 956	—43 915	—40 588	—36 871	—28 984	—37 348	—39 114	—49 697
4.B. Cropland	1 673	1 805	1 751	1 361	1 382	1 403	1 423	1 445	1 463	1 473	1 488	1 504	1 618	1 401	1 430	1 439	1 467
4.C Gray land	—182	—74	113	198	242	232	307	490	492	548	211	437	395	501	360	149	318
4.D Wetlands	646	820	653	596	585	622	578	665	635	583	603	697	677	518	621	1 058	920
4.E Building land	3 287	3 117	3 097	2 969	3 032	2 950	2 802	2 622	2 524	2 551	2 484	2 294	2 245	2 107	2 000	1 979	1 935
4.F Other land	FOR	FOR	FOR	FOR	FOR	FOR	FOR	FOR	FOR	FOR	FOR	FOR	FOR	FOR	FOR	FOR	FOR
4.G Harvested wood products	—1206	—856	—459	—321	—669	—923	—1 254	—942	—878	—1 217	— 1603	—2 283	—2 633	—2 349	—2 551	—2 982	—3 631
4.A Forest land	—21 807	—26 881	—33 650	—26 232	—4 778	—12 204	—11 330	—21 996	—39 363	—38 956	—43 915	—40 588	—36 871	—28 984	—37 348	—39 114	—49 697

IPCC Category	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
4.A Forest land	—49 594	—43 608	—36 102	—36 505	—36 126	—34 247	—39 667	—40 093	—42 436	—35 772	—31 678	—42 589	—40 183	—38 802	—20 740	—21 428	—22 085
4.B. Cropland	1 570	1 602	1 597	1 775	1 657	1 668	1 617	1 628	1 664	1 676	1 641	1 673	1 760	1 721	1 747	1 750	1 711
4.C Gray land	344	408	396	385	303	294	280	254	237	319	174	—65	165	—122	—98	—258	—281
4.D Wetlands	1 007	901	1 104	1 046	918	1 128	1 167	1 159	1 299	1 224	1 337	1 390	1 436	1 425	1 422	1 760	1 586
4.E Building land	1 941	2 052	1 867	2 113	1 962	2 026	1 953	2 007	2 115	2 950	3 390	7 514	4 002	3 803	3 939	3 688	3 851
4.F Other land	FOR	FOR	FOR	FOR	FOR	FOR	FOR	FOR	FOR	FOR	FOR	FOR	FOR	FOR	FOR	FOR	FOR
4.G Harvested wood products	—3 286	—3 463	—4 097	—3 646	—3 463	—3 831	—3 768	—3 755	—3 840	—3 879	—4 008	—4 319	—4 569	—4 773	—4 565	—4 469	—4 877
4.A Forest land	—49 594	—43 608	—36 102	—36 505	—36 126	—34 247	—39 667	—40 093	—42 436	—35 772	—31 678	—42 589	—40 183	—38 802	—20 740	—21 428	—22 085

Source: KOBISE, IOŚ-PIB

2.1.2. Projections of sector developments with existing national and EU policies and measures, as well as projections of emissions of air pollutants

Projections for greenhouse gas emissions, as well as air pollutants (in accordance with the NEC Directive) by 2030, are based on sector-specific activity projections, taking into account the classification of sources of the IPCC and NFR respectively, contained in the following data sources (Table 2.27):

Table 2.27. Data sources of activity change forecasts used to project emissions of greenhouse gases and air pollutants (in accordance with the NEC Directive)

Sector	Main source of data	Additional data sources/comments
1. Energy	forecasts of activity changes in selected sectors produced by ARE SA for the preparation of the NECPs	
2. Industrial processes and product use		Information obtained from professional organisations, studies and articles and others. Forecasts by the Central Statistical Office
3. Agriculture	forecasts of activity changes for specific economic sectors, prepared by the KOBISE IOŚ-PIB, for the purpose of preparing projections for greenhouse gas emissions and air pollutants, as set out in the report 'Projections of activity changes in selected sectors of the economy by 2040, December 2021.	Forecast of agricultural activity in Poland by 2050 for the KOBiSE. Institute of Agricultural and Food Economics – National Research Institute. Editor: Dr Konrad Prandecki
4. Land use, land use change and forestry		
5. Waste		National Waste Management Plan 2028 (KPGO 2028) MKiŚ 2023; Population forecast 2023-2060, Central Statistical Office 2023

The projections take into account the implementation of current policies and regulations on: improving energy efficiency, increasing security of supply of fuels and energy, diversifying the fuel mix in energy, developing the use of renewable energy sources, developing competitive fuel and energy markets, reducing the environmental impact of energy.

Below (Table 2.28; Figure 2.7) shows the synthesis of projected greenhouse gas emissions in Poland for 2025-2030, compared to 2005-2020 emissions, by IPCC sector.

Table 2.28. Projections of greenhouse gas emissions by sector

	GHG emissions [kt CO_2eq]					
Sector	2005	2010	2015	2020	2025	2030
1. Energy	334 317,08	344 423,02	321 729,78	307 991,99	285 486,79	231 835,39
2. Industrial processes and product use	23 732,01	22 878,65	24 351,84	24 516,29	24 223,83	24 038,87
3. Agriculture	31 659,42	31 659,66	31 705,48	34 051,67	33 334,78	34 650,27
4. Land use, land use change and forestry	— 48 018,52	— 32 962,30	— 29 143,46	—18 957,85	—15 261,43	— 6 891,63
5. Waste	11 000,17	8 275,63	5 608,23	4 752,48	4 652,44	4 268,70

Sector	GHG emissions [kt CO_2eq] 2005	2010	2015	2020	2025	2030
Indirect CO2emissions	564,93	567,87	546,19	582,52	545,78	539,97
Total (in accordance with LULUCF)*	**353 255,10**	**374 842,53**	**354 798,06**	**352 937,10**	**332 982,20**	**288 441,56**
Total (without LULUCF)*	**401 273,62**	**407 804,83**	**383 941,52**	**371 894,95**	**348 243,62**	**295 333,19**

** z uwzględnieniem emisji pośredniej CO_2*
Źródło: Opracowanie własne KOBIZE, IOŚ-PIB

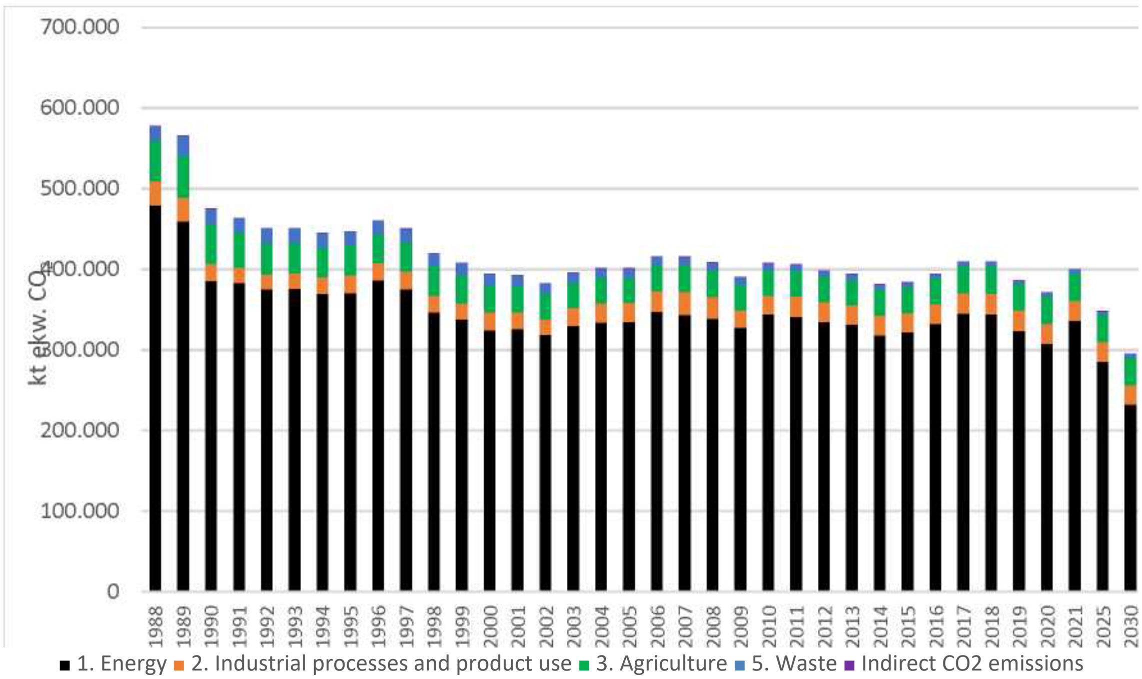


Figure 2.7 Projections of greenhouse gas emissions (including indirect CO2emissions and excluding LULUCF emissions and removals) by sector

Source: Own study by KOBISE, IOŚ-PIB

National GHG emissions (without LULUCF) are projected to reach 295.3 million tonnes ofco2eq in 2030 and decrease by close to 38 % in 2030 (without LULUCF) compared to 1990. The largest reductions in GHG emissions were observed in the waste sector (by 76 % in 2030) and the energy sector (by 40 % in 2030). The main factor reducing GHG emissions in the energy sector is the decrease in fuel consumption in both stationary and mobile sources. In the agricultural sector, GHG emissions fell by 30 % between 1990 and 2030.

The table below (Table 2.29) provides detailed projections for greenhouse gas emissions from the combustion of fuels in stationary sources (sectors 1A1. *Energy industries,* 1A2. *Manufacturing and construction* and 1A4. *Other sectors*) and mobile (sector 1A3. *Transport*).

Table 2.29. Projections of greenhouse gas emissions in sector 1A. Combustion of fuels

Sector	GHG emissions [kt CO_2eq] 2005	2010	2015	2020	2025	2030
1A Combustion of fuels	**308 125,76**	**320 243,46**	**294 804,48**	**284 563,58**	**264 454,40**	**213 448,40**
1A1 Energy industries	**178 362,41**	**173 529,26**	**163 700,19**	**139 603,24**	**128 283,67**	**96 720,12**
1A1a Electricity and heat production	171 009,45	165 731,48	155 616,22	131 814,93	120 933,83	89 760,18

Sector	GHG emissions [kt CO_2eq] 2005	2010	2015	2020	2025	2030
1A1ai Electricity generation	IE	IE	IE	IE	IE	IE
1A1aii CHP	157 945,05	151 563,31	145 480,52	121 875,37	113 139,87	84 663,53
1A1aiii Heat plants	13 064,40	14 168,17	10 135,69	9 939,55	7 793,95	13 064,40
1A1b Rafineries	3 569,54	4 789,81	4 435,10	4 592,73	4 405,87	4 013,54
1A1c Manufacture of solid fuels and other energy industries	3 783,42	3 007,97	3 648,87	3 195,58	2 943,98	2 946,40
1A2 Manufacturing and construction	**33 872,34**	**29 615,73**	**27 954,16**	**28 906,83**	**27 742,61**	**24 071,45**
1A3 Transport	**36 248,83**	**49 373,53**	**48 040,11**	**63 081,57**	**66 053,73**	**58 355,87**
1A4 Other sectors	**59 642,19**	**67 724,94**	**55 110,02**	**52 971,94**	**42 374,39**	**34 300,96**
1A4a Trade/Services/Institutions	7 796,21	10 614,49	7 944,34	6 031,18	5 885,17	5 436,69
1A4b Households	37 621,06	45 248,17	36 818,66	34 982,89	26 234,68	19 695,62
1A4c Agriculture/forestry/fisheries	14 224,92	11 862,28	10 347,02	11 957,87	10 254,54	9 168,66

IE – Included elsewhere (contained in 1A1aii) Source: Own study by KOBISE, IOŚ-PIB

In the years covered by the projections, greenhouse gas emissions from fuel combustion are projected to decrease by 25 % between 2020 and 2030. The largest impact on this reduction is the reduction of GHG emissions in category 1A1a Electricity and heat production. The projected decrease in this category, compared to 2020, will be 32 % by 2030. This is due to the reduction in the sector's fossil fuel consumption by 2030, around a reduction in hard coal consumption is expected. 33 %, lignite by more than 54 % and natural gas by 74 %. A significant decrease in GHG emissions is also projected in category 1A4b Households, by almost 43 % between 2020 and 2030. For this sector, such a significant reduction is also linked to a decrease in fuel consumption, mainly coal, of 63 % by 2030.

In the following tables (Table 2.30; Table 2.31; Table 2.32) presents the results of projected greenhouse gas emissions in Poland for the period 2025-2 030 in individual sectors and sub-sectors, compared to emissions in 2005-2020, by gas.

Table 2.30. Projected CO2emissions

Sector	Emissions[kt] 2005	2010	2015	2020	2025	2030
1. Energy	**305 292,48**	**316 852,23**	**293 495,67**	**281 978,11**	**263 321,33**	**213 353,10**
A. Combustion of fuels	301 905,38	313 363,43	288 748,81	277 753,06	258 937,54	208 871,23
1. Energy industries	177 651,35	172 795,91	162 990,16	138 993,06	127 700,48	96 224,92
2. Manufacturing and construction	33 669,65	29 402,61	27 703,78	28 596,72	27 429,02	23 773,35
3. Transportation	35 631,64	48 767,04	47 449,35	62 374,76	65 348,17	57 702,68
4. Other sectors	54 952,74	62 397,88	50 605,53	47 788,52	38 459,87	31 170,28
B. Fugitive emissions from fuels	3 387,10	3 488,80	4 746,86	4 225,05	4 383,80	4 481,87
1. Fuels	2 225,64	2 424,68	2 712,17	2 340,89	2 192,35	2 203,28
2. Crude petroleum and natural gas	1 161,46	1 064,11	2 034,69	1 884,16	2 191,45	2 278,59

Sector	Emissions[kt]					
	2005	2010	2015	2020	2025	2030
2. Industrial processes	**15 665,47**	**16 056,87**	**17 907,27**	**18 746,13**	**20 212,64**	**20 409,87**
A. Mineral products	8 355,79	9 849,54	10 088,59	11 738,98	12 675,14	12 882,64
B. Chemical industry	4 886,78	4 335,42	5 141,13	4 866,96	5 030,36	5 081,79
C. Manufacture of basic metals	2 236,00	1 639,16	2 419,96	1 824,37	2 172,04	2 118,33
D. Non-energy products from fuel and solvent consumption	186,90	232,76	257,59	315,82	335,10	327,12
3. Agriculture	**1 591,35**	**1 121,19**	**1 108,98**	**1 458,75**	**1 320,98**	**1 330,75**
G. Liming	944,90	391,55	373,84	836,30	628,37	675,15
H. Urea application	394,18	467,17	471,24	431,33	473,00	426,14
I. Other fertilisers	252,27	262,46	263,89	191,13	219,61	229,46
4. Land use, land use change and forestry (LULUCF)	**— 48 987,35**	**— 33 870,34**	**— 30 886,90**	**—20 783,76**	**— 16 938,87**	**—8 487,85**
5. Waste	**215,76**	**194,29**	**203,50**	**254,10**	**274,56**	**274,56**
C. Incineration and open burning of waste	215,76	194,29	203,50	254,10	274,56	274,56
Emissionsfrom biomass	**19 802,69**	**30 378,55**	**34 917,41**	**48 969,63**	**48 439,50**	**51 811,61**
Total (in accordance with LULUCF)	**274 342,63**	**300 922,11**	**282 374,71**	**282 235,85**	**268 736,42**	**227 420,41**
Total (without LULUCF)	**323 329,98**	**334 792,45**	**313 261,61**	**303 019,61**	**285 675,29**	**235 908,26**

Source: Own study by KOBISE, IOŚ-PIB

CO_2 will remain the main greenhouse gas emitted in Poland, accounting for 80 % of national emissions in 2030. A significant decrease in CO2 emissions is projected: from close to 377 million tonnesofCO 2eq in 1990 to 236 million tonnesofCO 2eq in 2030 (37 %). The most significant decrease in emissions was recorded in the energy sector, driven by a decrease in fuel consumption in stationary and mobile sources.

The LULUCF sector is characterised by a systematic decrease inprojected net CO2 removals from more than - 20 million tonnesof CO2eqpresent to approx. —8.5 million tonnes of CO_2eq in 2030. The significant decrease in removals described is due to the collapse in wood stock growth dynamics observed in forests since 2019. The decline in standing timber growth should primarily be combined with the two factors influencing the reported level of annual increment on an aggregated scale. These indicators are linked to the ageing of stands as well as to the significant increase in the growth of deadwood. Importantly, the increase in dead wood in forests is expected both as a result of the implementation of a range of local and global environmental policies and as a result of increased tree mortality as a result of climate change.

Table 2.31. Projected N_2O emissions

Sector	N_2O emissions [kt]					
	2005	2010	2015	2020	2025	2030
1. Energy	**8,91**	**8,20**	**7,88**	**9,25**	**8,53**	**7,68**
A. Combustion of fuels	8,91	8,20	7,88	9,25	8,53	7,68
1. Energy industries	2,61	2,69	2,60	2,19	2,07	1,72
2. Manufacturing and construction	0,44	0,46	0,54	0,66	0,67	0,63
3. Transportation	1,72	1,74	1,71	2,29	2,30	2,15
4. Other sectors	4,14	3,31	3,02	4,11	3,50	3,17
B. Fugitive emissions from fuels	0,00	0,00	0,00	0,00	0,00	0,00

Sector	N2O emissions [kt] 2005	2010	2015	2020	2025	2030
2. Crude petroleum and natural gas	0,00	0,00	0,00	0,00	0,00	0,00
2. Industrial processes	**15,29**	**4,15**	**2,62**	**1,84**	**2,17**	**2,18**
B. Chemical industry	14,87	3,71	2,18	1,39	1,71	1,71
G. Manufacture and use of other products	0,43	0,44	0,44	0,45	0,46	0,47
3. Agriculture	**57,01**	**58,94**	**58,49**	**63,10**	**62,19**	**62,55**
B. Animal manure	8,90	8,75	8,66	9,93	9,86	10,33
D. Agricultural soils	48,08	50,16	49,79	53,13	52,29	52,18
F. Incineration of vegetable waste	0,03	0,03	0,04	0,04	0,04	0,04
4. Land use, land use change and forestry (LULUCF)	**3,52**	**3,37**	**6,44**	**6,67**	**6,23**	**5,91**
5. Waste	**2,58**	**2,67**	**2,95**	**3,06**	**3,36**	**3,39**
B. Biological disposal of solid waste	0,13	0,12	0,39	0,42	0,82	0,87
C. Incineration and open burning of waste	0,02	0,01	0,02	0,02	0,02	0,02
D. Wastewater management	2,43	2,54	2,54	2,61	2,53	2,50
Total (in accordance with LULUCF)	**87,31**	**77,34**	**78,37**	**83,91**	**82,48**	**81,72**
Total (without LULUCF)	**83,80**	**73,96**	**71,93**	**77,24**	**76,26**	**75,81**

Source: Own study by KOBISE, IOŚ-PIB

For N_2O, projected emissions (without LULUCF) will decrease from 105 kt in 1990 to 76 kt (28 %) in 2030. The largest reductions in N_2O emissions between 1990 and 2030 were recorded in the industrial process and product use sector (mainly the chemical industry). On the other hand, in the agriculture sector, N_2O emissions decreased by around. 25 %, with a 24 % reduction already achieved by 2020. Agriculture is the most important source of N_2O emissions in Poland and in particular agricultural soils. In contrast, the waste sector saw an increase in N_2O emissions between 1990 and 2030 (2.5 kt to 3.4 kt), due to the projected increase in municipal, industrial, medical and municipal waste incineration sludge and the increase in the amount of waste treated in composting plants.

The share of nitrous oxide in national emissions will increase from 7 % in 2030.

Table 2.32. Projected CH_4emissions

Sector	CH4 emissions [kt] 2005	2010	2015	2020	2025	2030
1. Energy	**952,26**	**907,05**	**933,81**	**841,52**	**710,86**	**587,36**
A. Combustion of fuels	137,84	168,11	141,74	155,71	116,29	90,77
1. Energy industries	0,65	0,70	0,73	1,06	1,24	1,36
2. Manufacturing and construction	3,07	3,27	3,87	4,84	4,87	4,65
3. Transportation	5,81	5,18	4,89	3,60	3,46	2,96
4. Other sectors	128,31	158,96	132,25	146,22	106,72	81,80
B. Fugitive emissions from fuels	814,42	738,94	792,07	685,82	594,57	496,59
1. Fuels	719,82	651,44	690,01	579,09	484,58	383,44
2. Crude petroleum and natural gas	94,60	87,50	102,06	106,73	109,99	113,15
2. Industrial processes	**1,89**	**2,50**	**2,62**	**2,32**	**2,93**	**2,97**

Sector	CH_4 emissions [kt] 2005	2010	2015	2020	2025	2030
B. Chemical industry	1,39	2,03	2,02	1,91	2,47	2,53
C. Manufacture of basic metals	0,50	0,46	0,60	0,40	0,46	0,44
3. Agriculture	**534,26**	**532,84**	**539,19**	**566,85**	**554,74**	**597,95**
A. Enteric fermentation	460,56	473,53	486,61	515,16	503,56	539,99
B. Animal manure	72,93	58,47	51,62	50,59	50,15	56,90
F. Incineration of vegetable waste	0,77	0,85	0,95	1,10	1,03	1,06
4. Land use, land use change and forestry (LULUCF)	**1,33**	**0,51**	**1,35**	**2,11**	**0,97**	**1,11**
5. Waste	**360,76**	**263,30**	**165,14**	**131,74**	**124,53**	**110,54**
A. Storage of solid waste	257,45	143,48	80,29	49,42	35,26	22,84
B. Biological disposal of solid waste	2,15	2,04	6,58	7,04	13,62	14,51
D. Wastewater management	101,16	117,78	78,27	75,28	75,66	73,19
Total (in accordance with LULUCF)	**1 850,51**	**1 706,20**	**1 642,11**	**1 544,54**	**1 394,03**	**1 299,93**
Total (without LULUCF)	**1 849,17**	**1 705,69**	**1 640,76**	**1 542,43**	**1 393,06**	**1 298,82**

Source: Own study by KOBISE, IOŚ-PIB

The share of methane in domestic emissions will increase to 12 % in 2030.

Projected methane emissions are gradually decreasing from around. 2.5 million tonnes in 1990 to 1.3 million tonnes of CH_4 in 2030 (a decrease of 48 %; without LULUCF). The largest expected reduction in CH_4 emissions since 1990 has occurred in the Waste sector by 82 % in 2030, due to the projected reduction in landfill waste (including the reduction of biodegradable waste) and the increase in the management of sewage sludge from municipal treatment plants.

A decrease in CH_4 emissions since 1990 is also projected in the energy sector, mainly in volatile emissions: by 44 % in 2030, mainly due to a further decline in coal mining. For agriculture, methane emissions are projected to be reduced by 31 % from 1990 to 2030.

The projected evolution of emissions in the EU ETS and non-ETS sectors is presented in the table (Table 2.33). Greenhouse gas emissions from the part of sources that are covered by the EU ETS include energy and heating and part of industrial plants. A significant decrease in GHG emissions reported by installations covered by the EU ETS is projected: from 192 million tonnes ofco2eq in 2021 to 130 million tonnesofCO 2eq in 2030 (32 % decrease). At the same time, the share of GHG emissions from installations covered by the EU ETS in national emissions is projected to decrease from the current 48 % to 44 % in 2030.

GHG emissions from sectors not covered by the EU ETS, the so-called: The ESR is also declining since 2021, but at a much slower rate, i.e. by 20 % by 2030. The projected emissions in the ESR in 2030 will be 165 million tonnes of CO 2eqandwill reach a reduction of -14.1 % compared to emissions in the 2005 base year, meaning that the target for Poland of -17.7 % (158.4 million tonnes of CO_2eq) will not be met.

Table 2.33. GHG projections by ETS and non-ETS

Parameter	2005 (Basic)	2021	2025	2030
ETS emissions [kt CO_2eq]	— —	192 032,91	162 841,13	129 757,63
ESR emissions [kt CO_2eq]	192 472,25	207 851,06	185 142,42	165 256,53
Change in ESR emissions by 2005				—14.1 %

Source: Own study by KOBISE, IOŚ-PIB

The projections of greenhouse gas streams accounted for in the LULUCF sector assume a total deficit of credits required to comply with the so-called ‘zero debit’ principle (as defined in Article 4(1) of Regulation (EU) No

841/2018) of approximately 27 004 kt CO 2_{eq}. However, attention should be paid to the possibility of using flexibility, which would reduce the deficit to around 15 754 kt CO_{2eq}. By contrast, in the accounting period 2026-2030, each EU Member State is to ensure that the sum of its greenhouse gas emissions and removals reported in 2032 for the year 2030 and earlier compared to the average of its greenhouse gas inventory data for the years 2016, 2017 and 2018 does not exceed the target set out for that Member State in column C of Annex IIa. For the accounting period 2026-2030, the cumulative projected deficit of credits required to meet the LULUCF sectoral objective (as defined in Article 4(3) of Regulation (EU) No 841/2018) will be around. 26 401.2 kt CO 2_{eq}on an annual basis (totalling 132 006 kt CO 2 eq). The size of any flexibility available in this regard is 11 250 kt CO_{2eq}. In view of the possible use of this flexibility, the expected deficit of credit required to comply with the so-called zero debit rule (as defined in Article 4(1) of Regulation (EU) No 841/2018) will be significantly reduced to around 120 756 kt CO $2_{eq}$for the period 2026-2030.

Below (Table 2.34, Table 2.35; Table 2.36; Table 2.37; Table 2.38) presents the synthetic results of projected emissions of air pollutants in Poland for the period 2025-2030, compared with emissions between 2005 and 2020, by category NFR17. Emissions data for 2005-2020 were adopted on the basis of the national air pollutant emission inventory18 carried out in 2 023 in accordance with the applicable ***Guidelines for reporting emissions and projections under the LRTAP Convention*** (ECE/EB.AIR/125), adopted by Decision of the Executive Body of LRTAP Convention No 2013/3 (doc. ECE/EB.AIR.122/Add.1).

According to the NEC Directive, five pollutants are subject to emission limits: SO_2, NOx, NMVOC, NH_3 and PM2.5.

Table 2.34. Projections for sulphur dioxide emissions, by sector (NFR category)

Sector	SO_2 emissions [Gg]					
	2005	2010	2015	2020	2025	2030
1. Energy	**1 119,79**	**815,52**	**628,85**	**375,51**	**246,90**	**156,34**
A. Combustion of fuels	1 106,90	807,41	620,42	368,71	240,45	150,30
1. Energy industries	813,18	485,13	364,66	158,15	108,58	74,64
2. Manufacturing and construction	110,51	87,10	69,94	45,49	29,45	18,31
3. Transportation	1,24	0,56	0,55	0,63	0,83	0,79
4. Other sectors (small combustion sources including households)	181,97	234,63	185,26	164,43	101,59	56,56
B. Fugitive emissions from fuels	12,89	8,11	8,44	6,80	6,44	6,04
1. Fuels	0,01	0,01	0,01	0,01	0,01	0,01
2. Crude petroleum and natural gas	12,89	8,10	8,43	6,80	6,44	6,03
2. Industrial processes and product use	**9,13**	**9,15**	**9,61**	**9,79**	**9,74**	**9,91**
B. Chemical industry	4,40	4,25	4,46	4,37	4,55	4,74

17NFR — Nomenclature for Reporting, format for the categorisation of emission sources used under the CLRTAP Convention

18National emission inventory of SO2, NOx, CO, NH3, NMVOC, dust, heavy metals and POPs for the period 1990-2021; KOBISE-IOŚ PIB. A synthetic report; Warsaw, January 2023

Sector	SO_2 emissions [Gg] 2005	2010	2015	2020	2025	2030
C. Manufacture of basic metals	2,77	2,62	2,90	2,78	2,55	2,53
G. – L. Other	1,96	2,29	2,26	2,63	2,63	2,64
3. Agriculture	**0,01**	**0,00**	**0,01**	**0,01**	**0,00**	**0,00**
F. Incineration of vegetable residues	0,01	0,00	0,01	0,01	0,00	0,00
5. Waste	**0,04**	**0,04**	**0,05**	**0,07**	**0,07**	**0,08**
C. incineration and open incineration of waste	0,04	0,04	0,05	0,07	0,07	0,08
D. Wastewater management	0,00	0,00	0,00	0,00	0,00	0,00
TOTAL	**1 128,98**	**824,72**	**638,53**	**385,37**	**256,71**	**166,33**

Source: Own study by KOBISE, IOŚ-PIB

According to the NEC Directive, Poland should reduce SO2 emissions by a minimumof 59 % in 2020-2029 and by a minimum of 70 % from 2030 compared to 2005. The reduction of this pollution for 2005 exceeded the required level, reaching 65.9 % in 2020 and 65.2 % in 2021. In the forecast years, the reduction of SO_2 emissions in the WEM scenario continues to increase, ranging from 77.3 % in 2025 to 85.3 % in 2030 (Table 2.39), so the reduction targets for SO_2 set out in the NEC Directive are met in all projection years.

The main source of SO2emissions in Poland is the combustion of fuels (category 1A). The sector's share of total emissions was 96 % in 2020 and remains the main source of emissions in the forecast years. The main reason for the decrease in SO_2 emissions between 2025 and 2030 is the decrease in fuel consumption, including mainly coal and lignite in industry (categories 1A1 and 1A2) and small combustion sources (cats). 1A4). In addition, the structure of the heating installations used in the small emitting sector (1A4) is having a significant impact on emission reductions over the years. These changes consist of gradually replacing carbon-intensive boilers with modern, eco-design-compliant equipment. The change in the structure of the equipment has been reflected in decreasing fuel combustion emission rates in the sector.

Table 2.35. Projections for nitrogen oxide emissions, by sector (NFR category)

Sector	NOx emissions [Gg] 2005	2010	2015	2020	2025	2030
1. Energy	**775,74**	**758,39**	**633,82**	**514,07**	**449,00**	**363,55**
A. Combustion of fuels	770,24	753,45	629,46	510,66	445,20	359,99
1. Energy industries	304,23	287,18	214,14	127,14	105,71	84,34
2. Manufacturing and construction	64,65	54,50	48,75	50,19	44,72	38,80
3. Transportation	218,78	252,94	243,37	214,34	197,49	153,36
4. Other sectors (small combustion sources including households)	182,57	158,82	123,20	118,98	97,28	83,50
B. Fugitive emissions from fuels	5,51	4,94	4,36	3,41	3,80	3,56
1. Fuels	0,01	0,01	0,01	0,01	0,01	0,01
2. Crude petroleum and natural gas	5,50	4,93	4,35	3,40	3,79	3,55
2. Industrial processes and product use	**15,99**	**15,43**	**17,47**	**17,52**	**17,80**	**17,99**
B. Chemical industry	13,63	13,04	14,91	15,06	15,07	15,25
C. Manufacture of basic metals	1,42	1,39	1,59	1,42	1,73	1,72
G. – L. Other	0,94	1,01	0,98	1,04	1,00	1,01
3. Agriculture	**65,48**	**69,50**	**68,27**	**71,98**	**72,98**	**72,99**

Sector	NOx emissions [Gg] 2005	2010	2015	2020	2025	2030
B. Natural fertilisers	5,29	4,79	4,73	5,38	4,87	5,04
D. Agricultural soils	60,13	64,69	63,48	66,56	68,10	67,94
F. Incineration of vegetable residues	0,07	0,02	0,06	0,03	0,01	0,01
5. Waste	**1,27**	**1,33**	**1,53**	**1,81**	**1,82**	**1,89**
C. incineration and open incineration of waste	1,27	1,33	1,53	1,81	1,82	1,89
TOTAL	**858,49**	**844,65**	**721,10**	**605,38**	**541,60**	**456,42**

Source: Own study by KOBISE, IOŚ-PIB

According to the NEC Directive, Poland should reduce NOx emissions by a minimum of 30 % in 2020-2029 and from 2030 onwards by a minimum of 39 % compared to 2005, with NOx emissions from sectors 3B (natural fertilisers) and 3D (agricultural soils) not covered by the reduction target set for EU Member States in accordance with Article 4 of the NEC Directive. National NOx emissions (excluding sectors 3B and 3D) in 2020 were 32.7 % lower than 2005 emissions and in 2021 by 34.5 %, and therefore the emission limit for this pollutant was met in those years. In the forecast years, NOx reductions in the WEM scenario range from 40.9 % in 2025 to 51.7 % in 2030 (Table 2.39), so the NOx reduction targets of the NEC Directive are met in all forecast years.

As with sulphur dioxide, the combustion of fuels (category 1A) is the main source of nitrogen oxide emissions, with a share of 84 % of national emissions in 2020. The main reason for the decrease in NOx emissions between 2025 and 2030 is the projected decrease in fuel consumption in the energy industries (category 1A1), transport (category 1A3) and small combustion sources (category 1A4).

In addition, technological progress in the small emitters sector (1A4), with the projected structure of the heating equipment used in the sector changing over the years, has a significant impact on the reduction of NOx emissions. These changes consist of phasing out carbon-intensive devices and replacing them with modern, eco-design-compliant equipment. The change in the structure of the equipment has been reflected in decreasing fuel combustion emission rates in the sector.

Table 2.36. NMVOC emission projections, by sector (NFR category)

Sector	NMVOC emissions [Gg] 2005	2010	2015	2020	2025	2030
1. Energy	**414,50**	**402,18**	**366,66**	**347,47**	**241,04**	**172,32**
A. Combustion of fuels	298,66	300,69	265,61	262,31	161,05	103,98
1. Energy industries	2,86	3,04	3,29	3,25	3,52	3,70
2. Manufacturing and construction	28,36	28,37	31,91	39,11	36,61	34,15
3. Transportation	91,28	72,25	70,26	45,56	23,81	18,98
4. Other sectors (small combustion sources including households)	176,17	197,04	160,15	174,39	97,10	47,15
B. Fugitive emissions from fuels	115,84	101,48	101,05	85,15	79,99	68,34
1. Fuels	90,08	72,32	70,44	52,77	46,43	34,42
2. Crude petroleum and natural gas	25,76	29,17	30,61	32,39	33,57	33,92
2. Industrial processes and product use	**267,37**	**269,06**	**260,82**	**279,39**	**263,56**	**261,04**
B. Chemical industry	2,84	2,98	4,18	5,68	6,37	6,40
C. Manufacture of basic metals	1,07	1,04	1,27	0,91	1,18	1,17

Sector	NMVOC emissions [Gg] 2005	2010	2015	2020	2025	2030
D. Use of solvents and other products	256,78	258,12	248,27	264,78	248,08	245,44
G. – L. Other	6,68	6,92	7,11	8,02	7,93	8,03
3. Agriculture	**110,90**	**102,09**	**103,61**	**123,61**	**115,20**	**121,00**
B. Natural fertilisers	104,84	95,96	97,31	115,61	107,32	113,13
D. Agricultural soils	6,05	6,12	6,28	7,99	7,88	7,87
F. Incineration of vegetable residues	0,01	0,00	0,01	0,01	0,00	0,00
5. Waste	**4,05**	**2,98**	**2,43**	**2,45**	**2,45**	**2,28**
A. Storage of solid waste	2,52	1,53	0,89	0,57	0,49	0,31
C. incineration and open incineration of waste	1,50	1,41	1,51	1,85	1,93	1,95
D. Wastewater management	0,03	0,03	0,03	0,03	0,03	0,03
TOTAL	**796,83**	**776,30**	**733,52**	**752,91**	**622,26**	**556,64**

Source: Own study by KOBISE, IOŚ-PIB

According to the NEC Directive, Poland should reduce NMVOC emissions by a minimum of 25 % in 2020-2029 and from 2030 onwards by a minimum of 26 % compared to 2005, but according to Article 4 of that Directive, NMVOC emissions from sectors 3B (natural fertilisers) and 3D (agricultural soils) are not covered by the reduction target set for EU Member States. National emissions of NMVOCs (excluding sectors 3B and 3D) in 2020 were 8.3 % below 2005 emissions and in 2021 by 13.5 %, thus Poland did not meet its NMVOC emission reduction target under the NEC Directive in 2020-2021. In the forecast years, the reduction of NMVOC emissions in the WEM scenario ranges from 26.2 % in 2025 to 36.5 % in 2030 (Table 2.39), so the reduction targets for NMVOCs set out in the NEC Directive are met in all projection years.

NMVOC emission sources are more dispersed than sources of SO2and NO_x emissions. In 2020, the following categories accounted for the largest unit share of emissions: consumption of solvents and other products (cat. 2D) – 35 %, combustion of fuels in small sources (cat. 1A4) – 23 %, agricultural fertiliser use (cat. 3B) – 15 % and volatile emissions from fuels (cat. 1B) – 11 %. The share of the entire category 1A (combustion of fuels) in NMVOC emissions was 35 % in 2020, while the entire sector 1 (Energy) accounted for 46 %, and it is precisely the changes in category 1 (Energy) that have the biggest impact on the decrease in emissions in the forecast years. This concerns in particular the decrease in fuel consumption in all sub-categories of sector 1. Energy and a decrease in fugitive emissions from fuels (i.e. emissions from the extraction, storage and transport of fuels).

NMVOC emissions from solvent consumption are also steadily decreasing compared to 2020. This is mainly related to the projected shrinking population and the associated decrease in solvent consumption in households, as well as the projected decrease in solvent paint consumption in favour of dilute paints, which have a significantly lower NMVOC content.

Table 2.37. Projections for ammonia emissions, by sector (NFR category)

Sector	Ammonia emissions [Gg] 2005	2010	2015	2020	2025	2030
1. Energy	**6,62**	**6,85**	**5,20**	**4,52**	**3,50**	**2,99**
A. Combustion of fuels	6,57	6,79	5,13	4,46	3,44	2,93
2. Manufacturing and construction	0,04	0,05	0,07	0,10	0,12	0,12
3. Transportation	6,17	6,34	4,71	3,89	3,05	2,67

Sector	Ammonia emissions [Gg] 2005	2010	2015	2020	2025	2030
4. Other sectors (small combustion sources including households)	0,36	0,41	0,36	0,47	0,27	0,14
B. Fugitive emissions from fuels	0,05	0,06	0,06	0,06	0,06	0,06
1. Fuels	0,03	0,04	0,04	0,03	0,03	0,03
2. Crude petroleum and natural gas	0,02	0,03	0,03	0,03	0,03	0,03
2. Industrial processes and product use	**3,03**	**3,11**	**4,29**	**4,37**	**4,49**	**4,69**
B. Chemical industry	2,71	2,82	4,05	4,22	4,35	4,57
D. Use of solvents and other products	0,01	0,01	0,01	0,01	0,01	0,01
G. – L. Other	0,31	0,29	0,23	0,14	0,12	0,11
3. Agriculture	**307,83**	**286,47**	**277,61**	**299,99**	**269,60**	**276,83**
B. Natural fertilisers	151,15	126,61	122,55	138,31	132,70	136,50
D. Agricultural soils	156,61	159,84	155,00	161,64	136,90	140,33
F. Incineration of vegetable residues	0,07	0,02	0,06	0,04	0,01	0,01
5. Waste	**5,39**	**3,19**	**2,29**	**1,41**	**1,99**	**2,08**
B. Composting	0,21	0,20	0,69	0,73	1,50	1,59
D. Wastewater management	5,18	2,98	1,60	0,68	0,49	0,49
TOTAL	**322,88**	**299,62**	**289,39**	**310,29**	**279,58**	**286,59**

Source: Own study by KOBISE, IOŚ-PIB

According to the NEC Directive, Poland should reduce ammonia emissions by at least 1 % in 2020-2029 and by at least 17 % from 2030 compared to 2005. The reduction of this pollution in 2020 and 2021 for 2005 exceeded the required level of 3.9 % in 2020 and 10.4 % in 2021. In the forecast years, ammonia emission reductions in the WEM scenario range from 13.4 % in 2025 to 11.2 % in 2030 (Table 2.39), so the reduction targets for SO_2 of the NEC Directive are met in 2020-2029, but are not met after 2030, as projected emissions of this pollutant increase after 2025.

Agriculture is the main source of ammonia emissions in Poland, responsible for around 97 % of national emissions in 2020, with two sources dominated so far: livestock manure (cat. 3B Natural fertilisers), accounting for 45 % of NH_3 emissions and application of natural and mineral fertilisers to agricultural soils (cat. 3D Agricultural soils), which accounted for 52 % of NH_3 emissions. These shares are projected to slightly change until 2030. Without additional action in agriculture, the required emission reductions after 2030 will not be achieved.

Table 2.38. Projections for PM2.5 emissions, by sector (NFR category)

Sector	PM2.5 emissions [Gg] 2005	2010	2015	2020	2025	2030
1. Energy	**306,65**	**344,65**	**281,04**	**290,24**	**165,19**	**84,05**
A. Combustion of fuels	304,58	342,73	279,11	288,74	163,76	82,87
1. Energy industries	10,29	9,14	6,56	3,72	2,68	2,23
2. Manufacturing and construction	19,85	12,71	11,02	8,20	6,93	5,28
3. Transportation	10,49	13,20	11,57	11,71	10,39	8,66

Sector	PM2.5 emissions [Gg] 2005	2010	2015	2020	2025	2030
4. Other sectors (small combustion sources including households)	263,94	307,68	249,96	265,11	143,76	66,69
B. Fugitive emissions from fuels	2,07	1,92	1,93	1,49	1,43	1,19
1. Fuels	1,99	1,82	1,81	1,38	1,33	1,09
2. Crude petroleum and natural gas	0,08	0,10	0,11	0,11	0,11	0,10
2. Industrial processes and product use	**8,58**	**8,70**	**9,04**	**8,54**	**9,43**	**9,54**
A. Mineral products	2,79	3,01	2,74	2,99	3,74	3,79
B. Chemical industry	1,62	1,58	2,20	2,32	2,41	2,57
C. Manufacture of basic metals	1,17	1,04	1,44	1,09	1,28	1,27
D. Use of solvents and other products	0,49	0,66	0,62	0,64	0,64	0,64
G. – L. Other	2,52	2,41	2,05	1,49	1,36	1,27
3. Agriculture	**3,10**	**2,77**	**2,95**	**3,30**	**3,19**	**3,29**
B. Natural fertilisers	2,22	2,07	2,16	2,56	2,51	2,61
D. Agricultural soils	0,73	0,65	0,65	0,66	0,66	0,66
F. Incineration of vegetable residues	0,16	0,04	0,14	0,08	0,02	0,02
5. Waste	**3,75**	**3,97**	**4,21**	**4,52**	**4,64**	**4,68**
A. Storage of solid waste	0,001	0,001	0,001	0,001	0,001	0,001
C. incineration and open incineration of waste	1,06	1,17	1,31	1,51	1,42	1,47
E. Other	2,69	2,80	2,90	3,01	3,21	3,21
TOTAL	**322,08**	**360,09**	**297,24**	**306,59**	**182,45**	**101,56**

Source: Own study by KOBISE, IOŚ-PIB

According to the NEC Directive, Poland should reduce PM2.5 emissions by a minimum of 16 % in 2020-2029 and by at least 58 % from 2030 compared to 2005. The reduction of this pollution in relation to 2005 did not reach the required level in 2020-2021, reaching 4.8 % in 2020 and 7.7 % in 2021. In the projection years, the reduction of PM2.5 in the WEM scenario is increasing significantly, reaching 43.4 % in 2025, 68.5 % in 2030 (Table 2.39), so the reduction targets for this pollutant set out in the NEC Directive are met in all projection years.

The main source of PM2.5 emissions is the combustion of fuels in small sources (cat. 1A4), which accounted for 86 % of national emissions in 2020. The reason for the decrease in emissions in the forecast years is the decrease in fuel consumption in this category and the above-mentioned change in the structure of small heating equipment towards modern and low-carbon heating equipment.

Table 2.39. Projected reduction of air pollutant emissions between 2025 and 2030 compared to NEC Directive targets

Pollution	NECD targets – minimum required reduction in relation to 2005 emissions 2020-2029	from 2030 onwards	WEM emissions 2020	2025	2030
NO_x	30 %	39 %	—32.7 %	—40.9 %	—51.7 %
SO_2	59 %	70 %	—65.9 %	—77.3 %	—85.3 %

Pollution	NECD targets – minimum required reduction in relation to 2005 emissions		WEM emissions		
	2020-2029	from 2030 onwards	2020	2025	2030
NMVOC	25 %	26 %	—8.3 %	—26.1 %	—36.5 %
NH_3	1 %	17 %	—3.9 %	—13.4 %	—11.2 %
PM2,5	16 %	58 %	—4.8 %	—43.4 %	—68.5 %

2.2. Renewable energy

In 2022, the share of renewable energy in gross final energy consumption reached 16.81 % and was 4.98 pps higher than in 2015. The share of renewable energy has increased since 2017. The largest increase occurred between 2017 and 2018 and amounted to 3.89 pps. The total volume of energy from renewable energy sources amounted to 878 051.8 GWh in 2022, the main component of which was energy used in the heating and cooling sector, representing more than 49 % of the total. In 2020, the share of RES was 16.11 %.

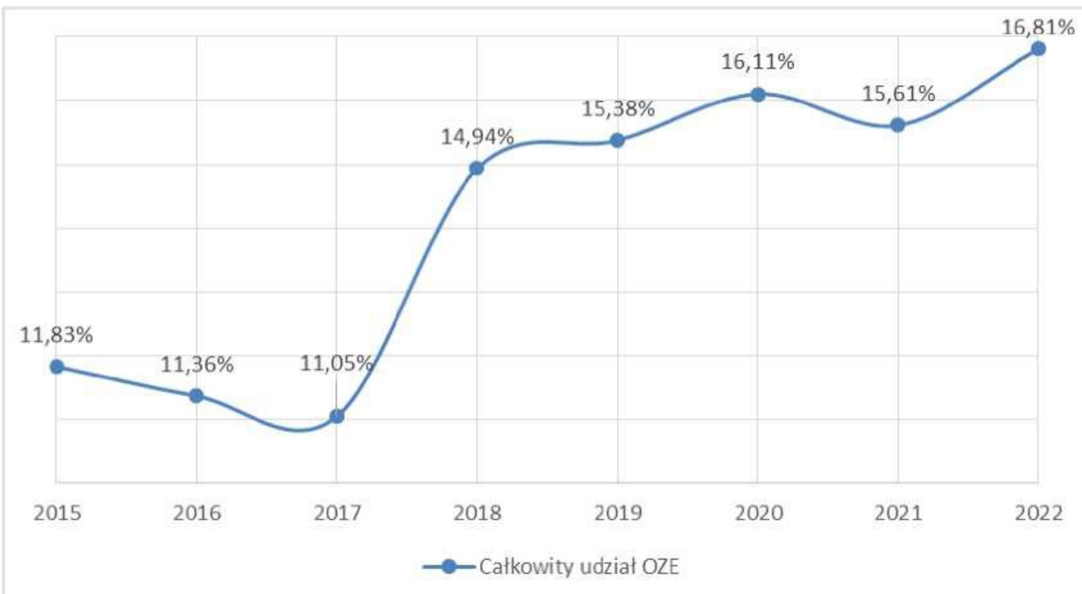


Figure 2.8 Share of RES in national terms

Source: Eurostat Shares

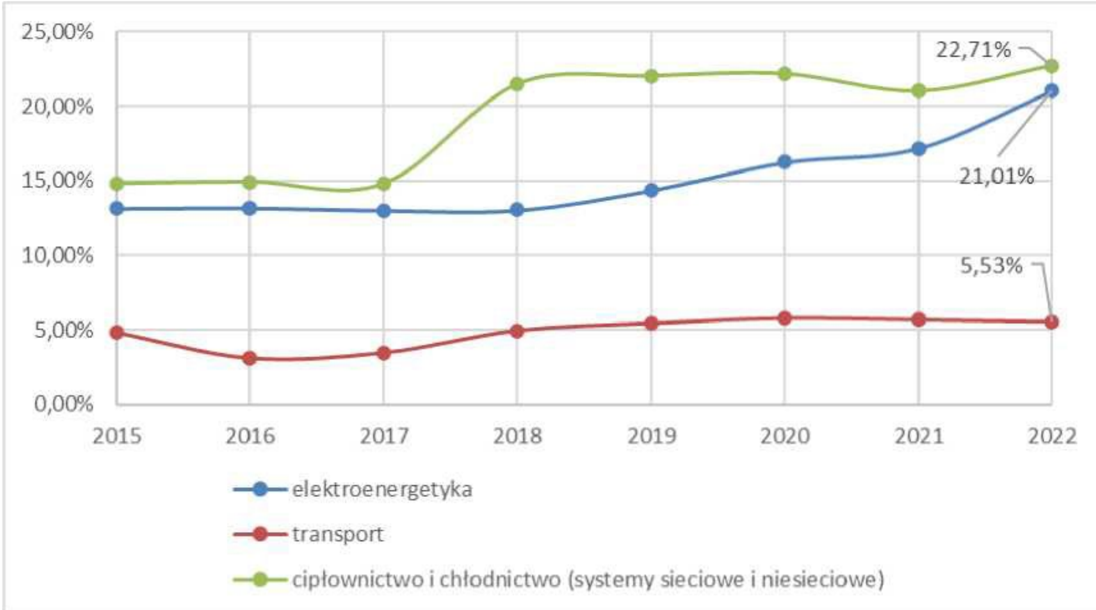


Figure 2.9 Comparison of RES shares in different economic sectors
Source: Eurostat Shares

The share of RES in the electricity sector in 2022 was 21.01 %, which was 7.87 pps higher than in 2015. The largest increase in value is observed over the years 2018-2022. Between 2015 and 2018, there were no significant changes in the share of renewables in the electricity mix.

In the electricity sector, the largest share of renewable energy production between 2015 and 2022 was the wind sub-sector. In 2022, the amount of energy produced in this sub-sector amounted to 18 934.5 GWh (equivalent to more than 50 % of total electricity production from renewable sources). Since the beginning of 2015, there has been a systematic increase in electricity production from photovoltaic installations (an increase of more than 14500 %, comparing production in 2022 with production in 2015). This sharp increase in production is mainly due to the development of prosumer photovoltaic installations, which is due to the introduction in Poland of support schemes for the construction of prosumer installations (e.g.: My Prąd) and rising electricity prices. The other renewable energy sub-sectors are not as dynamic as the energy sub-sector.

The share of renewable energy sources in transport in 2022 was 5.53 %, increasing by 0.71 pps compared to 2015. No significant changes in this value have been observed during the period considered. Biofuels accounted for the largest share of renewable energy in transport (12 669.2 GWh in 2022). There is an increase in the share of so-called green energy in the propulsion of road and rail vehicles (the number of electric cars, hybrid cars and electrification of rail networks) is increasing.

In the heating and cooling sector, the share of renewable energy in 2022 was 7.92 pps higher than in 2015. Over the period considered, the largest percentage increase in the share of renewables in heating and cooling occurred between 2017 and 2018 (an increase of 6.69 pps). There is an increase in the production of energy from heat pumps. Air heat pumps have dominated in recent years, which may be caused by lower costs in purchasing and installing such units relative to ground heat pumps.

2.2.1. Forecasts for the development of RES with existing policies and measures

The national and sectoral RES participation trajectories presented in this sub-chapter assume the continuation of current trends in the development of RES technologies (including cost) and the support mechanisms in place at the projection stage. Such mechanisms are systems: certificates of origin (phased-out system) and auctioning (for all RES technologies listed in the Act19, as well as offshore wind farms. The auction system assumes a maximum

19Act of 20 February 2015 on renewable energy sources (Journal Of Laws 2017, item 1148 and 1213, as amended) subsidy period of 15 years for technology, while for offshore wind farms this period is 25 years. It was also assumed that future auctions would favour solutions to lower the energy price, which is important for the competitiveness of the economy and further GDP growth. With regard to the development of prosumer energy, support schemes such as: My electricity, clean air, hot apartment, thermomodernisation reduction or the investment credit for agricultural holdings.

The calculation is based on the data presented in the Eurostat20 SHARES forms used to report the level of achievement of the RES share targets by Member States. 2020 is used as the base year. In the transport sector, the share of RES was calculated in accordance with the recommendations of REDIII21.

For the purposes of the work, the projected national gross final energy demand and production from individual RES generation units have been defined. A detailed description of the projection for the increase in energy demand used in the calculations is set out in the chapters below. For hydropower and wind power plants, the forecasted production values presented below are those normalised according to the methodology recommended by Eurostat. For hydropower plants, standardisation consists of a correction of the level of production based on the installed capacity utilisation rate averaged over the last 15 years. For wind power plants, an analogous method was used, but using a 5-year average.

The tables below present national and sectoral RES share projections based on the assumptions described above.

Cost optimisation, as well as an analysis of development opportunities based on past trends and **in the absence of emergency measures going beyond the existing legal and regulatory framework**, shows that the **share of RES in gross final energy consumption can be achieved to almost 30 % in 2030.** The share of RES is growing dynamically in all sectors – electricity, heating and transport.

20European Commission. Shares Tool Manual. Version 2022.181023

21Directive (EU) 2023/2413 of the European Parliament and of the Council of 18 October 2023 amending Directive (EU) 2018/2001, Regulation (EU) 2018/1999 and Directive 98/70/EC as regards the promotion of energy from renewable sources, and repealing Council Directive (EU) 2015/652

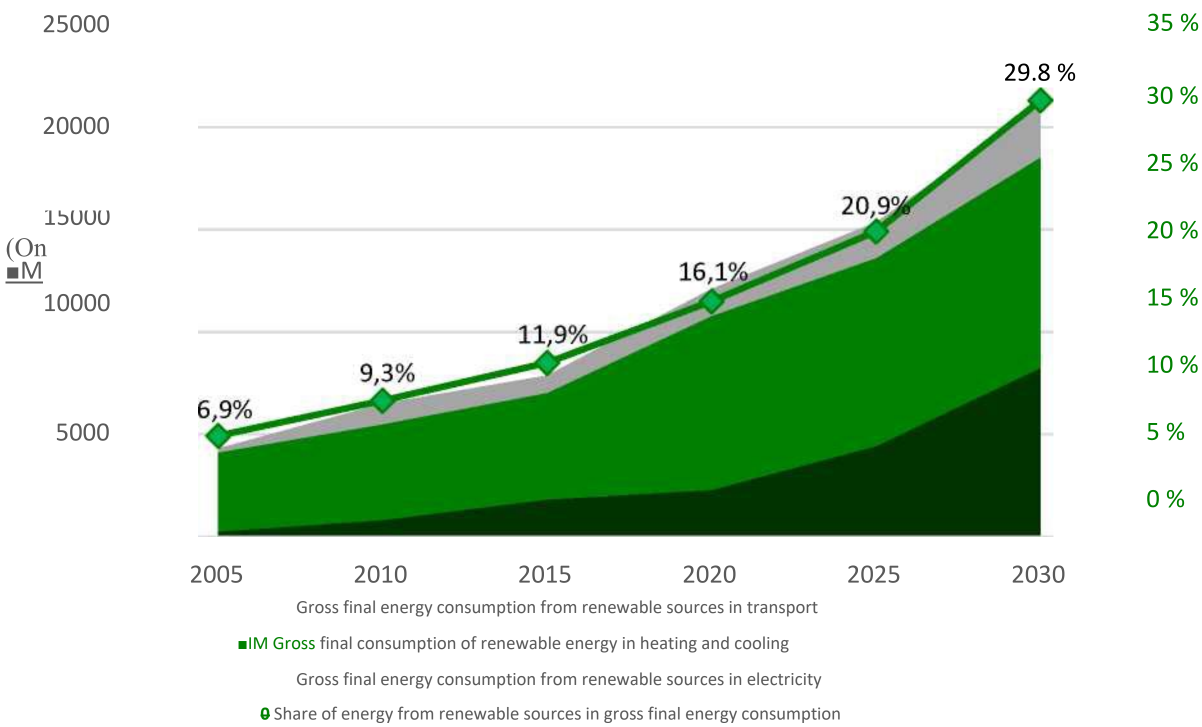


Figure 2.10 Share of RES in gross final demand and per economic sector

In the electricity sector, between 2020 and 2030, it is growing from 16.2 % to 50 % in 2030. Wind and solar technologies are the main drivers for increasing the share of RES in electricity production in Poland. (Figure 2.11).

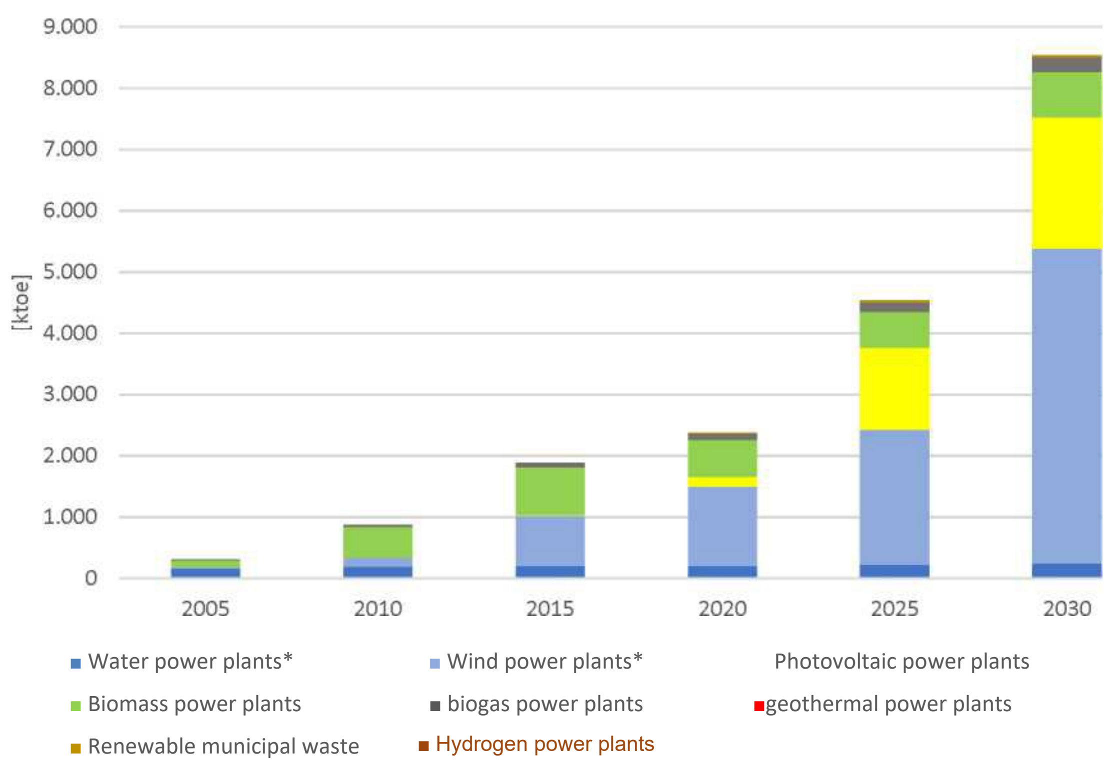


Figure 2.11 Electricity production from RES by technology – electricity sector [ktoe]

In the heating and cooling sector, where there is a relatively high potential, the share of RES increases from **22.1 % in 2020 to 32.1 % in 2030** (Figure 2.12), but achieving the values indicated in the analysis will require a much larger transition stream than hitherto. Heating is one of the most important industrial sectors of the economy and is of fundamental importance to society in Polish climate conditions (ca. 1/4 of the heat demand in Poland). The financial situation of most heating companies does not allow investments to be made in an area that would allow the transition to be accelerated. According to the path presented, the share of RES is growing at the rate required by the REDIII Directive, i.e. 0.8 % in 2021-2025 and 1.1 % in 2026-2030.

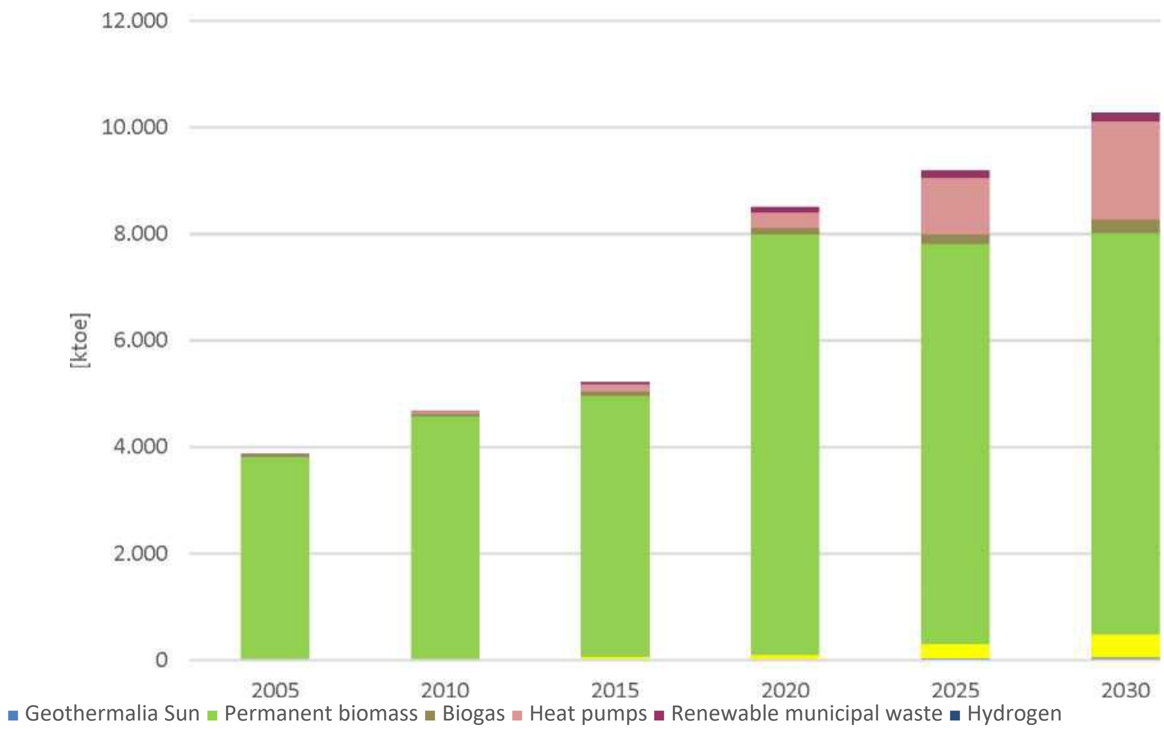


Figure 2.12 Gross final energy consumption from RES by technology – heating and cooling [ktoe]

The transport sector is an area where increasing the share of RES in overall energy consumption will be a major challenge. It is well known that the possibilities for the deployment of biofuels and biocomponents are limited by technical and economic considerations. The greatest hope therefore lies in the electrification of road transport, which, given the wealth of society, will not necessarily follow the scenario envisaged in the analysis. So far, the development of the market for electric vehicles and associated infrastructure is not in line with the expectations and assumptions of the previous NECPs for the period 2021-2030. Implementation of the plan presented in the analysis will therefore require the implementation of additional policies and measures.

Analyses of the **trajectory for the increase in the RES share in transport show an increase from 6.6 % in 2020 to 17.7 % in 2030. In** the following sub-periods, it is increasing at a geometric rate as transport electrification progresses, driven mainly by a decrease in the cost of electric vehicles (including hydrogen powered).

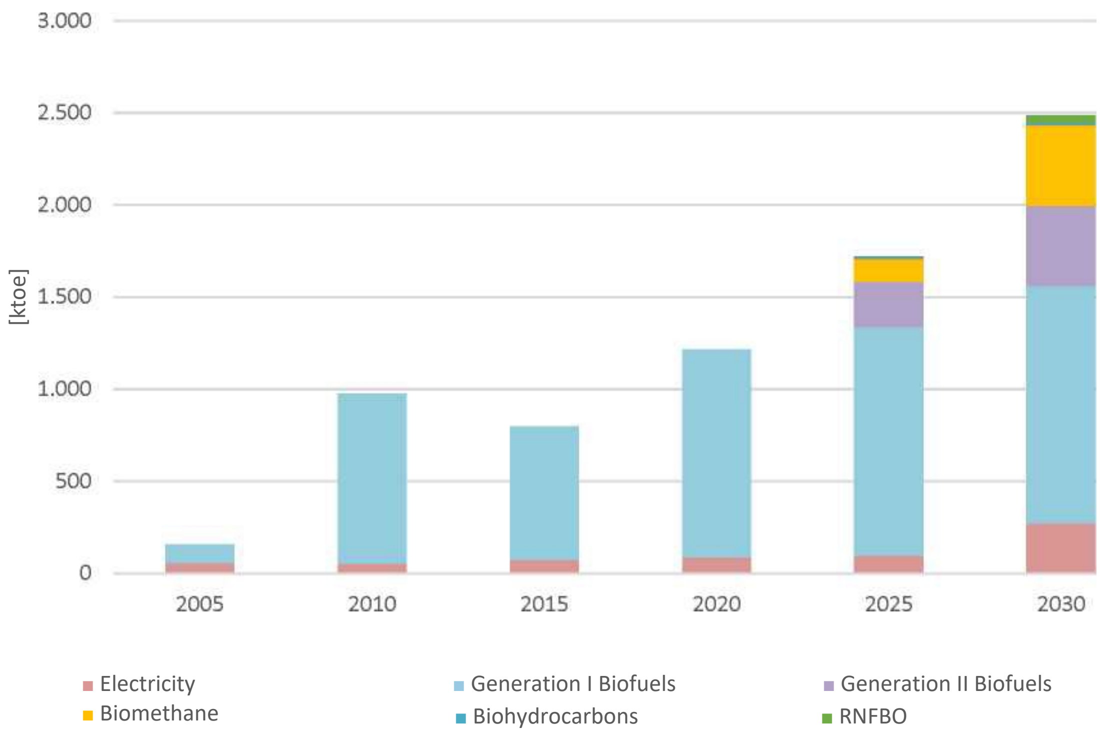


Figure 2.13 Gross final energy consumption from RES by technology – transport sector [ktoe]

Table 2.40. Sectoral and total gross final energy consumption from renewable sources

		2005	2010	2015	2020	2025	2030
Gross final energy consumption from RES by sector [ktoe]	**Gross final energy consumption (RES-OS deominator)**	**61 577**	**69 192**	**65 374**	**74 069**	**73 076**	**69 573**
	Gross final energy consumption from renewable sources (RES-OS number)	4 229	6 421	7 767	11 926	15 257	20 754
	Gross final energy consumption from renewable sources in electricity	257	824	1 818	2 292	4 441	8 264
	Gross final energy consumption from renewable sources in heating and cooling	3 868	4 677	5 224	8 507	9 191	10 274
	Gross final energy consumption from renewable sources in transport	178	993	824	1 291	1 723	2 489
Sectoral and total share of energy from renewable sources in gross final energy consumption	**Share of energy from renewable sources in gross final energy consumption**	**6.9 %**	**9.3 %**	**11.9 %**	**16.1 %**	**20.9 %**	**29.8 %**
	Share of RES energy in electricity	2.5 %	6.5 %	13.4 %	16.2 %	28.6 %	50.1 %
	Share of RES energy in heating and cooling	10.2 %	11.8 %	14.8 %	22.1 %	27.0 %	32.1 %
	Share of RES energy in transport (with multiplicators)	1.7 %	6.6 %	5.7 %	6.6 %	9.5 %	17.7 %

Source: Own study by ARE SA, Eurostat SHARES

Table 2.41. Electricity

		2005	2010	2015	2020	2025	2030
Electricity production from RES by technology – electricity sector [ktoe]	**Gross final electricity consumption (RES-E deominator)**	**12 397**	**13 391**	**14 102**	**14 660**	**15 892**	**17 025**
	Hydropower*	164	189	198	200	223	248
	Wind power plants*	17	146	833	1 294	2 201	5 135
	Photovoltaic power plants	0	0	5	168	1 335	2 134
	Biomass power plants	120	508	776	596	586	746
	Biogas power plants	10	34	78	106	163	237
	Geothermal plants	0	0	0	0	0	0
	Hydrogen power plants	0	0	0	0	0	0
	Municipal waste renewable	0	0	0	16	30	36
Share of different types of technologies in RES energy consumption in electricity	Hydropower plants	63.8 %	22.9 %	10.9 %	8.7 %	5.0 %	3.0 %
	Wind plants	6.6 %	17.7 %	45.8 %	56.5 %	49.6 %	62.1 %
	Photovoltaic power plants	0.0 %	0.0 %	0.3 %	7.3 %	30.1 %	25.8 %
	Biomass power plants	46.7 %	61.7 %	42.7 %	26.0 %	13.2 %	9.0 %
	Biogas power plants	3.9 %	4.1 %	4.3 %	4.6 %	3.7 %	2.9 %
	Geothermal plants	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %
	Hydrogen power plants	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %
	Municipal waste renewable	0.0 %	0.0 %	0.0 %	0.7 %	0.7 %	0.4 %

Source: Own study by ARE SA, Eurostat SHARES

Table 2.42. Heating and cooling sector

		2005	2010	2015	2020	2025	2030
Gross final energy consumption from RES by technology – heating and cooling [ktoe]	**Gross final consumption of energy for heating and cooling (RES-H&C deominator)**	**38 064**	**39 594**	**35 310**	**38 417**	**34 072**	**32 010**
	Geothermal	11	13	22	26	45	59
	Solar	0	10	45	80	259	430
	Solid biomass	3 814	4 555	4 896	7 892	7 513	7 526
	Biogas	41	51	88	114	177	258
	Heat pumps	0	45	133	298	1 056	1 840
	Hydrogen	0	0	0	0	0	4
	Municipal waste renewable	1	3	40	97	141	158
Contribution of different types of technologies to RES consumption in heating and cooling	Geothermal	0.3 %	0.3 %	0.4 %	0.3 %	0.5 %	0.6 %
	Solar	0.0 %	0.2 %	0.9 %	0.9 %	2.8 %	4.2 %
	Solid biomass	98.6 %	97.4 %	93.7 %	92.8 %	81.7 %	73.3 %
	Biogas	1.1 %	1.1 %	1.7 %	1.3 %	1.9 %	2.5 %
	Heat pumps	0.0 %	1.0 %	2.5 %	3.5 %	11.5 %	17.9 %
	Hydrogen	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %
	Municipal waste renewable	0.0 %	0.1 %	0.8 %	1.1 %	1.5 %	1.5 %

Source: Own study by ARE SA, Eurostat SHARES

Table 2.43. Transport sector

		2005	2010	2015	2020	2025	2030
Gross final energy consumption from RES by technology – transport sector [ktoe]	**Gross final energy consumption in transport (RES-T deominator)**	**10 189**	**14 957**	**14 493**	**19 628**	**23 123**	**21 421**
	Electricity	54	53	72	88	98	272
	Generation I biofuels	104	921	725	1 127	1 238	1 287
	Second generation biofuels	0	0	0	0	250	435
	Biomethane	0	0	0	0	121	438
	Biohydrocarbons	0	0	0	0	10	10
	RNFBO	0	0	0	0	6	45
	Ignition fuels from recycling	0	0	0	0	0	0
	Electricity consumption for road transport qualified as RES	0	0	1	2	16	95
	Electricity consumption for rail transport qualifying as RES	48	47	65	80	78	170
	Electricity consumption in pipeline transport qualifying for RES	6	6	7	6	4	8

Contribution of different types of technologies to RES consumption in transport	Electricity	30.6 %	5.4 %	8.7 %	6.8 %	5.7 %	10.9 %
	Biofuels	58.5 %	92.7 %	88.0 %	87.4 %	86.4 %	69.2 %
	Share of electricity for road transport	0.5 %	0.7 %	0.7 %	2.3 %	15.9 %	34.9 %
	Share of electricity for rail transport	89.0 %	88.8 %	90.1 %	91.1 %	79.6 %	62.3 %
	Share of electricity for other modes of transport	10.5 %	10.5 %	9.2 %	6.5 %	4.5 %	2.8 %
	Total electricity consumption in transport [ktoe]	343,0	287,0	267,2	273	404	655
	Actual electricity consumption for road transport [ktoe]	1,8	2,0	1,9	6	64	228
	Actual electricity consumption for rail transport [ktoe]	305,2	254,9	240,6	249	321	408
	Actual electricity consumption in pipeline transport [ktoe]	36,0	30,2	24,7	18	18	18

Source: Own study by ARE SA, Eurostat SHARES

2.2.2. Forecasts for the development of RES in buildings and industry with existing policies and measures

The results of the forecasts for electricity generation in buildings* taking into account the current legal framework for the development of distributed energy based on RES and the prediction of the potential for a reduction in technology costs are derived from the cost optimisation carried out in the MESSAGE model. In this model, distributed sources compete with the price of electricity for end-users.

In accordance with the provisions of the amended Renewable Energy Sources Act of 29 October 2021, adopted by the Sejm on 2 December 2021, the results set out below concerning production volumes from small and micro-installations based on RES were generated on the assumption of a gradual decrease in technology costs, rising retail electricity prices (mainly as a result of an increase in the cost of purchasing CO2 emission allowancesaffecting the level of the wholesale price), as well as support arrangements (mainly consisting of partial coverage of investment costs, the possibility of using loans granted on preferential terms and the value of the settlement of excess energy produced by the prosumer).

The results show that the fastest-growing building technology will be photovoltaics (with the highest cost reduction dynamics and a convenient technical solution for households, housing communities and service buildings).

The tables below present the projections for electricity and heat generation from renewable energy sources in small and micro-installations in buildings, including data on energy produced, self-consumption and fed into the grid. The share of energy fed into the grid for each period was determined on the basis of an analysis of the historical data provided by ERO22. The projections for heat production from micro-installations were obtained using the simulation model STEAM-PL, where elements such as: the level of demand for useful energy, the potential involved, the cost of technology, the level of subsidies, user preferences, the pace of development to date, the prediction of industry institutions and recognised research centres at home and abroad.

Table 2.44. Electricity generation from renewable energy sources in buildings [GWh]

	Year	Biogas plants	Photovoltaics	Wind plants	MEW
Gross production [GWh]	2015	0	9	0	0
	2020	1	1 527	0	0
	2025	8	9 897	0	0
	2030	13	14 036	1	0
Own consumption [GWh]	2015	0	5	0	0
	2020	0	893	0	0
	2025	6	5 790	0	0
	2030	10	8 211	0	0
Energy fed into the grid [GWh]	2015	0	4	0	0
	2020	0	634	0	0
	2025	2	4 107	0	0
	2030	3	5 825	1	0

withinthe meaning of Article 2 paragraph 1 of Directive 2010/31/EU

22‘Summary information on electricity generation from renewable energy sources in a micro-installation or small-scale installation for 2016 (Article 17 of the RES Act)’ – URE report. Warsaw, April 2017.

Source: Own study by ARE SA (STEAM-PL, MESSAGE-PL)

Table 2.45. Heat generation from renewable energy sources in buildings [ktoe]

	Year	Biogas plants	Collectors solar	Biomass boilers	Heat pumps	Geothermal
Gross production [ktoe]	2015	0	45	2 281	133	0
	2020	0	80	2 098	298	0
	2025	4	259	2 088	1 056	0
	2030	6	430	2 048	1 840	0
Own consumption [ktoe]	2015	0	45	2 281	133	0
	2020	0	80	2 098	298	0
	2025	4	259	2 088	1 056	0
	2030	6	430	2 048	1 840	0
Energy fed into the grid [ktoe]	2015	0	0	0	0	0
	2020	0	0	0	0	0
	2025	0	0	0	0	0
	2030	0	0	0	0	0

Source: Own study by ARE SA (STEAM-PL, MESSAGE-PL)

3. Dimension energy efficiency

Between 2011 and 2021, the annual cumulative rate of energy efficiency growth was 0.9 %. Primary energy intensity of GDP decreased by 2.6 % per year on average over this period and final GDP energy intensity by 1.5 %. The fastest pace of energy efficiency improvements was recorded in transport (by 2.2 %). Total primary energy consumption increased from 96.6 Mtoe to 104.0 Mtoe between 2011 and 2021 (i.e. cumulative annual growth rate of 0.7 %). By contrast, final energy consumption increased from 64.7 % to 75.2 Mtoe over the period under review (i.e. a cumulative annual growth rate of 1.5 %). Both total and final consumption peaked in 2018 (respectively 104.1 Mtoe and 74.9 Mtoe).

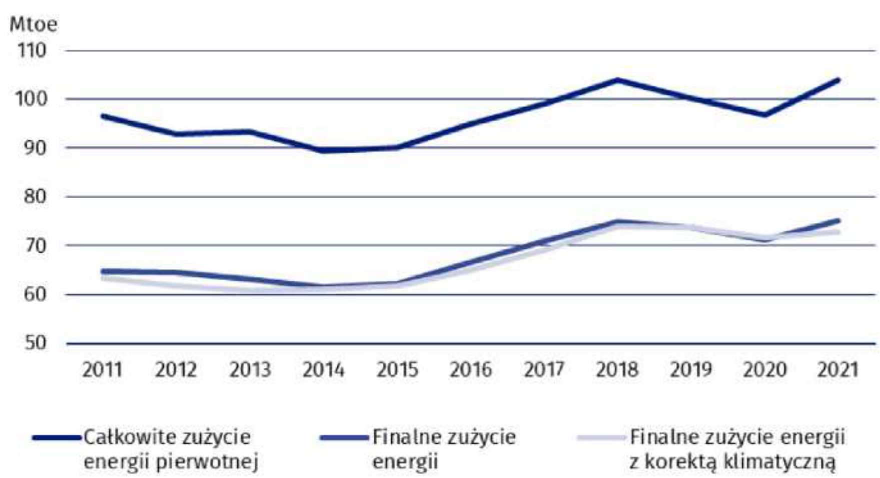


Figure 2.14. Total primary and final energy consumption 2011-2021[23]

[23] Energy efficiency 2011-2021'. Central Statistical Office, Warsaw, 15 June 2023

In 2021, for 2011, primary GDP energy intensity decreased by 20.3 % and final energy intensity by 13.8 %. After taking into account the climate adjustment, the rate of improvement was slightly higher (by 21.0 % and 15.0 % respectively).

The largest impact on the change in consumption was economic activity, with an increase in energy demand of

11.7 Mtoe in 2021 compared to 2011. For households, increasing energy demand was driven by an increase in housing and lifestyle changes (more dwellings) and weather conditions. Structural changes in industry have reduced energy consumption by 0.4 Mtoe, while in transport they increased by 1.6 Mtoe. Energy savings totalled 5.8 Mtoe, with the largest reductions being achieved in households (2.4 Mtoe). Weather conditions have increased energy consumption by 1.0 Mtoe, while the remaining factors contributed to a 0.1 Mtoe reduction.

3.1. Primary and final energy consumption

The table below shows the historical and projected primary and final energy consumption in the country. Based on the data obtained, the country's primary energy demand decreased moderately from 103.3 Mtoe to 95.4 Mtoe between 2020 and 2030. Final energy consumption decreases over the period considered from 77.1 Mtoe to 72.2 Mtoe in 2030. A deeper reduction in national energy consumption over the next 7 years seems extremely difficult, if not impossible. Poland is a developing country whose ambition since accession is to achieve at least the EU average level of prosperity (measured as GDP/Ma in PPPs). However, economic development is inextricably linked to the increase in energy needs, especially as the average energy consumption in Poland (per capita) is much lower than most of the developed Western European countries. Energy efficiency improvement measures implemented are only to some extent capable of reducing energy consumption. For this reason, further pro-efficiency measures are needed.

Table 2.46. Total primary and final energy consumption [ktoe]

	2005	2010	2015	2020	2025	2030
Primary energy consumption*	92 905	101 819	96 061	103 280	101 355	95 433
Primary energy consumption	92 582	101 604	95 868	102 979	100 967	94 993
Primary energy consumption (Europe 2020-2030)	**87 974**	**96 590**	**90 075**	**96 859**	**94 440**	**87 764**
Final energy consumption*	61 700	70 380	65 169	77 134	75 642	72 234
Final Energy Consumption	57 473	65 250	60 863	70 257	70 171	66 845
Final energy consumption (Europe 2020-2021)	**58 487**	**66 283**	**62 299**	**71 145**	**70 820**	**66 831**

**with non-energy consumption*
Source: Own study by ARE SA (STEAM-PL, MESSAGE-PL), EUROSTAT

3.1.1. Final energy consumption by sector

The trajectories for final energy demand in total and by sector are shown in the table (Table 2.47) and in Figure (Figure 2.16). According to projections, final energy consumption (without non-energy consumption) decreases from 70.2 Mtoe to 66.8 Mtoe between 2020 and 2030. At the end of the forecast, it reaches 56.8 Mtoe. The trajectory presented assumes a decrease in final consumption in 2020-2030, in all sectors of the national economy. From today's perspective, it will be hardest to achieve any reduction in energy consumption in the next seven years in the transport sector. It is a sector that continues to grow, in line with economic growth. Later, with the development of new transport technologies and the popularisation of collective transport, there is an opportunity to significantly reduce the energy intensity of transport, but this depends on the growth rate of prosperity in society.

Table 2.47. Final energy consumption by sector (without non-energy consumption) [ktoe]

	2005	**2010**	**2015**	**2020**	**2025**	**2030**
Industry	14 616	13 498	14 097	15 921	16 002	15 391
Transportation	12 223	17 187	16 561	21 779	23 494	21 831
of which: passenger	b.d.	b.d.	8 985	11 002	12 242	10 879
freight	b.d.	b.d.	7 496	10 695	11 168	10 865
special vehicles	b.d.	b.d.	79	82	84	86
Households	19 467	22 002	19 032	21 101	18 864	17 750
Services	6 730	8 833	7 842	7 565	8 170	8 401
Agriculture	4 438	3 730	3 330	3 869	3 640	3 473
TOTAL	**57 473**	**65 250**	**60 863**	**70 235**	**70 171**	**66 845**

Source: Own study by ARE SA (STEAM-PL), EUROSTAT

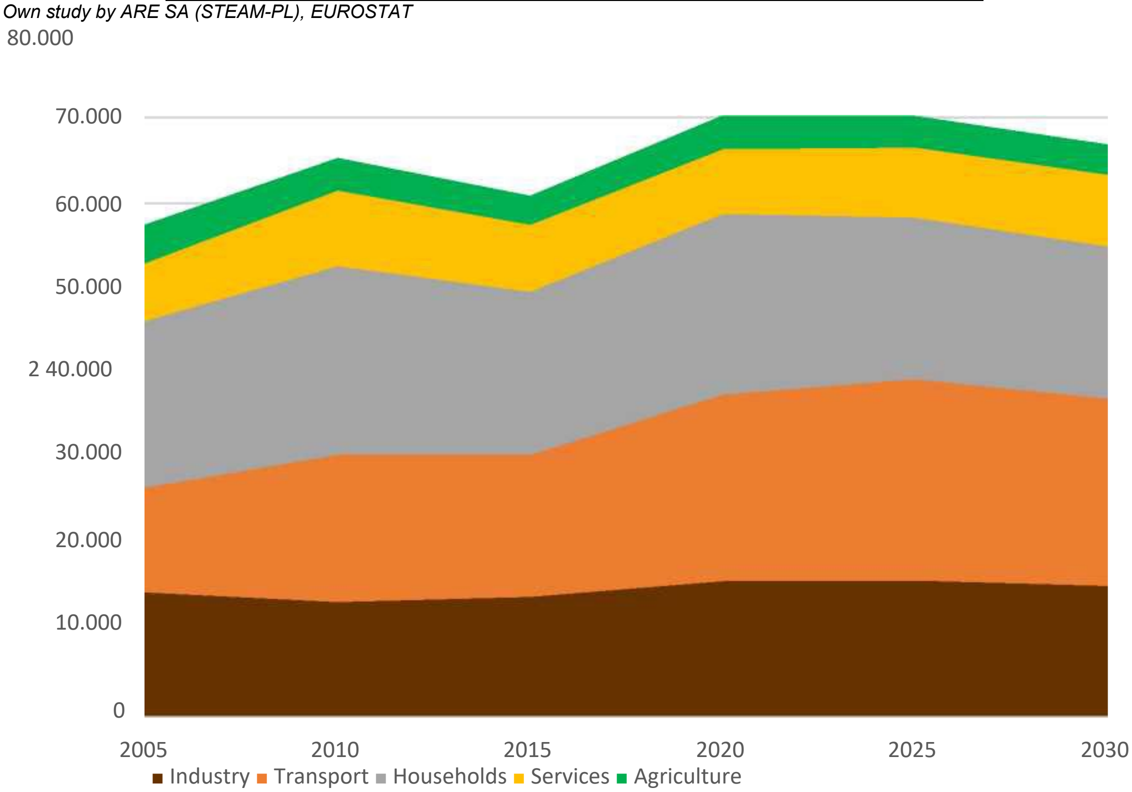


Figure 2.15. Final energy consumption by sector (without non-energy consumption)

3.1.2. Final energy consumption by fuel

The final energy consumption is subject to gradual changes in the fuel structure (Table 2.48; Figure 2.17). Coal consumption decreases significantly (from 14 % in 2020 to 6 % in 2030), while electricity and renewable energy consumption is gradually increasing. The role of natural gas is growing only until 2030. Based on assumptions, a gradual, albeit slight decrease in the demand for district heating, is also projected. It is the result of a large-scale thermomodernisation effort and an increase in the use of heat pumps in individual heating systems. The decrease in hard coal consumption (other than electricity and district heating) is mainly due to a slow but gradual process of upgrading production facilities (in the industry sector), partly due to the operation of the ETS system, resulting in a shift to fuels and carriers such as: RES or electricity. Next, the process of replacing old, inefficient domestic boilers, supported by subsidies (e.g. from the Clean Air Programme), will also influence the decrease in coal consumption. These processes are enforced, including through anti-smog resolutions introduced at regional level, which prohibit the use of solid fuel boilers that do not comply with certain environmental standards, and some introduce total bans on the use of solid fuels.

Table 2.48. Final energy consumption by fuel and carrier [ktoe]

	2005	2010	2015	2020	2025	2030
Electricity	9 028	10 206	10 990	11 806	12 821	13 687
District heat	6 634	6 547	5 462	5 603	5 272	5 085
Coal	12 340	13 733	11 218	9 335	6 275	3 684
Petroleum products	17 563	20 213	18 647	24 384	24 653	21 743
Natural gas	7 917	8 884	8 490	9 236	10 373	10 679
Biogas	40	48	78	92	131	165
Solid biomass	3 755	4 306	4 639	7 447	6 786	6 422
Biofuels	47	867	653	1 040	1498	1733
Municipal and industrial waste	136	378	486	889	894	915
Solar collectors, heat pumps, geothermal	12	69	200	404	1 341	2 246
Hydrogen	0	0	0	0	6	49
Biomethane	0	0	0	0	121	438
TOTAL	**57 473**	**65 250**	**60 863**	**70 235**	**70 171**	**66 845**

Source: Own study by ARE SA (STEAM-PL), EUROSTAT

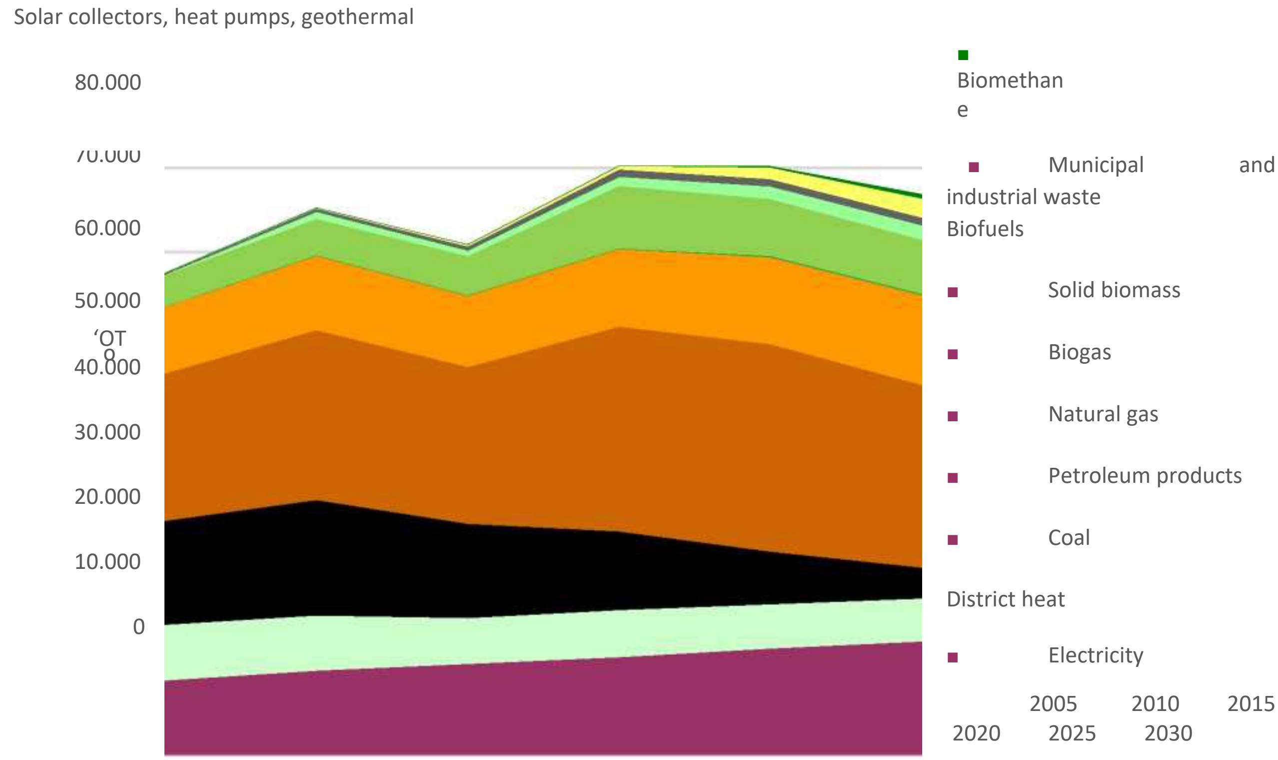


Figure 2.16. Final energy consumption by fuel and carrier

3.1.3. Non-energy use

Non-energy consumption is the amount of energy products used for the technological production of certain products (e.g. the use of natural gas for the production of synthetic fertilisers, or hard coal for the production of electrodes). The forecast assumes a moderate decrease in the consumption of all energy products used so far for non-energy purposes.

Table 2.49. Non-energy consumption by fuel [ktoe]

	2005	2010	2015	2020	2025	2030
Coal	52	54	133	64	54	55
Coke	39	1	0	33	30	27
Peat	90	30	0	11	0	0
NAFTA	672	986	1 048	1 197	1 114	1 068
LPG	73	81	138	89	90	90
Other kerosene products.	1 664	2 156	2 222	2 350	2 007	1 995
Natural gas	2 017	1 661	2 120	2 052	2 176	2 087
Hydrogen	0	0	0	0	0	66
TOTAL	**4 608**	**4 969**	**5 660**	**5 795**	**5 471**	**5 389**

Source: Own study by ARE SA (STEAM-PL), EUROSTAT

3.1.4. Primary energy intensity

The table (Table 2.50) shows the primary energy intensity indicator relative to GDP. This indicator gradually decreases throughout the period considered, reflecting ongoing processes of energy efficiency improvements. Comparisons show that energy intensity per unit of GDP has decreased in Poland over the last few decades more than twice as fast as in the EU average (by about 2005. 33 %). Calculated for 2020, the primary GDP intensity of 217 [toe/millionEUR’2020] is still almost twice as high as the Union average. Hence, the conclusion that there is still some relatively significant potential for further efficiency improvements, but there is very limited scope to achieve it in a simple way. Another issue is that the energy intensity rate based on Purchasing Power Parity (PPP), which in 2020 was 117 [toe/millionEUR] and 15 % higher than the Union average, is by far the better indicator for such comparisons.

Table 2.50. Primary energy intensity indicators relative to GDP [toe/EUR million'2020]

	2005	2010	2015	2020	2025	2030
toe/million EUR'2020	324	281	229	217	181	151
toe/PLN million'2020	81	70	55	49	41	34

Source: Own study by ARE SA

Table 4.48 shows the country's primary energy intensity per inhabitant indicator.
It is 2.72 toe/Ma in 2020 and is projected to decrease to 2.52 by 2030.

Table 2.51. Primary energy intensity indicators relative to GDP [toe/Ma]

	2005	2010	2015	2020	2025	2030
Total country	2,44	2,67	2,53	2,72	2,67	2,52

Source: Own study by ARE SA

3.1.5. Final energy intensity

The table (Table 2.52) shows the final energy intensity indicators by sector. According to the data presented, these indicators are gradually improving over the relevant time horizon in all sectors of the national economy. The significant increase in the energy intensity rate in the transport sector during the period 2015-2020 is due to the statistical correction of fuel consumption in the transport sector as a result of the introduction, on 1 July 2016, of the so-called ‘fuel package’. As a result, additional volumes of fuel consumption were revealed as a result of the elimination of the so-called shadow economy in fuel trade.

Table 2.52. Final energy intensity indicators by sector [toe/EUR million’2020]

	2005	2010	2015	2020	2025	2030
Total country	215	195	155	162	135	114
Industry	260	179	157	153	127	109
Transportation	749	1029	780	1066	851	684
of which: passenger	b.d	b.d	420	535	441	339
freight	b.d	b.d	351	520	402	339
Services	44	46	36	30	28	26
Agriculture	477	402	386	432	385	349
Households [toe/gosp.dom.]	1524	1633	1363	1405	1202	1103

Source: Own study by ARE SA

3.1.6. Fuel input for electricity and heat generation

The table (Table 2.53) illustrates fuel consumption projections for electricity and heat generation. The consumption figures presented for the period 2020-2 030 are derived from a dedicated model (MESSAGE-PL), the optimal capacity structure and production of electricity and heat in the country. A key conclusion from the results obtained is the projected gradual reduction in the use of coal (both coal and lignite) in the electricity and heating sector, driven mainly by the increasing cost of purchasing CO2 emission allowances, theneed to permanently set aside used and mostly carbon-intensive units, and the existence of other unfavourable conditions in the regulatory and market environment for carbon-intensive units. This is at the expense of increasing the share of zero- or low-carbon fuels (RES, natural gas, nuclear). In view of the functioning of the capacity market, a significant decrease in coal consumption occurs only after 2028. 4.9.1) grow significantly during this period, resulting in a rapid push from the substance curve of coal units. However, the price level of CO_2 allowances is an important factor in the uncertainty of the results obtained.

Table 2.53. Fuel input for electricity and heat generation [ktoe]

		2005	2010	2015	2020	2025	2030
Power plants	Coal	2 265	1 118	507	776	0	0
	Petroleum products	10	4	1	11	5	4
	Gas	1	0	0	0	1 254	2 031
	RES, waste	6	61	441	342	577	882
		2005	2010	2015	2020	2025	2030
CHP plants	Coal	34 392	33 935	32 375	25 695	23 655	16 290
	Petroleum products	555	563	407	364	763	723
	Gas	1 182	1 093	1 347	2 959	2 431	3 225
	RES, waste	435	1 547	2 021	1 981	2 154	2 629
	Nuclear fuel	0	0	0	0	0	0
District heating	Electric energy.	0	0	0	0	31	59

plants	Coal	3 063	3 360	2 403	2 341	1 740	1 092
	Petroleum products	52	36	16	20	35	28
	Gas	295	277	209	217	309	261
	RES, waste	40	47	42	129	310	622

Source: Own study by ARE SA (MESSAGE-PL)

3.1.7. Fuel input into other conversion processes

The transformation sector includes industrial plants where technological processes are carried out in which one form of energy (mostly primary energy carriers, e.g. coal) is converted into another derivative form of energy (e.g. electricity heat, coke, process gas, etc.). In addition to the power plants, combined heat and power plants referred to in the previous paragraph, the transformation sector also includes: refineries, petrochemicals, gas plants, coke ovens, briquettes and blast furnaces. The table (Table 2.54) shows the total fuel consumption of the other conversion processes. The data presented show a gradual decrease in fuel consumption, mainly due to the ongoing energy transition and a gradual shift away from the consumption of motor fuels in transport (the decrease concerns crude oil, petroleum products and natural gas in refineries).

Table 2.54. Fuel input into other conversion processes [ktoe]

	2005	2010	2015	2020	2025	2030
Crude oil	18 432	23 188	26 537	26 145	24 686	23 128
Coal	9 519	10 559	11 063	8 773	9 233	9 179
Petroleum products	1 085	1 703	1 906	2 697	1 579	1 476
Gas	204	308	638	558	455	401
RES, waste	0	0	0	0	0	5

Source: Own study by ARE SA (STEAM-PL)

3.1.8. Share of CHP in electricity and heat production

The development of high-efficiency cogeneration in Poland is a priority element of the current Energy Policy of February 2021. The unquestionable advantage of combined systems is their high energy efficiency, which significantly reduces the consumption of primary fuels, thus reducing CO_2 emissions and other pollutants. The main energy savings in combined systems consist of the fuller use of the energy supplied by the fuel through the management of waste heat, accompanying the process of separate production of useful heat and electricity. Around 2020 65 % of useful[24] heat comes from cogeneration, while the rest of the heat is produced in water boilers (heat and commercial heating boilers). Poland has significant potential to be exploited by converting non-environmentally compliant water boilers into cogeneration units. In addition, there are technical possibilities to use waste heat generated by waste incineration installations, industrial installations or other installations generating waste heat. Another solution is the development of micro-cogeneration and prosumer energy.

In the model simulations, the rate of development of cogeneration in Poland was determined in accordance with the forecast of useful heat demand, taking into account economic factors and assuming continued support for high-efficiency cogeneration. The results of the modelling calculations (Table 2.55) show a slight increase in the share of electricity produced from high-efficiency cogeneration from 65 % in 2020 to 66 % in 2030. Under the assumptions set out in the work, the leading technology is large gas-fired power plants (the green nature of these units, the availability of fuel and the competitiveness in the context of rising CO_2 emission allowance prices) are the leading technology.

Table 2.55. Percentage of CHP in electricity and heat production

	2005	2010	2015	2020	2025	2030

24 'Fuel and energy economy' – Central Statistical Office, Warsaw 2021

Share of association	16.8 %	17.6 %	16.2 %	20.5 %	17.0 %	17.8 %
High-efficiency cogeneration	63.9 %	61.2 %	65.1 %	64.7 %	62.5 %	65.7 %

Source: Own study by ARE SA (MESSAGE-PL)

3.1.9. Heat generation in power plants, combined heat and power plants

According to the methodology used in EUROSTAT (according to which all the statistics presented in the report have been prepared), CHP plants include units that produce even minimal heat quantities (also in processes separated by, for example, commercial heating boilers). As a natural consequence, almost all heat-producing power plants are classified as CHP plants (however, their contribution to heat production is virtually zero). The forecasts for heat production from CHP plants are the result of the cost optimisation carried out in the MESSAGE-PL model.

Table 2.56. Heat generation in power plants, combined heat and power plants [TJ]

	2005	2010	2015	2020	2025	2030
Power stations and combined thermal power plants	219 883	205 851	185 618	186 389	170 405	172 888
of which industrial waste heat	214	82	271	788	1 261	1 577
District heating plants	116 508	129 980	95 274	99 553	98 939	87 603

Source: Own study by ARE SA (MESSAGE-PL)

3.1.10. Potential of high-efficiency cogeneration

The development potential of cogeneration in the country depends on the amount of useful heat demand. The assessment shall distinguish between the following levels of potential:

- total potential, equal to total useful heat demand
- technical Potential = the part of the total potential that can actually be exploited at the current level of technology and technology
- economic potential = part of the technical potential the actual use of which is economically justifiable

According to another criterion, the total potential is divided into:

- potential already used = the share of useful heat that is currently produced in cogeneration installations
- additional potential = the portion of useful heat that is currently produced by other techniques[25].

Poland’s current total annual useful heat demand (total cogeneration potential) is estimated at 940-1 040 PJ (weather fluctuations may cause changes in annual demand of up to ± 10 %), including:

- 500-600 PJ is the needs of the household sector
- 440 PJ are the needs of economic sectors (industry – approx. 270 PJ, services – approx. 125 PJ and agriculture – approx. 45 PJ)
- 250 PJ is the heat sourced by these sectors from district heating networks
- 800 PJ is covered in individual sources and combined heat and power plants industrial heat production for their parent plants.

The additional potential is relatively small, it is about. 60 PJ heat recovery in industry and coke ovens.

From a technical point of view, full power cogeneration technologies are now available ranging from a few kW (small residential houses) to hundreds of MW (large combined heat and power plants). Hence, the technical potential of cogeneration is the total annual useful heat demand of the country, less only heat recovery in industry

[25] “Analysis of the national potential of heating and cooling. 2017 Update, Warsaw University of Technology, Warsaw 2017.

and coking plants, in which cases it would be pointless to replace recovery with any cogeneration technology. The technical potential of cogeneration in Poland is therefore estimated at 1040 – 60 = 980 PJ.

For a realistic planning of the future development of cogeneration, the relevant category is the additional economic potential, i.e. the amount of useful heat that is currently not produced by cogeneration installations and the production of which in such installations is considered economically viable after a detailed analysis.

The calculation of the additional economic potential for the development of cogeneration was carried out on the basis of an economic analysis of the effects of the implementation of cogeneration instead of separate electricity and heat generation. The efficiency of cogeneration investments was assessed using the sum of discounted financial flows (NPV) method. External costs of electricity and heat generation, i.e. social costs not passed on in the prices of energy carriers, were also taken into account.

Calculations have been made for the following technologies which are considered to be representative of the future development of cogeneration:

- technologies for large and medium-sized district heating (capacity ≥ 20 MW)
  - 50 MW steam-gas unit
  - fluidised boiler steam block of an electrical capacity of 100 MW
- technologies for small district heating (1 MW ≤ capacity & 20 MW)
  - gas turbine with an electrical capacity of 5 MW
  - 5 MW steam block
  - 5 MW electrically powered gas engine
- micro-cogeneration technologies (power & 1 MW)
  - gas engine with an electrical power of 0.5 MW
  - gas turbine with an electrical capacity of 0.3 MW

The results of the additional economic potential show that CHP investments are socially viable (NPV > 0) already with a relatively short period of power utilisation (even below 2 700 hours per year). In order to rationalise profitability, installed capacity utilisation times typical for CHP plants – 4600 h per year for CHP plants generating heat for heating buildings and CWU and 6000 h per year for industrial combined heat and power plants were used.

The problem of time of capacity utilisation is different from the investor's perspective. Given that electricity and heat prices do not pass on all external costs (and thus do not reflect the real costs and benefits of using a given generation technology), the construction of short-time cogeneration installations would carry a high risk of not achieving the required profitability of the project. Therefore, in order to determine the economic potential of cogeneration, the timescales typical of CHP plants have been used to use the installed capacity:

- 4 600 hours per year for heat-generating plants for heating buildings and domestic hot water,
- 6 000 hours per year for industrial combined heat and power plants.

As a result of the overall calculation, the total additional economic potential of cogeneration was found to be 190 PJ of heat. In order to make full use of this potential, cogeneration installations with a total electrical capacity of approx. should be built. 10 GW and total heat output approx. 11 GW. These installations would produce 182 PJ of heat and 46 TWh of electricity each year, which would save around an annual amount of approx. 250 PJ primary energy and reduce carbon emissions by 25 million tonnes.

The analysis also made it possible to recommend specific cogeneration technologies which are most cost-effective in current price relationships:

- for large district heating systems (power > 50 MW), evaporative systems or steam units;
- for smaller systems, internal combustion engines and, in selected cases, gas turbines;
- for micro-cogeneration systems in residential buildings, microturbines, internal combustion engines or Stirling engines.

In addition to cogeneration heat, district cooling production is also assessed as a forward-looking energy efficiency advantage. For climate reasons, the role of space cooling in Poland is not as large as in southern European countries. However, many buildings, mainly in the service sector, have air-conditioning equipment installed. Existing air conditioning equipment is generally local, powered by electricity, and district cooling distribution is in Poland in a test phase or very modest applications. In this respect, the situation of air conditioned buildings is similar to that of buildings heated by their own individual sources of heat. The national total potential for cooling production, limited to its primary use, i.e. the tertiary sector, was assessed at 19 PJ, which is twice as low as the heating needs of its buildings26.

4.The dimension "Energy security"

4.1. National energy resources

Hard coal

According to data from the State Geological Institute (PIG), the documented balances of hard coal deposits at the end of 2022 amounted to 64 615 million tonnes. 71 % of the resources were energy coals, less than 28 % were coking coals and other types of coal represented only 1.2 %. Managed deposits accounted for 43 % of the balance sheet stock (27 828 million t). The industrial resources of developed deposits amounted to 4 266 million tonnes. Coal mining in 2022 amounted to 46.5 million tonnes.27

Despite the declining coal extraction since the beginning of the 1990s (Figure 2.21), no restrictions on the supply of this raw material are expected. Assuming extraction at 2022 level, industrial resources will be sufficient for at least 40 years. For the purposes of this analysis, it is assumed that future demand will be covered to the extent possible by domestic coal and complemented by imports. Coal due to the location of resources in areas free from armed and political conflicts, the high efficiency of the logistics network, the availability of new deposits and the availability of highly developed mining technologies, should remain available in the long term and its price should be stable. Current information on the state of the world's coal stock is optimistic and suggests that at the current level of coal mining it should be sufficient for about 200 years.

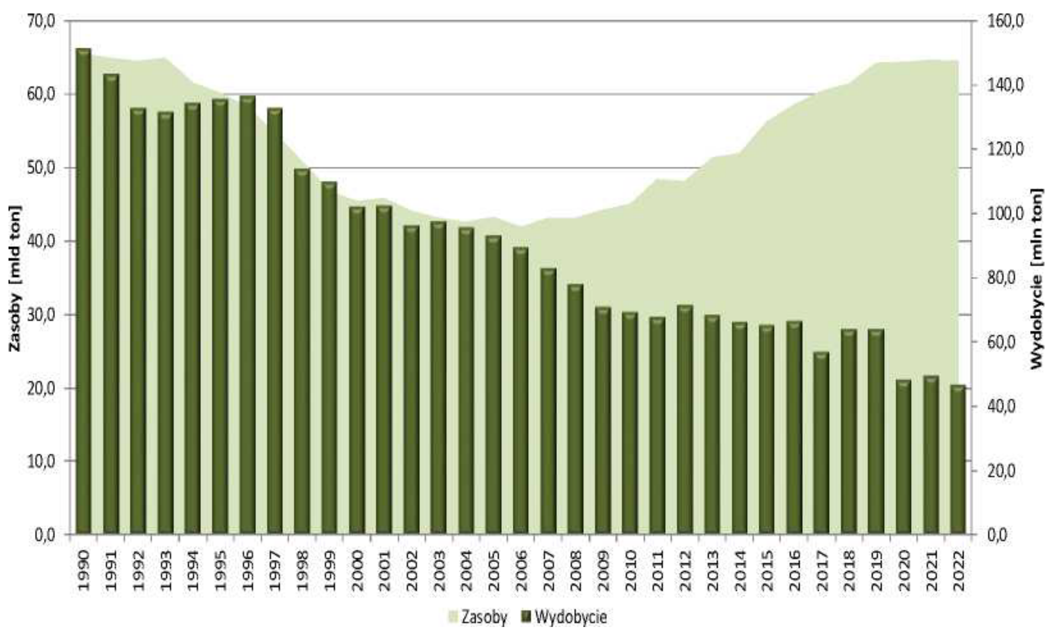


Figure 2.17. Coal resources and mining in Poland from 1990 to 2022

Source: State Mining Institute – EIG

Brown coal

As at 31 December 2022, the geological balances of lignite amounted to 23 084 million tonnes.

26Ibid

27'Balance of resources of mineral deposits in Poland as at 31 December 2022' – National Geological Institute. Warsaw, June 2023

Managed deposits currently account for 4.3 % of the balance sheet resources and amount to 982 million tonnes.

On the other hand, lignite industrial reserves amount to 819 million tonnes. In 2022, according to the data reported by the PIG, the output amounted to 57.7 million tonnes (Figure 2.22).

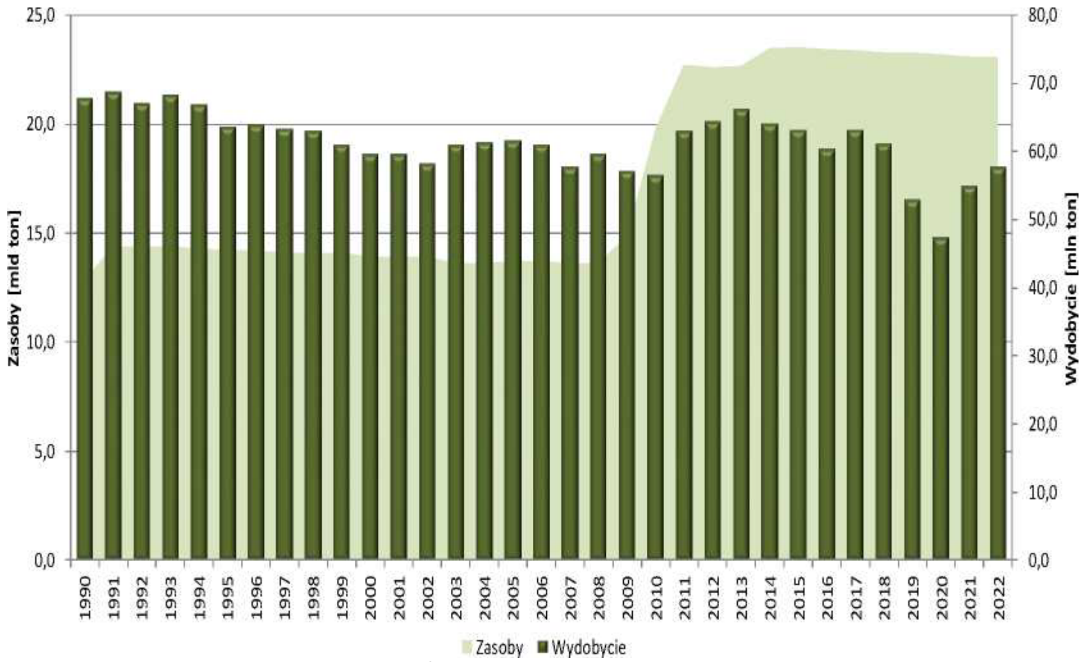


Figure 2.18. Lignite resources and extraction in Poland from 1990 to 2022

Source: PIG

Natural gas

According to the data provided by the EIG, the state of extracted natural gas balance sheet resources in 2022 was 153.5 billion m^3 (Figure 2.23). The total extracted resources of managed natural gas deposits amounted to 104.8 billion m^3 in the year analysed, representing 68 % of the total amount of extracted resources. The industrial reserves of natural gas in 2022 stood at 78 billion m^3. In 2022, the extraction of natural gas from deposits with documented resources amounted to 4.7 billion m3.

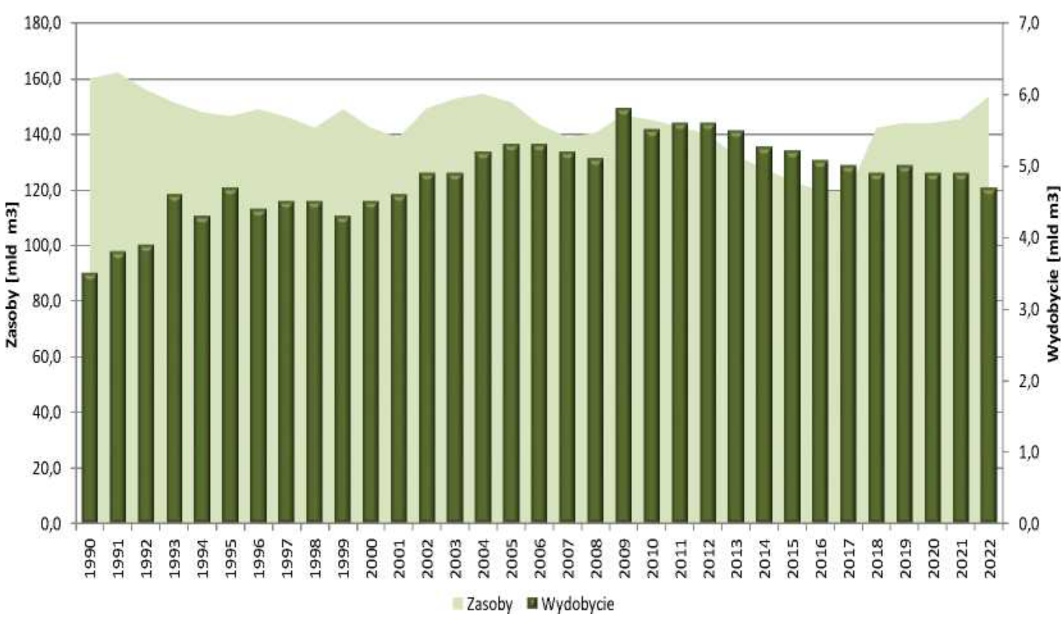


Figure 2.19. Natural gas resources and extraction in Poland from 1990 to 2022

Source: PIG

Nuclear fuel

Poland does not have an amount of uranium ore deposits for which exploitation would currently be profitable, although the exploitation of these deposits is not excluded in the future. On the global market, nuclear fuel is widely available (this concerns both uranium ore and the conversion capacity to uranium hexafluoride and the capacity of enrichment and reactor fuel elements production facilities). It is therefore assumed that nuclear fuel resources will not slow down the pace of development of nuclear power in view of the forecast and operation of EJ and its price will remain relatively stable.

Biomass

Biomass in Poland has the highest technical potential from all national renewable energy sources. The technical potential taking into account solid biomass from agriculture (energy crops and crop waste), food processing and biogas was estimated at 900 PJ/year in 203028. However, the use of biomass for energy purposes should be seen locally. Production units using biomass should be located close to the production site in order to minimise the CO2 emissions associated with the transport of biomass29.

The analysis assumes that the supply of this raw material will not limit the development of technologies based on biomass fuels, although such a situation cannot be ruled out altogether, as the development of this sector in the country is conditional, inter alia, on the functioning of support schemes and on the availability limited by the need to meet sustainability criteria.

Agricultural biogas

The resources of domestic wet biomass of agricultural origin that can be used locally for the production of electricity in agricultural biogas plants make it possible to reach around a level of production by 2030. 4.4 TWh. The resources of national wet biomass also allow for the significant development of agricultural biogas plants producing heat from cogeneration. The potential for heat production for 2030 was estimated at 45 PJ.30

Other biogas

The potential for using landfill biogas and waste water treatment plants to produce electricity is estimated to be around. 1.3 TWh by 2030. If biogas is used for the production of heat in cogeneration, potential opportunities of 6.2 PJ are projected for 2030[38]

Biomethane

Biomethane is a purified biogas that is suitable for the quality of natural gas and can be injected into the gas network. The estimated total biomethane production potential in Poland is around. 8 billion m^3/year. Biomethane can be used in electricity in installations currently using natural gas, in the transport sector because biomethane consumption is counted towards the National Indicative Target (NCW), in industry and heating instead of natural gas, and in the production of green hydrogen.

Geothermal

Theoretical geothermal energy reserves in Poland are unlimited, but relatively few in places where it is economically meaningful. The potential for heat production from installations other than heat pumps using deep rock heat has been assessed taking into account the significant economic constraints in their use. These potentials have been identified at 45 PJ by 2030.

Water

The hydropower potential in Poland is limited by the country's hydrological conditions. The Institute of Renewable Energy assesses the real economic potential of hydropower in Poland, including the Lower Vistula cascade (3 TWh/year), at approx. 30 PJ (8 TWh/year) of which approx. is currently used. 25 %.

28'Assessing the resources of renewable energy sources technically and economically feasible for electricity generation'. Report to the Polish Electricity Committee carried out by System Research EnergSys sp. z o.o. Warszawa 2008

29Jagustyn B., Bątorek-Giesa N., Wilk B., Assessment of the properties of biomass used for energy purposes, chemistry 2011, 65, 6, 557-563

30"Development of forecasts of final energy demand, RES development and improvement of energy efficiency for 2021-2030"- Ernst&Young. Warsaw, November 2017

Wind

According to Ernst &Young estimates, Poland has wind resources that create economic potential to install up to approx. 30 GW of capacity in onshore wind farms by 2030. However, the existence of environmental, infrastructural and regulatory constraints should be taken into account in the assessment of real potential. The real potential for the construction of wind farms at sea, as identified by the Polish Wind Energy Association (PSEw), is based on the opportunities on the Polish Baltic coasts and an analysis of the pace and prospects of development of this technology in other countries. According to these data, the potential of such units is approx. 33 GW by 2050[31]

Solar

On the basis of analyses carried out on the development of large PV installations in other European countries and the observed cost trends, the real potential for developing this technology was estimated to be 30-35 GW by 2030. However, the state of the network infrastructure, which makes it impossible to connect many new sources, is a powerful constraint on the development of this technology (as well as other RES technologies). In the coming years, significant funding is expected to be directed towards removing the bottleneck in the form of network constraints.

4.2. National energy mix 2005-2020

Between 2005 and 2020, national primary energy production decreased by about. 26 %. Overall primary energy production decreased from 77.9 Mtoe to 58.0 Mtoe over the period analysed. However, attention should be paid to the fact that 2020 was a crisis year in the context of COVID-19 energy demand. In principle, the decrease in primary energy production only affects the coal sector, as natural gas extraction fell only slightly during this period. The share of coal in total primary energy production decreased from 88 % in 2005 to 69 % in 2020. Renewable energy is the only group of energy carriers whose production increased markedly in those years. Energy production from RES almost tripled over this period and its share of total primary energy production increased from 6 % in 2005 to 22 % in 2020.

Net imports of energy increased significantly during the period under review. The increase was significantly affected both by an increase in imports of oil and liquid fuels (by more than 30 %), of natural gas (by 60 %) and by a decrease in hard coal exports. The import/export balance of hard coal in 2020 was close to zero.

Gross inland consumption of energy fluctuated in the range of 92-103 Mtoe between 2005 and 2020, with the main reasons for this volatility being: uneven GDP growth, energy efficiency improvements and volatile weather conditions. The share of liquid fuels (from 24 to 28 %), natural gas (from 13 to 17 %) and renewable energy (from 5 to 13 %) has increased in the composition of gross inland energy consumption in the years in question. In turn, the share of solid fuels decreased from 59 % to 40 % over this period. Final energy consumption fluctuated in the period 2005-2020 similar to gross inland consumption, with a share of 63-68 % in gross consumption.

Between 2005 and 2020, Poland's dependence on energy imports increased dramatically from 17 % to 43 %, with net imports almost tripling. At the time, the import dependency was the highest for liquid fuels (ca. 97 % – stable over a multi-annual period) and high for natural gas (over 70 % – a mildly growing trend). Total import dependency has been reduced by significant net exports of solid fuels, mainly coke.

Table 2.57. National Energy Balance Sheet 2005-2020 (Mtoe)

	2005	2010	2015	2020
Total primary energy production	77,9	66,7	67,3	58,0
of which: coal and lignite	68,4	55,1	53,6	40,0
crude oil	0,9	0,7	0,9	0,9
natural gas	3,9	3,7	3,7	3,4

31Offshore wind energy potential. Comprehensive analysis of the possibilities for developing offshore wind energy in Polish offshore areas. Polish Wind Energy Association, Warsaw 11/2022

renewable energy	4,5	6,8	8,6	12,5
other	0,2	0,4	0,5	2,1
Net imports of energy	15,9	31,5	28,0	44,2
of which: fuels	—13,0	—2,8	—5,6	0,1
liquid fuel	21,5	25,2	23,3	28,8
natural gas	8,5	8,9	9,9	13,6
renewable energy	0,0	0,4	0,4	0,4
other	0,0	0,0	0,0	0,0
Gross inland consumption of energy	92,2	100,7	95,4	103,0
of which: fuels	54,6	54,6	48,3	40,9

	2005	2010	2015	2020
liquid fuel	21,7	25,7	23,9	29,4
natural gas	12,2	12,8	13,8	17,4
renewable energy	4,5	7,3	9,0	13,0
other	0,2	0,4	0,5	1,1
Final energy consumption	58,5	66,3	62,3	70,2
Import dependency – total	17.2 %	31.3 %	29.8 %	42.8 %
fuels	—23.9 %	—5.2 %	—11.4 %	0.3 %
liquid fuel	97.5 %	97.0 %	96.8 %	96,9
natural gas	69.7 %	69.3 %	72.2 %	78,3
Share of energy from renewable sources in gross final energy consumption	6.9 %	9.3 %	11.8 %	16.1 %

Source: EUROSTAT, ARE S.A.

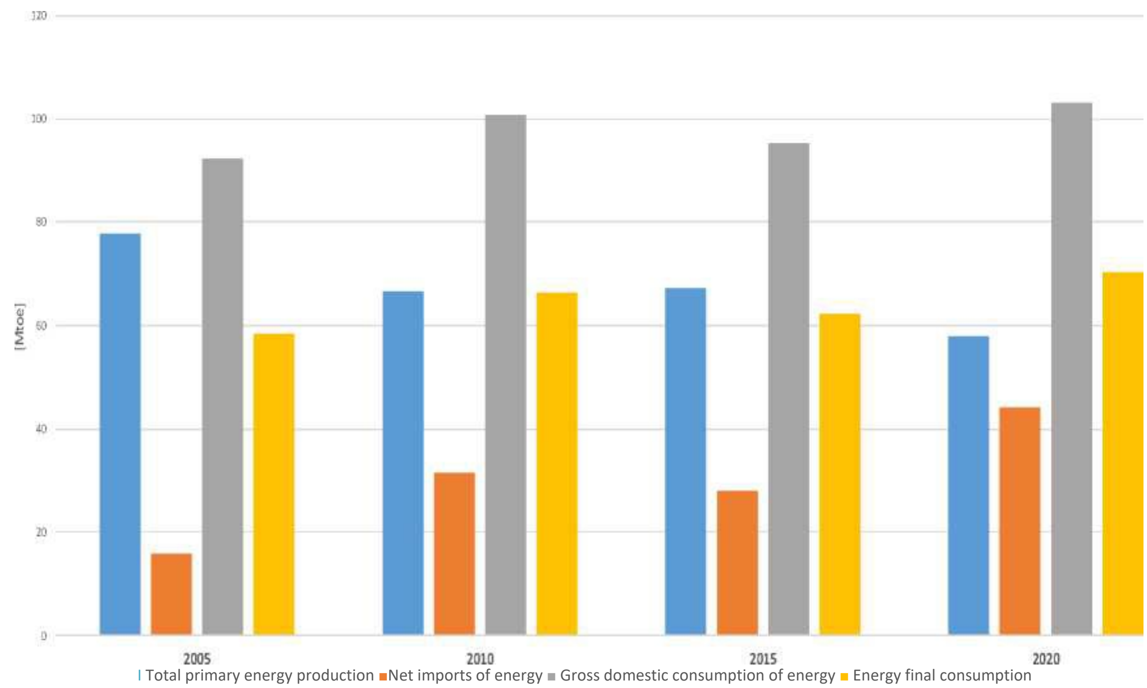


Figure 2.20. National energy balance 2005-2020

Source: ARE S.A.

4.3. Domestic production by fuel type

The table below shows the national supply of individual fuels and energy carriers with a view to 2030. The following conclusions can be drawn from the results obtained:

- In the period 2020-2030, the supply of hard coal continues to follow the downward trend observed between 2005 and 2020. The extraction of this raw material could be reduced from 42 million tonnes in 2020 to around. 30 million tonnes in 2030 (in line with the notification proposal for hard coal mining). The reduction in production in this case is linked to a decrease in demand in all sectors of the national economy, including electricity and heating in particular. There is no economic justification for the construction of new coal-fired units under the conditions laid down in the calculation of the price level of CO2 emission allowances, the ever-increasing environmental requirements and a clear anti-carbon EU policy.
- Demand for hard coal will also fall in the industry sector (in particular in industrial plants covered by the ETS and as a result of the process of progressive modernisation of production processes). As part of the fight against smog in urban households and services, inefficient backup boilers will be gradually replaced by zero- or low-carbon boilers (RES, natural gas, system heat). The pace of these developments depends

on a number of factors, including the speed at which funding is raised for mechanisms to support this process. The WEM scenario assumes active and large-scale government actions. The main driving force behind this process is the financial support from EU funds, such as the programmes implemented so far. "Clean air", "Stop smog", as well as the increasing availability of new clean technologies and changing public awareness. Fighting against so-called "low emissions" is one of the top priorities of the new government. Much more funding than hitherto is likely to be directed towards thermomodernisation of buildings and the process of replacing old inefficient filling furnaces with solid fuels.

- The forecast assumes a stabilisation of the extraction of coking coal (closely linked to coke production) at around the level. 10 Mtoe. Domestic and foreign demand for coke is determined by the pace of global economic growth and is therefore subject to significant and unpredictable fluctuations.
- Lignite supply is significantly reduced already after 2025 (mainly as a result of the shutdown of depleted power units and the depletion of part of the deposits). The analysis did not envisage the launch of new lignite deposits. Under the assumptions made with regard to the cost of CO2 permits, the operation of power-generating facilities and the launch of new opencasts is not an economically justified option.
- The extraction of crude oil in the country represents a small percentage of the demand for this raw material and there is no significant increase in production over the relevant time horizon. The challenge for operating extractive companies will be to keep production at levels similar to those achieved between 2005 and 2020.
- Natural gas extraction in Poland should remain stable at around the level. 3.3 Mtoe per year.
- Uranium ore extraction and conversion into nuclear fuel are not foreseen in the country.
- Domestic production of biofuels (mainly HVO/coHVO I and generation II) is expected to increase due to the growing demand in the transport sector and the properties of these substances to replace conventional fuels without significant technical constraints.
- Biomethane is a fuel that plays an important role in the vision presented in the WEM scenario for the development of the fuel and energy sector. The use of biomethane is an important element contributing to the country's energy security and rural development. The analysis assumes the deployment of domestic production from 2025 onwards and the use of this fuel as a priority in the transport sector. The use of biomethane is primarily intended to help achieve the overall RES target and the sectorial target for transport).
- It is expected to stabilise the yield of solid biomass in 2020-2030 at around the level. 9 Mtoe. With the increase in the price of CO2 emission allowancesin the electricity and heating sectors, the cost-effectiveness of biomass use in both dedicated boilers, hybrid systems and coal co-incineration installations is increasing. While the use of this fuel is projected to increase further in these sectors, a limiting factor in the use of biomass is the need for the fuel to meet the sustainability criteria. In households and services, biomass consumption will decrease as the heat pump market develops, which will gradually crowd out biomass boilers.
- Compared to 2020, the use of municipal and industrial waste for energy purposes is projected to increase slightly as a result of the assumption that investments in waste incinerators have started in Poland's largest cities. In view of the need to replace coal blocks with cleaner energy sources and the inability to recycle part of this waste, this would seem appropriate. However, high emissions related to waste incineration are a problem, which, in the context of the inclusion of such installations in the ETS as of 2026, is a brake on the wider use of waste for energy purposes.
- In the long term, the use of "green hydrogen" as a missing link in the country's energy transition is foreseen. Hydrogen will play an important role in the transformation of the transport, industry and heating sectors. In the electricity sector, hydrogen can act as a source of flexibility in systems with a high share of RES sources.

Table 2.58. Domestic production by fuel type [ktoe] – WEM scenario

	2005	2010	2015	2020	2025	2030
Hard coal	45 736	35 302	32 136	22 554	22 010	16 233
Coking coal	9 948	8 216	9 155	8 654	7 685	7 619
Coke	5 721	6 701	6 666	5 205	5 558	5 586
Brown coal	12 736	11 559	12 299	8 824	8 587	3 997
Crude oil	840	681	922	934	1 000	1 000

LPG	312	466	632	749	524	496
Gasoline	4 415	4 326	4 046	4 089	4 218	4 026
Diesel	7 643	10 743	12 075	13 253	12 265	10 798
Natural gas	3 884	3 693	3 683	3 396	3 300	3 300
Nuclear fuel	0	0	0	0	0	0
Biofuels	117	446	936	973	1 403	1 622
Biomethane	0	0	0	0	120	438
Solid biomass	4166	5 866	6 268	8 964	8 621	9 023
Municipal and industrial waste	157	400	564	1 193	1 316	1 439
Green hydrogen	0	0	0	0	6	51

Source: Own study by ARE SA (STEAM-PL)

4.4. Net imports by fuel type

The table (Table 2.60) summarises the state of play and forecasts of net imports of fuels and energy carriers. The following conclusions can be drawn from the data presented:

- the continued existence of a positive balance of hard coal imports with a view to 2030 due to differences in the cost of supplying coal from the domestic market and foreign directions (to the detriment of domestic coal),
- exports of coking coal remain stable. The lack of sufficient sources of supply of its own means that the European Union is wholly dependent on imports of coking coal and Poland is the only producer in the EU alongside the Czech Republic. Polish producers benefit from a so-called 'geographical pension';
- a gradual decrease in dependence on imported oil supplies as a result of the transformation of the sector towards technological diversification (e-mobility development and increased use of alternative fuels);
- a gradual decrease in dependence on the supply of finished fuel products (LPG, petrol, SA),
- an increase in the supply of natural gas from abroad towards 2030, followed by a gradual decrease in import dependency as a long-term outcome of the transition;
- the need to import nuclear fuel into newly established nuclear units, as Poland does not have the amount of uranium deposits for which exploitation would be profitable, although the exploitation of these deposits is not excluded in the future. Nuclear fuel is widely available on the global market (this concerns both uranium ore and the conversion capacity to uranium hexafluoride and the capacity of enrichment and reactor fuel units, so imports are likely to be cheaper).
- low level of imports of biomass and biofuels, given that domestic production is rewarded in the forecasts submitted.

Table 2.59. Net import/export balance [ktoe]

	2005	2010	2015	2020	2025	2030
Hard coal	—8 161	489	—1 588	4 865	2 892	1 896
Coking coal	—1 801	944	275	—634	148	223
Coke	—3 068	—4 227	—4 333	—4 115	—3 983	—4 101
Brown coal	—2	—19	16	19	11	5
Crude oil	17 741	22 484	26 311	25 418	23 974	22 418
LPG	2 172	1 974	1 868	1 838	1 934	1 479
Gasoline	—69	111	—204	187	371	332

Diesel	2 260	2 202	309	4 124	4 949	4 210
Natural gas	8 531	8 874	9 947	13 647	15 056	16 628
Nuclear fuel	0	0	0	0	0	0
Biofuels	—65	427	—144	67	96	110
Biomethane	0	0	0	0	0	0
Solid biomass	0	0	506	366	341	371
Hydrogen	0	0	0	0	0	0

Source: Own study by ARE SA (STEAM-PL, MESSAGE-PL), EUROSTAT

The analysis assumes a zero import/export balance for electricity, which does not mean that the model calculations exclude the possibility of exporting and importing electricity to and from neighbouring countries. Given the increasing integration of the electricity market, price relationships conducive to cross-border trade and the differences between systems in terms of e.g. fuel mix of energy sources, a non-zero import/export balance is very likely, however, the determination of energy flow directions on interconnections due to high volatility and increasing market liquidity is subject to high uncertainty. This assumption is based on the objectives set out in the objectives for updating PEP2040 – Strengthening energy security and independence with regard to building energy independence.

Table 2.60. Net import/export balance of electricity [ktoe]

	2005	2010	2015	2020	2025	2030
Electricity	—962	—116	—29	1 141	0	0

"-" before value indicates export
'+' sign before value denotes imports
Source: Own study by ARE SA (MESSAGE-PL), EUROSTAT

The degree of dependence on imports from third countries is defined as the total volume of energy imports from non-EU countries by gross inland consumption of energy

Table 2.61. Dependence on imports from third countries

	2005	2010	2015	2020	2025	2030
Electricity	1.4 %	0.0 %	0.0 %	0.9 %	0.0 %	0.0 %
Hard coal	4.2 %	13.1 %	8.6 %	22.3 %	18.3 %	18.3 %
Coking coal	0.3 %	18.3 %	17.0 %	16.1 %	19.8 %	20.9 %
Coke	0.5 %	1.2 %	2.0 %	3.8 %	5.5 %	6.2 %
Brown coal	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %
Crude oil	98.0 %	98.2 %	101.1 %	96.5 %	96.9 %	96.7 %
LPG	47.3 %	64.1 %	68.9 %	55.5 %	87.5 %	87.0 %
Gasoline	0.0 %	0.0 %	0.0 %	0.0 %	9.2 %	8.8 %
Diesel	10.7 %	0.9 %	4.5 %	17.3 %	31.3 %	30.5 %
Natural gas	67.7 %	61.8 %	52.6 %	67.7 %	64.9 %	67.8 %
Nuclear fuel	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %
Biofuels	0.0 %	0.0 %	6.4 %	3.7 %	1.2 %	1.2 %
Biomethane	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %
Solid biomass	0.0 %	0.0 %	8.4 %	6.5 %	6.2 %	6.2 %
Hydrogen	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %

Source: Own study by ARE SA

4.4.1. Main sources of imports

For the main sources of imports, an expert approach was used, based on an analysis of past supply directions and prospects for the emergence of new sources of imports (Table 4.62). With regard to natural gas, significant changes occurred in 2022 and 2023. Poland has completely phased out its dependence on imports from the Russian Federation and replaced this direction mainly with supplies from Norway (Baltic Pipe) and Germany (pipeline transport) and other countries via the LNG terminal (mainly the US and Qatar). As a result of the key diversification investments completed in 2022, i.e. the construction of the Baltic Pipe pipeline and the increase of the regasification capacity of the LNG terminal in Świnoujście, the historic route of gas supply from east-west direction to the north-south direction was changed. As part of the diversification policy, interconnections with Lithuania and Slovakia have also been activated[32].

Still in 2022, the largest oil supplier to Poland was the Russian Federation. 11.7 million tonnes of raw material were brought to Poland, representing 47 % of total oil imports. Russian oil imports have gradually decreased every quarter. Poland suspended imports of Russian oil by sea in August 2022, while on 25 February 2023, the Russian side unilaterally halted the supply of crude oil via the 'Przyjazhń' pipeline. According to external trade statistics, there were no longer any imports of oil from the Russian Federation in March and April 2023. Poland's most important oil supplier since Q1 Saudi Arabia became Saudi Arabia in 2023. Today, the share of the country's supply is at 65 % of total oil imports. Norway is the second most important importer of oil to our country, but its importance is much less important. On the other hand, supplies from other countries are mainly based on spot purchases. Germany is currently the largest supplier of diesel and petrol to Poland. Dynamic changes in import patterns indicate that the direction of supply is closely influenced by market conditions.

Coal imports in 2022 were at record levels due to the European energy crisis. Coal was imported into the country from many different directions (except for Russia, which was abandoned in April 2022). Most coal was imported into Poland from South Africa (3.4 million tonnes) and Colombia (3.3 million tonnes), accounting for more than 40 % of Poland's coal imports. Kazakhstan, Australia and Indonesia were also important suppliers. Imports are projected to decline significantly in subsequent periods as a result of their gradual phase-out in all sectors of the domestic economy.

The only fuel currently imported from the Russian Federation is LPG. Nevertheless, the 12 package of sanctions under preparation envisages an embargo on this product, so it will be necessary to change this direction of supply. Sweden is likely to become the largest importer of LPG, but as with other petroleum products, market conditions will determine this.

As regards electricity, Poland was and is a self-sufficient country. Cross-border trade with both EU and non-EU countries is complementary to domestic production and its direction and volume is driven by dynamic energy prices on wholesale markets. Due to electricity system configurations and cross-border interconnection capacity, the main electricity import destinations are Germany and Sweden, while Slovakia and Czechia export.

Table 2.62. Main sources of imports (countries)

	2005	2010	2015	2020	2025	2030
Electricity*	Germany	Germany	Sweden	Sweden	Sweden	Sweden
	Ukraine	Sweden	Germany	Germany	Germany	Germany
	Belarus	Czechia	Czechia	Lithuania	Lithuania	Lithuania
Hard coal	Russia	Russia	Russia	Russia	RPA	Australia
	Ukraine	Czechia	Czechia	Australia	Colombia	Colombia
		Ukraine	Colombia	Colombia	Kazakhstan	Kazakhstan
Coking coal	Czechia	USA	Australia	Australia	Australia	Australia
	Australia	Czechia	Czechia	USA	USA	USA
	Germany	Australia	USA	Russia		
Coke	Czechia	Czechia	Russia	Russia	Australia	Australia
		Russia				
Brown coal	— —	Germany	Czechia	Germany	Germany	Germany
			Germany			
Crude oil	Russia	Russia	Russia	Russia	Saudi Arabia	Saudi Arabia
		Norway	Iraq		Norway	Norway
Diesel	Belarus	Germany	Germany	Russia	Germany	Germany

32 Report on the results of the safety monitoring of gaseous fuels for the period from 1 January 2022 to 31 December 2022.

	Germany	Lithuania	Russia	Germany	Lithuania	Lithuania
		Slovakia	Belarus	Belarus	Slovakia	Slovakia
Gasoline	Slovakia	Germany	Slovakia	Germany	Germany	Germany
	Germany	Slovakia	Germany	Slovakia	Slovakia	Slovakia
LPG	Russia	Russia	Russia	Russia	Sweden	Sweden
	Kazakhstan	Kazakhstan	Kazakhstan	Sweden	Norway	Norway
Natural gas	Russia	Russia	Russia	Russia	Norway	Norway
	Uzbekistan	Germany	Germany	USA	USA	USA
	Kazakhstan		Qatar	Qatar	Qatar	Qatar
Nuclear fuel	— —	— —	— —	— —	— —	— —
Biofuels	— —	b.d.	Germany	Germany	Germany	Germany
			Netherlands			
			Switzerland			
	2005	**2010**	**2015**	**2020**	**2025**	**2030**
Solid biomass	Belarus	Belarus	Belarus	Belarus	b.d.	b.d.

Source: Own study by ARE SA

4.5. Gross inland consumption of fuels and energy

The gross inland consumption of individual fuels and energy carriers, as shown in the table (Table 2.63), has been calculated according to the following algorithm:

(+) Final consumption
(+) Energy sector consumption
(+) Consumption in the transformation sector
(−) Transmission and distribution losses
(±) statistical differences
(=) Gross inland consumption of energy
The following conclusions can be drawn from the data presented:

- An increase of 13 % in domestic electricity consumption between 2020 and 2030. The average annual growth rate of this category over the period considered is 1.7 %. Electricity consumption is increasing in all sectors, with the most significant increases in transport, heating and industry. In the transport sector, electricity consumption in road transport is expected to increase (e-mobility). The forecast assumes that by 2030 Polish roads will be circulating around. 870 thousand, consuming 0.51 TWh respectively. The increase in electricity consumption in industry will mainly be linked to the modernisation and automation of production facilities. As a result of the energy transition process, solid and gaseous fuels will be replaced by technical solutions using electricity.
- The significant increase in electricity consumption in the transformed energy mix will concern the use of heat pumps in heating. The development of individual heat pumps will increase electricity demand in households, while the use of centralised heat pumps in district heating plants will increase demand in the energy sector.
- The heat demand from the grid is projected to decrease slightly, as a result of assumptions regarding the rate and scope of energy renovation of buildings, the speed and extent of new customers' connections and market conditions. The forecast assumes that the measures taken to combat low emissions will stimulate investment in the development of district heating networks, while the assumed increase in the price of CO_2 emission allowances will lead to a gradual loss of competitiveness in comparison with individual heating technologies, especially in the initial forecast period. However, this assumption is subject to uncertainty regarding fuel prices and CO_2 emission allowances.
- The consumption of coal and lignite is projected to fall due to energy transition processes. The decrease in coal consumption in electricity and heating significantly accelerates around 2030, when the capacity market for most coal blocks ends.

- The consumption of crude oil and petroleum productsis projected to decrease over the period under review. The increase in oil consumption observed between 2015 and 2020 was linked to the introduction of a package of laws in Poland limiting the so-called grey economy in fuel trade. From 2020, a gradual reduction in the use of motor fuels and a gradual substitution of alternative fuels is foreseen. Improving energy efficiency also plays an important role in this regard, including the gradual decline of specific fuel consumption rates for new vehicles, as envisaged by EU legislation.

- The results of the analyses show an increase in domestic demand for natural gas over the 2030 horizon (from 17.1 Mtoe in 2020 to 21.8 Mtoe). Natural gas in Poland will play a role as a transitional fuel in the energy transition, but only in the initial 10-15 summer period. Later it will be gradually replaced
- The demand for renewable energy sources is expected to increase further gradually, such as: biomass, biogas, biofuels.

Table 2.63. Gross inland consumption of fuels and energy [ktoe] – WEM scenario

	2005	2010	2015	2020	2025	2030
Electricity	12 532	13 440	14 154	14 730	15 757	16 628
District heat	8 032	8 021	6 721	6 843	6 427	6 226
Hard coal	37 651	39 774	31 248	28 188	22 006	16 230
Coking coal	7 891	8 700	9 489	7 997	7 833	7 841
Coke	2 318	2 074	2 228	1 308	1 575	1 484
Brown coal	12 726	11 579	12 299	8 850	8 598	4 002
Crude oil	18 459	23 184	26 506	25 992	24 686	23 128
Petroleum products	21 987	25 956	24 074	31 037	31 789	28 697
Natural gas	12 235	12 805	13 776	17 107	18 356	19 928
Coke oven gas	1 447	1 707	1 704	1 406	1 221	1 118
Blast furnace gas	560	526	632	464	551	458
Other gaseous fuels	161	149	163	84	83	81
Solid biomass	4 166	5 866	6 884	9 330	8 962	9 394
Biogas	54	115	229	322	535	755
Biofuels	54	868	782	1 042	1 498	1 733
Biomethane	0	0	0	0	120	438
Nuclear fuel	0	0	0	0	0	0
Hydrogen	0	0	0	0	6	51
Municipal and industrial waste	157	400	564	1 193	1 316	1 439

Source: Own study by ARE SA (STEAM-PL, MESSAGE-PL), EUROSTAT

4.6. Public electricity and heat production

Data on gross electricity and district heating production in Poland are presented below. According to the forecast results, domestic electricity production is projected to increase from 158.2 TWh in 2020 to 197 TWh in 2030. The percentage increase in 2020is 25 %. Domestic production of network heat, in turn, falls from 286 PJ in 2020 to approx. 260 PJ in 2030

Table 2.64. Gross electricity and district heating production

	2005	2010	2015	2020	2025	2030
Electricity [GWh]	157 295	158 186	165 128	158 247	184 829	196 900
District heating [TJ]	336 292	335 831	274 357	285 870	268 062	259 586

Source: Own study by ARE SA (STEAM-PL, MESSAGE-PL), EUROSTAT

4.6.1. Gross electricity production by fuel

The electricity production by fuel is shown in the table (Table 2.65) and in Figure (Figure 2.26). The results of the analysis carried out on the development of the national electricity sector show dynamic changes in the structure of electricity production due to conditions determined mainly by the EU's energy and climate policy. The stimulated development of renewable energy sources and the obligation to purchase the corresponding amounts of CO2 emissionallowances under the ETS will result in a gradual decline in the share of coal-fired power plants in the electricity production structure. Electricity production from coal and lignite in power plants and combined heat and power plants is expected to decrease significantly over the course of this decade. Electricity generation in el. and ec for hard coal falls from 70.7 TWh in 2020 to 39.8 in 2030, while for lignite from 38.1 TWh to 17.8 TWh. The main driver of this process is the gradual pushing of coal units from the Mercit Order curve due, inter alia, to the continued dynamic growth of RES production and new gas capacity. These units will produce less energy per unit of capacity, but their role will be to a large extent to provide back-up capacity in a dynamic, technologically diversified system. In order to comply with the systemic safety criterion, it was assumed that, regardless of the expected working time of individual units and thus their ability to break even, coal units would not be set aside until other generation sources cover their capacity needs. Some 200 MW class carbon generation units may need to be upgraded to improve their performance to better fulfil the regulatory function and ensure sufficiency of capacity in the NES. Keeping coal units in good working order is important for the security of energy supply, especially during the initial development of alternative solutions that ensure a stable generation or reinforce balancing needs. Maintaining and modernising these units will make optimum use of the national resources available, support the balancing of RES, reduce the increase in gas demand and may benefit from technological delay payments that allow existing sources to be replaced by proven, modern energy technologies, which, once mature, will be further characterised by reduced unit investment. It should be noted that coal sources have so-called technical minima. A lower use would mean that they would be temporarily switched off. A long cold start-up period makes it impossible to perform the system functions and their frequent shutdown results in faster power utilisation and deterioration.

Production in gas units (new units are mainly efficient steam and gas units) will increase from 17.4 TWh in 2020 to 32 TWh in 2030. However, this depends on the pace and scope of development of other generation sources (including primarily nuclear sources).

Both EU and national energy policies will support the deployment of new low-carbon sources, of which a large part will be non-sterile renewable sources characterised by high fluctuations in production (wind power plants and photovoltaics). The presence of such sources of generation in anticipated quantities will require investment in flexible sources: gas turbines and storage facilities necessary for their integration into the electricity system. The share of RES in net electricity production will be tripled between 2020 and 2030 (the share will increase from 16.2 % to 50.1 %). A very important element of the transformation of the electricity sector is the development of nuclear power in Poland.

The Polish energy transitionprocess will be a lengthy and costly process. This process must be staggered over time in such a way that the economic and social impact of the process can be mitigated. At a later stage of the analysis, the economic impact of the proposed development orientations for the energy sector and their possible impact on investment needs and their costs will be examined in detail.

Table 2.65. Gross electricity production [TWh]

	2005	2010	2015	2020	2025	2030
Brown coal	54,8	48,7	52,8	38,1	38,1	17,8
Coal*	88,5	89,3	79,4	70,7	67,3	39,8
Gaseous fuels**	5,2	5,1	6,4	17,4	21,8	31,9
Fuel oil	2,7	2,6	2,1	1,7	1,9	1,7
Biomass	1,4	5,9	9,0	6,9	6,8	8,7
Biogas	0,1	0,4	0,9	1,2	1,9	2,8
Hydro power	2,2	2,9	1,8	2,1	2,6	2,9
From pumped water	1,6	0,6	0,6	0,8	1,1	3,3
Onshore wind energy	0,1	1,7	10,9	15,8	25,6	38,1
Offshore wind energy	0,0	0,0	0,0	0,0	0,0	21,7
Solar power	0,0	0,0	0,1	2,0	15,5	24,8
Geothermal energy	0,0	0,0	0,0	0,0	0,0	0,0
Hydrogen	0,0	0,0	0,0	0,0	0,0	0,0
Other***	0,7	1,1	1,0	1,5	2,2	2,4
Warehouses (Bateries)	0,0	0,0	0,0	0,0	0,0	1,2
Total	**157,3**	**158,2**	**165,1**	**158,2**	**184,8**	**197**

** Including coke oven and blast furnace gas*
*** High-methane and nitrogen-rich natural gas, mine drainage gas, associated petroleum gas*
**** Inorganic industrial and municipal waste*
Source: Own study by ARE SA (MESSAGE-PL), EUROSTAT

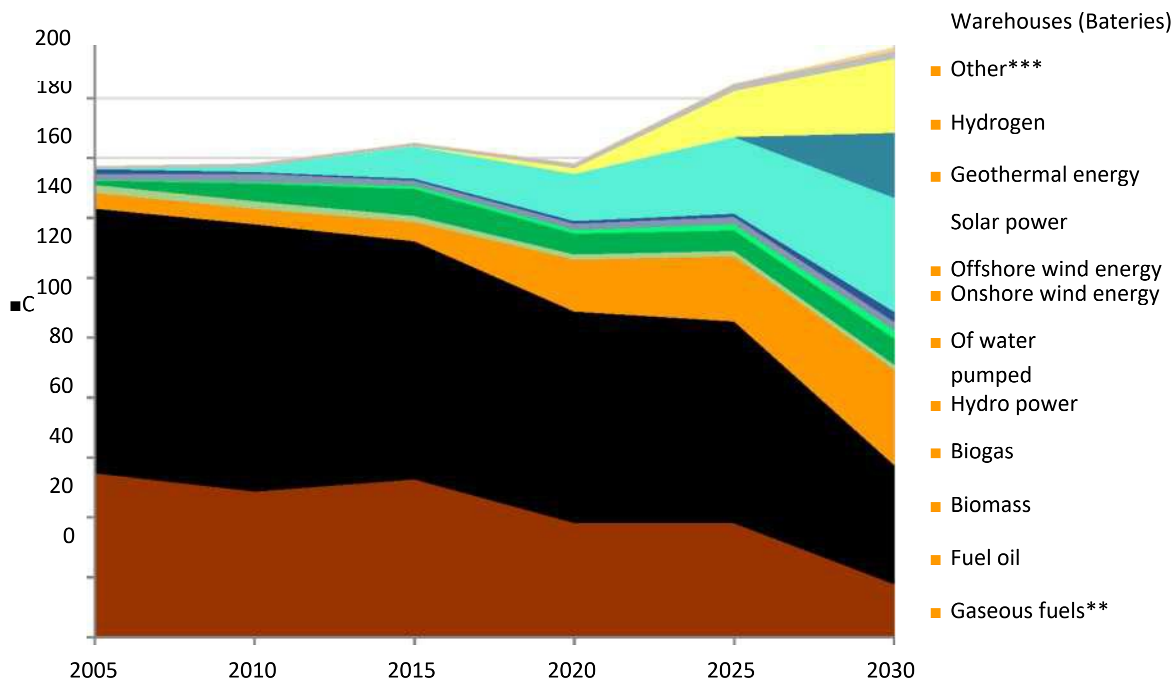


Figure 2.21. Gross electricity production in Poland by fuel (reference scenario)

Source: Own study by ARE S.A.

4.6.2. Electricity generation capacity by source

The results of the analyses carried out indicate that, in the light of the assumptions discussed, far-reaching changes in the structure of electricity generation in Poland are expected. First of all, a significant increase in capacity from 45 GW in 2020 to 92 GW in 2030 is expected. This increase is the result of an increase in capacity characterised by low installed capacity rates (PV, wind). Onshore wind capacity increases from 6.65 GW in 2020 to 15.8 GW in 2030. An important component of the future energy mix will also be offshore wind power. By the end of 2030, an installation of less than 6 GW had been set up. Photovoltaics (both micro-installations and large farms) are the fastest and largest increments in the system. As a result, the role of carbon-fuelled system units will be significantly reduced – their share of net installed capacity will be reduced from around. 70 % in 2020 to 30 % in 2030. The share of renewables in the power structure of the NES will increase significantly (from 19 % in 2020 to 57 % in 2030).

Table 2.66. Net capacity of power generation sources by technology (reference scenario) [MW]

	2005	2010	2015	2020	2025	2030
EL_Brown coal	8 197	8 145	8 643	7 445	7 012	6 566
EL_Rock coal	14 613	14 655	13 617	15 889	14 911	9 860
EL_Gaz/Hydrogen	0	0	0	0	1 332	5 957
EL_Nuclear System	0	0	0	0	0	0
EL_Water	914	935	964	987	1 008	1 118
EL_Pumped-up	1 679	1 679	1 705	1 705	1 767	2 507
EC_Industrial	6140	6126	1 605	1 945	2 093	2 124
EC_WK	6140 760 760	6126 807 807	4 968	5 226	4 578	4 149
EC_Gaz/Hydrogen			928	2 688	3 515	5 071
EL and EC_Biomasa	102	140	513	534	669	1283
EC_Biogas	102 0 0	140 0 0	216	241	326	454
BECCS			0	0	0	0
EL_Intra onshore	121	1 108	4 886	6 499	11 096	15 842
EL_Impact at sea	0	0	0	0	0	5 927
EL_Geothermal	0	0	0	0	0	0
Photovoltaics	0	0	108	1 229	19 979	29 269
Gas/hydrogen turbines	0	0	0	0	0	0
DSR/Energy products	0	0	150	615	1 080	2 420
Total	**32 526**	**33 594**	**38 302**	**45 002**	**69 365**	**92 547**

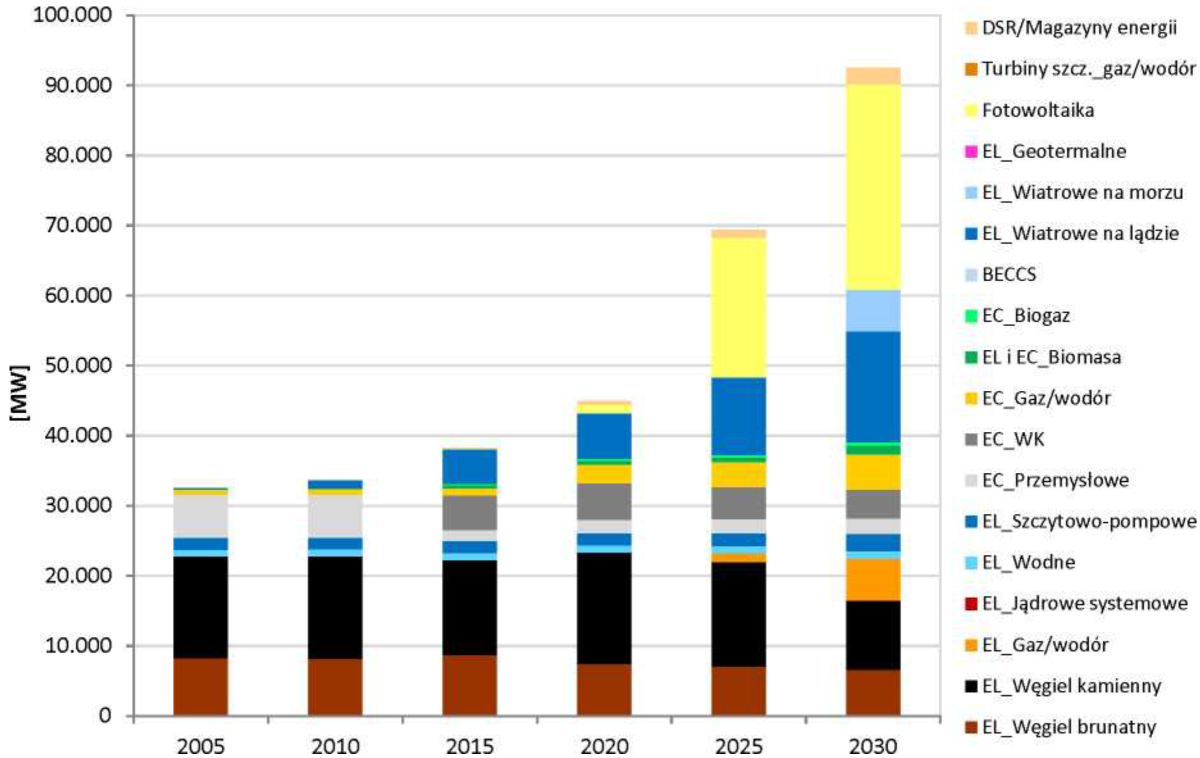


Figure 2.22. Technological capacity of power generation sources (Reference scenario)

The level of coal capacity in the NES will decrease for technical and economic reasons, including the operation of generation units, the non-compliance with the requirements on generated emissions and the need to decarbonise the sector. In the coming years, coal capacity will be essential for the system to ensure the security of supply of electricity to customers, in a context of large increases in the capacity available in zero-emission technologies, but dependent on weather conditions. At least by 2030, coal sources will act as a technology to ensure a stable energy supply, although the energy generated by these sources will no longer be predominant. Maintaining coal capacity until other solutions to ensure the stability of supply are sufficiently developed is essential for the development of RES, given the real impossibility of covering the needs of the NES by alternative solutions.

In 2030, coal-based capacity (electric plants and combined heat and power plants) will be around. 10 GW and 6.6 GW for lignite, which together will account for 18 % of the KSE structure. The average working time of coal units (amounting to 51 % in 2020) will decrease significantly to 46 % in 2030. By 2030, the capacity of lignite-fired power plants will be reduced by about. 880 MW. The capacity of lignite-fired power plants is decreasing due to the phase-out of existing units. The role of coal-fired power plants in the system will also decrease significantly, as most of the new system cogeneration units are likely to be natural gas-fired installations. Together with new CHP plants, they will increase the reliability of the electricity system, which is essential with a large share of non-sterile renewable sources (wind and solar).

5. Dimension Internal energy market

5.1. Interconnections

5.1.1. Electricity

Current level of (cross-border) interconnections and main interconnections

Cross-border exchanges of electricity enable the highest, high and medium-voltage connections with the electricity systems of neighbouring countries.

The National Transmission System (NTS) currently cooperates:

- synchronously with the systems of mainland European countries ENTSO-E (formerly UCTE), i.e. German, Czech, Slovak and Ukrainian (from 2023)
- asynchronously with the Swedish system via submarine direct current cable,
- asynchronously with the Lithuanian system via the AC line and the DC joint.

The current status of cross- **border interconnections on synchronous cross-section** is as follows:

<u>Western border (Poland – Germany):</u>

- 2-track 400 kV Krajnik – Vierraden line, using a phase shifter;
- 2-track 400 kV Mikulova – Hagenwerder line, using a phase shifter.

<u>Southern border (Poland-Czech Republic):</u>

- 2-track 400 kV Wielopole/Dobrzeń – Nosovice/Albrechtice,
- 2-track line 220 kV Kopanina/bujaków – Liskovec.

<u>Southern border (Poland-Slovakia):</u>

- 2-track 400 kV line Krosno Iskrzynia – Lemĕšany.

The current state of **asynchronous cross-border connections of the transmission network** is as follows:

<u>Northern border (Poland – Sweden):</u>

- DC 450 kV cable line Słupsk Wierzbięcino – Stärno,

<u>Eastern border (Poland-Ukraine) – also synchronously cooperating:</u>

- 1-track 220 kV Zamość – Good-forming line, operating on the side Ukrainian power generation units (the connection makes it possible only to import energy into Poland).
- 1-track 400 kV Rzeszów – hopper line put into operation in the system synchronous in 2023, (this is the existing 750 kV line, not in service since 1993).

<u>Eastern border (Poland – Lithuania):</u>

- 2-track 400 kV Ełk – Alytus line, operating with the Lithuanian system via a powerbridge fixed (at Alytus station).

The current situation of cross-border interconnections of **the distribution network on synchronous cross-section** is as follows:

<u>Southern border (Poland-Czech Republic):</u>

- Two-track 110 kV Boguszów – Porici line,
- 1-track line 110 kV Kudowa – Income,
- Two-track line of Pogvisions – Darkov,
- 2-track Ustroń/Mnisztno – Trzyniec line,

<u>Western border (Poland – Germany):</u>

- 1-track 110 kV Turów1 – Neueibau line.

The current state of **asynchronous cross-border connections of the distribution network** is as follows:

<u>Eastern border (Poland-Belarus):</u>

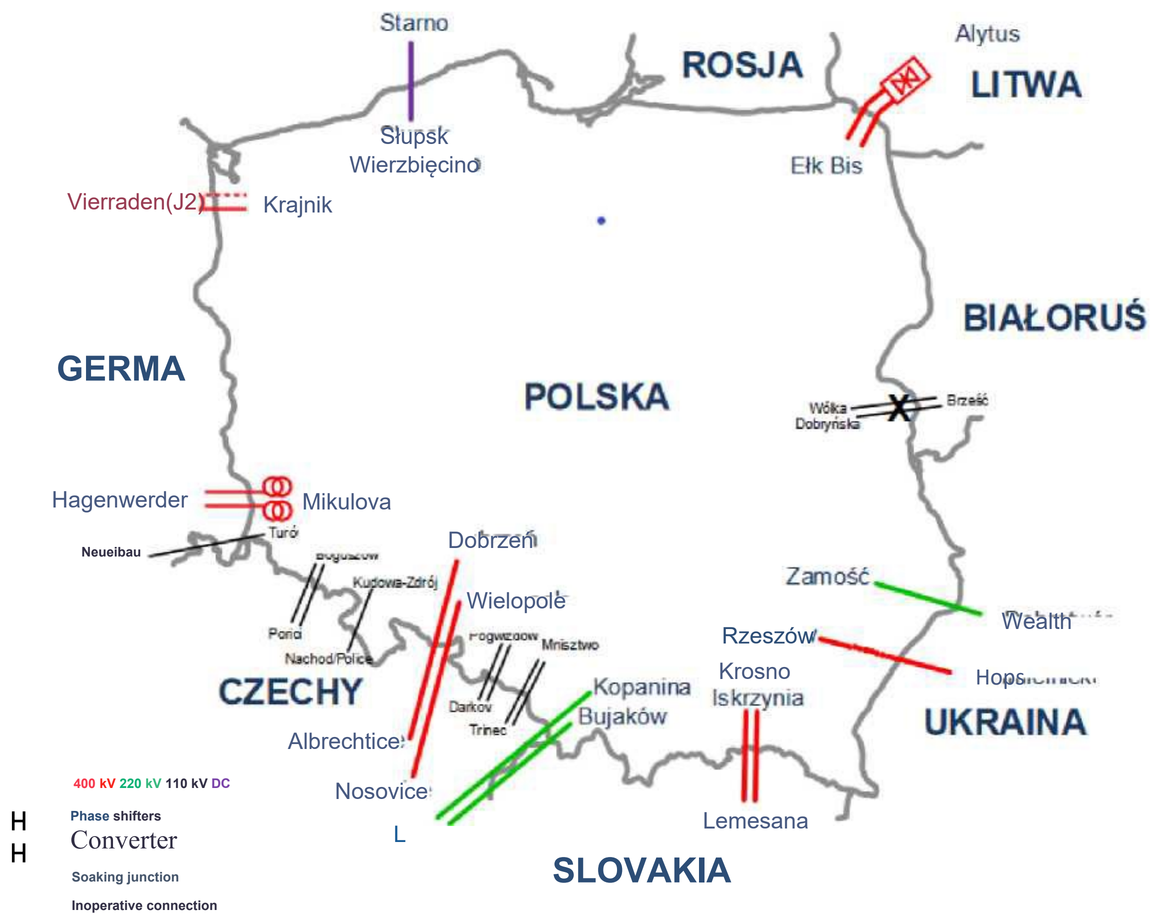
- 2-track 110 kV Wólka Dobryńska – Brest 2.

Basic information on individual interconnectors is provided in the table below.

Table 2.67. Characteristics of the Polish cross-border connections of the electricity system

Border country	Merger	Voltage [kV]	Load capacity	number of tracks	Additional information
Germany	Krajnik – Vierraden	400	1 039 MW	2	— In 2018, the connection was equipped with a phase shifter
	Mikulova – Hagenverder	400	1 385 MW	2	In 2016, the connection was equipped with a phase shifter
Czechia	Wielopole/Dobrzeń – Nosovice/Albrechtice	400	1 385 MW	2	— —
	Boujakers – Liskovec	220	400 MW	1	— —
	Kopanina – Liskovec	220	400 MW	1	— —
Lithuania	Ełk Bis- Alytus	400	500 MW	2	alternating current with DC
Slovakia	Krosno Iskrzynia – Leměšany	400	1 353 MW	2	— —
Sweden	Słupsk – Stärno	450	600 MW	1	direct current
Ukraine	Goodmaking – Filmness	220	251 MW	1	The line operates in radial system
	Rzeszów – Hopper	400	1 300 MW	1	The line has been working as synchronous since 2023.

The current status of cross-border connections is shown in figure (Figure 2.28).



Source: PSE S.A.

Figure 2.23. General scheme of cross-border connections of the electricity system

Source: PSE S.A.

An example of the trade balance of electricity interconnections and the actual energy flows from individual countries to Poland and from Poland to other countries in 2 022 are shown in the figure (Figure 2.29).

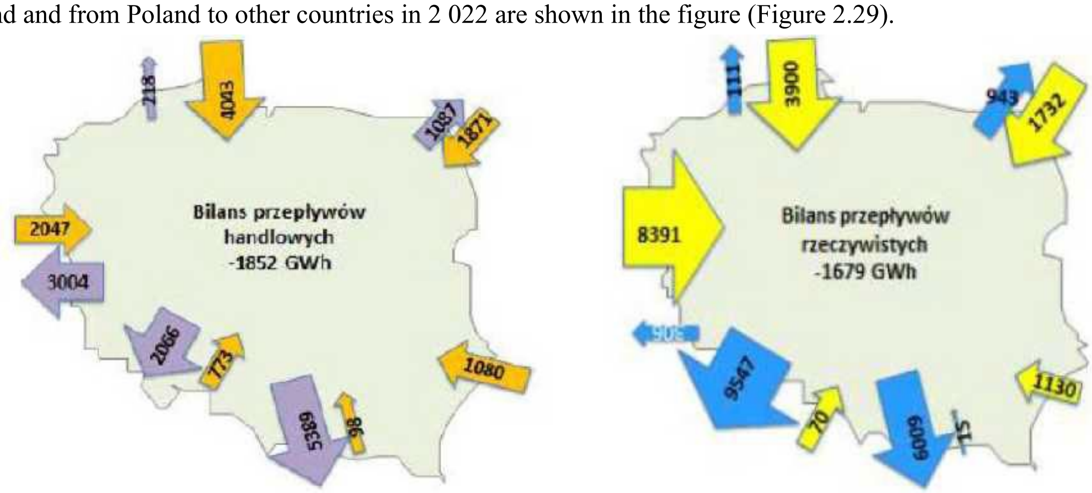


Figure 2.24. Balance of commercial and actual electricity flows on interconnections with other countries in 2022 [GWh]

Source: ARE SA

At the same time, attention should be drawn to the significant difference in previous years between commercial and actual electricity flows at synchronous borders (Germany, Czechia, Slovakia), which is the result of unplanned electricity flows contributing to the reduction of the capacity offered to participants at these borders. This difference in flows has been reduced by the installation of phase shifters on Polish-German connections. The wheel flows were thus limited to the values controlled by the TSOs. It is also worth noting the significant increase in the volume of cross-border flows on synchronous cross-section, thanks to the introduction of Core capacity calculation (Core CCR), which includes the Polish system, a flow *-based*method. This contributes to a significant increase in trade flows.

Electricity interconnections – state of play and prospects for development

According to the Treaty on the Functioning of the European Union, the energy market is part of the internal market. It is therefore subject to the Treaty principle of free movement of goods. As a result, Member States can restrict trade only in exceptional situations. In 2019, a legislative package regulating the electricity sector in the European Union – Clean Energy Package (CEP) was adopted33. Regulation (EU) 2019/943 of the European Parliament and of the Council, which is part of the package, lays down, inter alia, the obligations of transmission system operators (TSOs) to make capacity available on cross-border connections. According to its provisions, EU rules, TSOs are obliged to make available cross-border interconnection capacity up to the maximum, but allowed for operational security reasons. In this context, a requirement has been introduced to make available from 1 January 2020 not less than 70 % of the technical interconnection capacity for cross-border exchanges (the so-called CEP70 requirement). Countries that were unable to meet this requirement in accordance with the deadline set out in the Regulation have the right to temporarily postpone it, but take remedial action. Poland adopted an Action Plan in 2019, which aims to make available a minimum level of 70 % of technical transmission capacity on synchronous connections by the end of 2025, while on asynchronous connections the required 70 % is already generally reached.

a) Cross-border synchronous connections

The allocation of transmission capacity on synchronous cross-section was carried out in the framework of coordinated explicit tenders until 8 June 2022. However, from 9 June 2022, after several years of preparation, an allocation method based on physical flows, known as ‘physical flows’, has been introduced in Poland and the rest of the Central and Eastern European region. Flow Based Allocation – FBA), which already applies throughout Core CCR.

On cross-border synchronous links, capacity shall be allocated in the day-ahead and intraday markets. It is based on mechanisms, as appropriate: single Day-ahead Coupling and Single Intraday Coupling.

Interconnection within the framework of the Single Market coupling of the Next Day and the Single Market coupling of Current Day is organised by nominated Electricity Market Operators (Nominated Electricity Market Operator (NEMO) whose terms of cooperation with TSOs are specified in the MNA OA (Multi-NEMO Arrangements Operational Agreement). The authority designating NEMOs on the Polish market is the President of the Energy Regulatory Office.

On the other hand, long-term contracts include coordinated auctions organised by the Joint Allocation Office (Jao), i.e. an auction platform with 25 European TSOs (also outside the EU) as shareholders.

b) Asynchronous cross-border connections

<u>Poland-Sweden merger</u>

A direct current cable called SwePol Link, running under the Baltic seabed between Poland and Sweden, is an important connection of the national electricity system for cross-border exchange. Since December 2010, the allocation of transmission capacity on this link between the PSE S.A. and Affärsverket Svenska Kraftnat (Swedish TSO) has been carried out by *implicit* auctions under the day-ahead market coupling mechanism. *Market Coupling*), organised by the Polish Power Exchange S.A. (TGE) and Nord Pool Spot AS (NPS). The rules for the allocation and settlement of transmission capacity on the Poland-Sweden link are laid down in the four party *Market Coupling Agreement*, to which electricity exchanges are signatories: Freight Exchange S.A. and Nordpool Spot AS and the Transmission System Operators of Poland and Sweden.

The capacity offered in 2021 and 2022 on this link towards export and import was due to the permissible load on the DC cable and converter stations and to the constraints resulting from the safety standards and the operating and operational planning rules of the KSE, as laid down in the IRiESP. 34. In the direction of export, transmission capacity in working days was offered mainly in the night zone. In the network set-up without outage, the capacity offered was generally 300 MW. In the direction of imports, capacity was mainly offered in the daily zone. In the network design without outage,

33Some of the legislative acts of the package have been amended since 2023, including the Internal Energy Market Regulation and the REMIT Regulation. An amendment to the Commission Regulation on capacity allocation and congestion management is also planned.
34Instructions for the operation and operation of the transmission system

the capacity offered was generally 600 MW. The transmission capacity offered by PSE S.A., which is lower than the nominal capacity of the fixed current line itself, was due to network congestion and constraints linked to the need to meet the operational security criteria of the KSE set out in the IRiESP.

The direction and volume of the electricity flow on the SwePol Link link is due to the current price relationship between the Scandinavian and Polish markets. The direction of the flow of electricity is determined on the basis of the clearing prices set on both exchanges, from lower to higher prices.

Poland-Lithuania routes

In 2023, the construction of the 400 kV Ostrołęka – Stanisławów line, which was the last element of the project 'LitPol Link Stage II', included in the list of Projects of Common Interest (PCI), still linked to the construction of the LitPol Link link launched in December 2015. This line is also important for the safety of the Baltic States' synchronous systems after synchronisation with the synchronous area of continental Europe.

The second connection currently planned and under preparation for synchronisation is a line called Harmony Link. This is a central element of the synchronisation project and was considered as an undersea direct current (HVDC) cable for Poland and Lithuania, together with accompanying investments in the Baltic States and Poland. Due to the significant increase in costs and the high number of orders from DC cable and converter station manufacturers, tenders for the planned HVDC *Harmony Link* connection were cancelled in April 2023. The Polish and Lithuanian TSOs started preparing for new tenders. Solutions that could reduce costs and allow a second connection to be launched as soon as possible are currently being explored.

One of the options considered by PSE and Litgrid is a 220 kV land cable, which could partly be built in parallel with the planned Rail Baltica rail line between Poland and Lithuania. According to the preliminary assessment, the choice of this option may reduce project costs and speed up implementation.

Synchronisation of Baltic States systems with continental Europe

On 28 June 2018, a political roadmap for synchronising the Baltic States' electricity system with the continental Europe system was approved at the level of Prime Ministers of the Baltic States, Poland and the European Commission through the current LitPol Link connection.

The next step was the roadmap at the same political level of 20 June 2019, which set out that synchronisation would be ensured by the second connection Poland-Lithuania, as the Harmony Link submarine cable. The document also pointed to the considerable financial commitment of the European Commission from the Connecting Europe Facility (Connecting Europe Facility) budget.

The possibility of an alternative to the submarine cable and the **implementation of synchronisation through the PL-LT land cable linked to Rail Baltica has been taken into account** at the level of the Ministers for Energy and Climate and the Commissioner for **Energy and Climate. Energy**, 19 December 2023. The document also indicates an acceleration of synchronisation by February 2025.

The synchronisation project aims to adapt the Baltic States' electricity systems to synchronous work with continental Europe. The project plans to build a second "Harmony Link" connection with a capacity of 700 MW. The new connection will be accompanied by investments on the Polish side for the construction of new double-track 400 kV lines Dunowo-Żydowo Kierzkowo and Żydowo Kierzkowo – Piła Krzewina and the modernisation of the existing Krajnik-Morzyczyn, Morzyczy – Dunowo – Słupsk – Żarnowiec and Żarnowiec -Gdańsk – Gdańsk Przyjaźń-Gdańsk Błonia lines. In addition to synchronising the Baltic States, these investments will also support the transfer of capacity from offshore wind farms (IMFs) to NESCs. Synchronisation, as agreed by the Prime Ministers and the Baltic States' TSOs, is planned for February 2025.

c) Connections to Ukraine

Poland currently operates two connections to Ukraine: 400 kV Rzeszów – EJ hopper and 220 kV Zamość-Dobrstwo.

The first has the capacity to transport energy bilaterally, transmission capacity on the connection is made available as of January 2024 through coordinated tenders by the Jao Auction Office, for day-ahead contracts. Imports are carried out within the limits of volumes resulting from technical transmission capacity and market conditions.

The transmission capacity of the second link is used exclusively for the import of energy from Ukraine, from the separate units at the Dobrogen power plant and is made available under one-sided monthly contracts organised by PSE SA. Imports are carried out within the framework of the availability of generation blocks and market conditions. Transmission capacity on the Polish side is made available on market terms in monthly auctions organised by PSE.

The Rzeszów-Hopper hopper link was deactivated since 1993 and operated as a 750 kV line. In 2022, following the outbreak of the war in Ukraine, it was decided to start working to restart the Rzeszów-Chmienicsk connection at 400 kV. Thanks to the joint involvement of the Polish Electricity Network (PSE) and the TSO of Ukraine Ukrenergo, the Rzeszów-Chmienicsk line was launched as a synchronous connection in May 2023. This connection allows for the exchange of electricity in both directions. After the capacity offer period in the unilateral capacity bidding process, from 16 January, capacity is offered by the Jao Tender Office.

d) Connections in the western part of Poland

Projects for the extension of the NES involve, inter alia, an increase in transmission capacity on Poland's connections to Germany. They include the expansion of the transmission system in the western part of the country: construction of a 2-track 400 kV Krajnik-Baczyna-Plewiska line and two-track 400 kV line Mikułowa – Czarna – Pasikurowice and two-track 400 kV line Mikułowa – Świebodzice. Projects are planned to be implemented by the end of 2024. This extension will enable 2 000 MW of transmission capacity to be reached. The development of transmission networks will make it possible, inter alia, to comply with the requirement of CEP70 of the European Parliament and of the Council under Regulation (EU) 2019/943 of the European Parliament and of the Council concerning the obligation to make available to market participants inter-zonal capacity of not less than 70 % of the capacity for a given border or critical network element determined taking into account operational security limits.

Development of cross-border connections – forecast

Merger		2005	2010	2015	2020	2025	2030
Germany	Krajnik-Vierraden	592	592	592	3492	3492	3492
Germany	Mikulova-Hagenverder	2730	2730	2730	2640	2640	2640
Czechia	Wielopole/Dobrzeń – Nosovice/Albrechtice	2772	2772	2772	2772	2772	2772
Czechia	Kopanina/buoys – Liskovec	800	800	800	800	800	800
Slovakia	Krosno Iskrzynia – Lemĕšany	2078	2078	2078	2772	2772	2772
Sweden	Słupsk – Stärno	600	600	600	600	600	600
Belarus	Białystok – Farm	0	0	0	0	0	0
Ukraine	Rzeszów – Hopper shark*	0	0	0	0	1039	1039
Ukraine	Soundness – Good formation	381	381	381	381	265	265
Lithuania	Ełk – Alytus**	0	0	488	488	0	0
Lithuania	Żarnowiec-Darbenai***/Elk-Gizai	0	0	0	0	0	700
SUM		**9953**	**9953**	**10441**	**13945**	**14380**	**15080**

Basic information on the current and forecast situation of interconnectors is provided in the table (Table 2.68). The total power on all cross-border connections in 2015 was around. 7 600 MW.

Table 2.68. Cross-border electricity interconnection capacity on existing and planned connections [MW] – data reported for the winter season

Source: PSE S.A., Development of ARE S.A.

Cross-border electricity infrastructure allows cross-border trade in electricity. A characteristic feature of network infrastructure is the existence of restrictions on the transmission of electricity between national electricity systems, which may temporarily restrict trade. These constraints range from renovation works and network failures to constraints imposed by transmission system operators to ensure operational security. The table below shows the net transmission capacity (total capacity less the safety margin determined by the Transmission System Operator).

Table 2.69. Net transmission capacity of electricity interconnectors on existing and planned connections [MW]

**line put into operation in May 2023*
*** corresponds to the permissible load capacity of the concurrent block at Alytus station. Once the Baltic States' electricity systems are synchronised with the continental Europe system, the total capacity of the Ełk-Alytus link will be dedicated to technical exchanges; the lack of trade on this link; trade opportunities in this connection are determined by the degree of adaptation of the Baltic States' systems to synchronous work with that of continental Europe.*
**** the start date of the route (Harmony Link) depends on the decision of PSE and Litgrid following the cancellation of the tender procedure on the part of Lithuania. A new Elk-Gizai route and a voltage level of 220 kV are also being considered. Pre-projected connection capacity of 700 MW*

	2010	2015	2020	2025	2030
PL ☙ DE/CZ/SK	900	1000	2 500	3899	3899
DE/CZ/ 💧😐 EN	0	0	600	4758	4758
PL ✌☠👎 SE	100	100	300	600	600
SE ♊ EN	600	600	600	600	600
🏱☹ AU	0	0	0	425	425
THE AU ♊ EN	220	220	220	365	365
PL ♊ LT	0	500	500	0	700
LT ♊ EN	0	500	500	0	700
EN export	**1 000**	**1 600**	**2700**	**4924**	**4924**
EN Imports	**820**	**1 320**	**1325**	**5723**	**5723**

Source: Scenario outlook and adequacy forecast 2015, Mid-term Adequacy Forecast 2017, ENTSOE

5.1.2. Natural gas

The cross-border exchange of natural gas is facilitated by interconnections between the National Transmission System (NTS) and neighbouring countries' systems. In addition, the NSP is connected to the Transit Gas Pipeline System (TGPS) at the two Points of Interconnection in Włocławek and Lwówk.

In accordance with Article 9h 2 and Article 9k of the Energy Law Act, a single gas transmission system operator or a combined gas system operator operating in the form of a joint-stock company, the sole shareholder of which is the State Treasury, are designated. The role of TSO for both the national transmission system and the Polish section of the Yamal-Europe pipeline, by decision of the President of the ERO, until 6 December 2068, is performed by OGP GAZ-SYSTEM S.A.

The owner of the Polish section of the TGPS is the Transit Gas Pipeline company EuRoPol GAZ S.A.

The national transmission system, managed by OGP GAZ-SYSTEM S.A., shall be fed through the following entry points related to:

1. <u>imports of gaseous fuels:</u>
   a) Point GCP Gaz-System/UA TSO (Drozdowicze – Polish-Ukrainian border);
   b) FAXE – entry point on the Baltic Pipe pipeline (Poland-Denmark link),

c) Santaka (Polish-Lithuanian border),
d) Vyrava (Polish-Slovak border),
e) GCP Gaz-System/ONTRAS point (Lasów – Polish-German border);
f) Cieszyn (Polish-Czech border);
g) Gas Transit Pipeline System (Polish section of the Yamal-Europe pipeline):
   - Interconnection Point (physical entry points in Włocławek and Lwówek);
   - Mallnow (entry/exit point to the TGPS from the German direction),
h) local import connections:
   - GCP Gaz-System/ONTRAS point (Gubin – Polish-German border),
   - Branice (Polish/Czech border);
i) entry point from the LNG terminal in Świnoujście;

2. national deposits:
   a) mines in the methane-rich natural gas system – 40 entry points;
   b) nitrogen removal plants KRIO Odolanów and Grodzisk – connect the systems of nitrogen-rich and methane-rich natural gas (2 entry points to the methane-rich gas system)
   c) nodes in the nitrogen-rich natural gas system – 4 entry points: Krobia, Kotowo, Chynów, New Tłoki,
   d) mines in the nitrogen-rich natural gas system – 4 entry points: Mchy, Radlin, Roszków and Szczyglice,

3. UGSs – 7 storage facilities in the high-methane natural gas system which, during gas withdrawal, constitute entry points to the transmission system:
   a) The Sanok GSF – comprising the Husów, Strachocina, Swarzów and Brzeźnica UGSs;
   b) The Kawerna [Cavern] GSF – comprising the Mogilno and Kosakowo CUGSFs; and
   c) separate Wierzchowice Storage Facility (including Wierzchowice UGS).

The table below (Table 2.71) shows the transmission capacity of the interconnection entry points to the Polish gas system.

Table 2.70. Parameters of cross-border entry points to the Transmission System

Entrance point	Operator	Technical capacity bn m³/year	GWh/h	thousand m³/h
FAXE	Energinet/GAZ-SYSTEM	10,0		13,41
Santaka	AB Amber Grid/GAZ-SYSTEM	1,9		2,42
Vyrava	Eustream a.s./GAZ-SYSTEM	5,7		7,25
Drozdovychi	LLC Gas Transmission System Operator of Ukraine/GAZ-SYSTEM S.A.	4,4	500	5,65
Mallnow	GASCADE Gastransport GmbH/GAZ-SYSTEM S.A.	9,1		11,57
Forests	ONTRAS/GAS-SYSTEM S.A.	1,6	180	2,03
Cieszyn	NET4GAS/GAS-SYSTEM S.A.	0,6	111,7	1,17/0,18
LNG terminal	GAZ-SYSTEM S.A.	6,2		9,47

Source: National Ten-Year Transmission System Development Plan 2018-2027, GAZ-SYSTEM S.A.

Transmission capacity shall be understood as the maximum transmission capacity that a TSO can offer to users, taking into account system integrity and network operational requirements. Transmission capacity between 2022 and 2005 is presented in the table below.

Table 2.71. Transmission capacity of gas interconnectors by supply direction

Direction of natural gas supply	2022	2020	2 015 million m³/year	2010	2005
Poland	31 443	27 972	25 541,2	17 861,5	10 290,0
Germany	441	448	131,4	131,4	44,0
Czechia	17	0	0,004*	0,0	0,0
Ukraine	476	422	139,3*	0,0	0,0

**Physical transmission of natural gas completed, available transmission capacity on these routes in 2015 was 0 Source: Activity reports of the President of the URE for 2022, 2020, 2015, 2010, 2005*

Świnoujście LNG terminal

In August 2008, the Council of Ministers recognised the construction of an LNG terminal as a strategic investment in the interests of the country. Work on the technical project was completed in 2009 and the construction itself was completed in 2015. The cost of the terminal was approximately PLN 3 billion. At the time, the terminal's control capacity was 5 billion m^3/year. The first gas supply took place on 17 June 2016. The Liquefied Natural Gas (LNG) terminal in Świnoujście is currently one of three large-scale regasification installations operating in the Baltic Sea. The other terminals within the Baltic Sea are the FSRU terminal in Klaipėda, Lithuania, and the FSRU TERMINALINAND NKOO/P ALDISKI, ANDthese issues, unlike the land TERMINALatTHE GUST, use the FSRU (FSRU) solution. *Floating Storage Regasification Unit*).

From 1 January 2018 to 2034, ORLEN S.A. (formerly PGNiG S.A.) has a contracted capacity of 100 % of the regasification infrastructure of the Świnoujście terminal.

Transit Gas Pipeline System (SGT)

The Transit Gas Pipeline system on the territory of the Republic of Poland is part of a gas pipeline measuring approximately 4 000 km from Russia via Belarus and Poland to Western Europe. The owner of the Polish section of the TGPS is the Transit Gas Pipeline EuRoPol GAZ S.A. in Warsaw, and the operator of the Polish section of the Yamal pipeline is Operator Gazociągów Przessowe GAZ-SYSTEM S.A. On 17 November 2010, the President of the Energy Regulatory Office issued a decision designating GAZ-SYSTEM S.A. as an independent operator of the Polish section of the Yamal pipeline until 31 December 2025, which was extended by law until 6 December 2068.

The transit pipeline runs through Poland from east to west, from the Polish-Belarusian border in the area of Kondratki village, to the Polish-German border, in the area of Górzyca. Basic technical characteristics of the transit pipeline:

- Operating pressure – 8.4 MPa
- Length – 683.9 km,
- Diameter of gas pipeline – DN1400
- 1 physical entry point – Kondratkis, – not operational
- 3 physical exit points – Mallnow, Lwówek, Włocławek,
- 5 compressor stations with a total capacity of approx. 400 MW – TG Kondratki, TG Zambrów, TG Ciechanów, TG Włocławek, TG Szamotuła.

Development of interconnections

North Barama (LNG terminal in Świnoujście and Baltic Pipe) and interconnection with neighbouring countries of the European Union are considered as key infrastructure to ensure the country's energy security by diversifying sources and routes of natural gas supplies.

Baltic Pipe gas pipeline

Baltic Pipe is a strategic infrastructure facility constituting a new gas supply corridor on the European market. It makes it possible, for the first time ever, to transfer gas directly from Norway's deposits to markets in Denmark and Poland, as well as to customers in neighbouring countries of Central and Eastern Europe. At the same time, the Baltic Pipe allows bidirectional transport, i.e. gas can be supplied from Poland to Denmark. Gaz-SYSTEM S.A., in cooperation with the Danish partner, completed the investment before the announced deadline with a full capacity of 10 billion m^3 per year on 30 November 2022.

The Baltic Pipe project consisted of:

- the construction of an undersea connection of the Norwegian and Danish gas system;
- extending the Danish transmission system (from west to east);
- the construction of a compressor station in Denmark;
- the construction of an undersea gas pipeline connecting the Danish and Polish transmission system;
- the expansion of the Polish gas transmission system:
  - the construction of a pipeline connecting the undersea pipeline with the national transmission system;
  - the construction of the Goleniów-Lwówek pipeline;
  - expanding the Goleniów compressor station;
  - expanding the Odolanów compressor station;
  - construction of a compressor station in Gustorzyn.

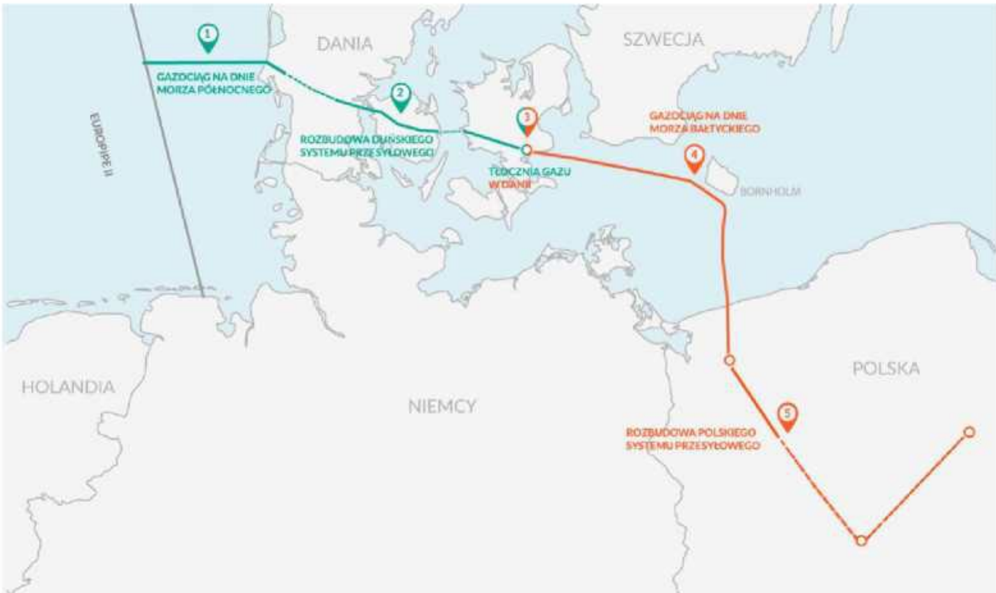


Figure 4.25. Illustrative design of the Baltic Pipe pipeline

Source: GAZ-SYSTEM S.A.

Extension of the LNG terminal in Świnoujście

The aim of the extension of the LNG terminal is to increase the regasification capacity to[8.3] billion m³ of natural gas per year and to introduce new functionalities for the installation. The extension of the terminal consists of three tasks: increasing the regasification capacity of the technological installation by additional SCV equipment (methan pumps, regasifiers); additional capacities by building a third liquefied natural gas tank; increasing flexibility of supplies to the terminal through the construction of a second quay.

In 2022, phase I of the works, consisting of the extension of the infrastructure with new SCV regasifiers and LNG pumps, enabling the terminal's nominal regasification capacity to be increased to about. Billion m^3/year.

The second phase of the extension of the terminal assumes an increase in regasification capacity to approx. Billion m 3/y[by]constructing a third liquefied natural gas storage tank (approx. 180 thousand m^3 with the required installations and equipment) and increasing flexibility of supplies to the terminal through the construction of a second quay with associated facilities and facilities. Completion of investment – Q2 2024

Poland – Slovakia interconnection

The investment related to the construction of the Poland-Slovakia gas link was carried out by OGP GAZ-SYSTEM S.A. and Eustream a.s. The launch of the Strachocina hub and the Strachocina pipeline in 2022 – the national border is finalising a huge investment project in Poland called the North-South Corridor. This gas bus consists of 15 pipelines with a total length of more than 860 km, a gas hub in Strachocina and a new compressor station in Kędzierzyn-Koźlu.

Figure 4.26. Illustrative diagram of the Poland-Slovakia gas link

Source: GAZ-SYSTEM S.A.

The connection capacity is 5.7 billion m of^3 natural gas per year towards Poland and 4.7 billion m^3 towards Slovakia. The following investments were made under this project:

- construction of the Tworóg-Tworzeń pipeline,
- construction of the Pogórska Wola-Tworzeń pipeline,
- construction of the Strachocina-Pogórska Wola pipeline,
- construction of the Strachocina gas pipeline – Polish border,
- construction of Strachocina interchange.

Poland-Lithuania interconnection

The Poland-Lithuania interconnection is part of the Baltic Sea gas system integration plan for north-eastern Europe. As a key project for energy market integration activities in the Baltic region, it was granted PCI status. Launched in May 2022, the Poland-Lithuania gas link enables Baltic countries to diversify the directions and sources of natural gas supplies, in particular linking them to the European natural gas market.

The new pipeline runs through Mazowieckie, Podlaskie and Warmińsko-Mazurskie provinces, i.e. areas with poorly developed gas infrastructure. Thus, the implementation of the project, coupled with the development of the distribution network, has increased access to gaseous fuels in north-eastern Poland.

The interconnection capacity towards Lithuania is 2 billion m^3 per year and 1.9 billion m of natural^{gas} towards Poland. The Poland-Lithuania interconnection project was co-financed by the CEF-Energy financial instrument for construction works amounting to EUR 26.5 million (including OGP GAZ-SYSTEM S.A. – EUR 208.5 million) and for works that were completed and settled with the final co-financing amount for OGP GAZ-SYSTEM S.A. of EUR 3.3 million.

5.2. Energy transmission infrastructure

5.2.1. Electricity

a) Key parameters of the existing electricity transmission infrastructure.

The Transmission System Operator (TSO) – defined in the Energy Law Act – is an electricity company engaged in the transmission of electricity, is Polskie Sieci ElektroEnergia S.A. This follows from the concession issued by the President of the URE on 16 June 2014, for the period from 2 July 2014 to 31 December 2030.

PSE S.A. owns and manages the transmission network of the highest voltages which it created (as of 31 December 2022):

- 303 lines with a total length of 15 964 km, of which:
  - 131 lines with a voltage of 400 kV, with a total length of 8 562 km,
- 171 lines with a voltage of 220 kV, with a total length of 7 288 km,
- 110 highest-voltage stations (NN),
- the 450 kV DC Poland-Sweden submarine connection, with a total length of 254 km, of which 127 km is owned by PSE S.A.

The characteristics of the main technical infrastructure items of the national electricity transmission and distribution sub-sector are set out in the table (Table 2.74). The current diagram of the highest voltage electricity grid is shown in the figure below (Figure 2.34).

Table 2.72. Characteristics of national transmission and distribution networks

Breakdown	Unit of measurement	2005	2010	2015	2020	2022
LENGTH OF OVERHEAD POWER LINES:						
— high voltage (NN+WN)	km	45 378	46 112	47 177	48 923	49 661
750 kV	km	114	114	114	114	114
400 kV	km	4 831	5 303	5 984	7 823	8 490
220 kV	km	8 123	8 088	8 054	7 461	7 369
110 kV	km	32 310	32 607	33 025	33 525	33 688
— mean voltages (SN)	km	233 855	234 741	233 044	227 043	225 032
— low voltage (nN)	km	286 994	289 977	316 589	317 205	321 393
Total all voltages	km	566 227	570 830	596 810	593 171	596 086
LENGTH OF CABLE LINES:						
— high voltage (NN+WN)	km	79	164	467	769	951
— mean voltages (SN)	km	61 988	68 998	79 382	92 651	97 345
— low voltage (nN)	km	125 776	140 320	160 510	177 159	185 834
Total all voltages	km	187 843	209 482	240 359	270 579	284 130
NUMBER OF STATIONS WITH UPPER VOLTAGE:						
400 and 750 kV	unit	31	35	44	53	50
220 kV	unit	67	67	64	61	62
110 kV	unit	1 356	1 405	1 517	1 574	1 639
— mean voltages (SN)	unit	236 067	246 562	258 835	269 726	274 088

Breakdown	Unit of measurement	2005	2010	2015	2020	2022
Total all voltages	unit	237 521	248 069	260 460	271 414	275 839
NUMBER OF MAINS TRANSFORMERS WITH TRANSMISSION:						
— NN/(NN+WN)	unit	168	185	202	224	220
— WN/SN	unit	2 527	2 553	2 744	2 882	2 975
— SN/SN	unit	264	1 215	1 183	1 191	1 260
— SN/nN	unit	237 595	247 479	258 847	267 402	271 142
Total	unit	240 554	251 432	262 976	271 699	275 597
POWER OF TRANSMISSION NETWORK TRANSFORMERS:						
— NN/(NN+WN)	MVA	37 812	42 302	50 610	62 400	61 119
— WN/SN	MVA	46 904	49 700	56 202	62 789	65 218
— SN/SN	MVA	1 055	5 280	5 305	5 560	6 108
— SN/nN	MVA	40 858	44 135	48 356	52 449	53 946
Total	MVA	126 629	141 417	160 473	183 198	186 391
NUMBER OF CONNECTIONS:						
— overheads	thousand pcs	5 633	5 635	5 479	5 315	5 245
— cable	thousand pcs	719	989	1 285	1 950	2 136
Total	thousand pcs	6 352	6 624	6 764	7 265	7 381
LENGTH OF CONNECTIONS:						
— overheads	km	119 829	120 595	115 223	109 966	109 172
— cable	Km	23 837	32 320	44 610	60 214	66 548
Total	km	143 666	152 915	159 833	170 180	175 720

Source: Are S.A. based on test results 1.44.02.

Figure 2.27. Map of the transmission network with the areas of operation of the various branches of PSE S.A. (as at 31.12.2023)

PSE S.A. implements investments in network development on the basis of the Transmission System Development Plan prepared by PSE and approved by the President of the Energy Regulatory Office. The Development Plan focuses on investments supporting Poland's energy transition (including the integration of significant RES capacity into the National Energy System) and supporting the security of the work of the NESC. In the period 2015-2019, PSE transferred a total of PLN 7.7 billion to investments, which allowed 344 power lines and 54 power stations to be modernised. In addition, 6 new stations and 1440 new power lines were created under these measures. In the period 2020-2022, investment expenditure amounted to PLN 3.35 billion and a further PLN 6.9 billion is planned by PSE to invest in 2023-2024. These funds are expected to create a further 2784 new lines and 3 electricity stations.

Table 2.73. Total investment expenditure at TSOs [PLN million]

Investments	2005	2010	2015	2020	2022
TSO	481,9	492,6	1 536,1	1 109,6	1 269,5

Source: ARE SA

b) Projections of network expansion requirements, at least until 2040 (including a 2030 perspective)

Polskie Sieci ElektroEnergia S.A. draws up a Transmission System Development Plan. The current version of this document includes an analysis of the development of the network for the period 2023-2032. This document is the basis for the national transmission system operator's investment planning.

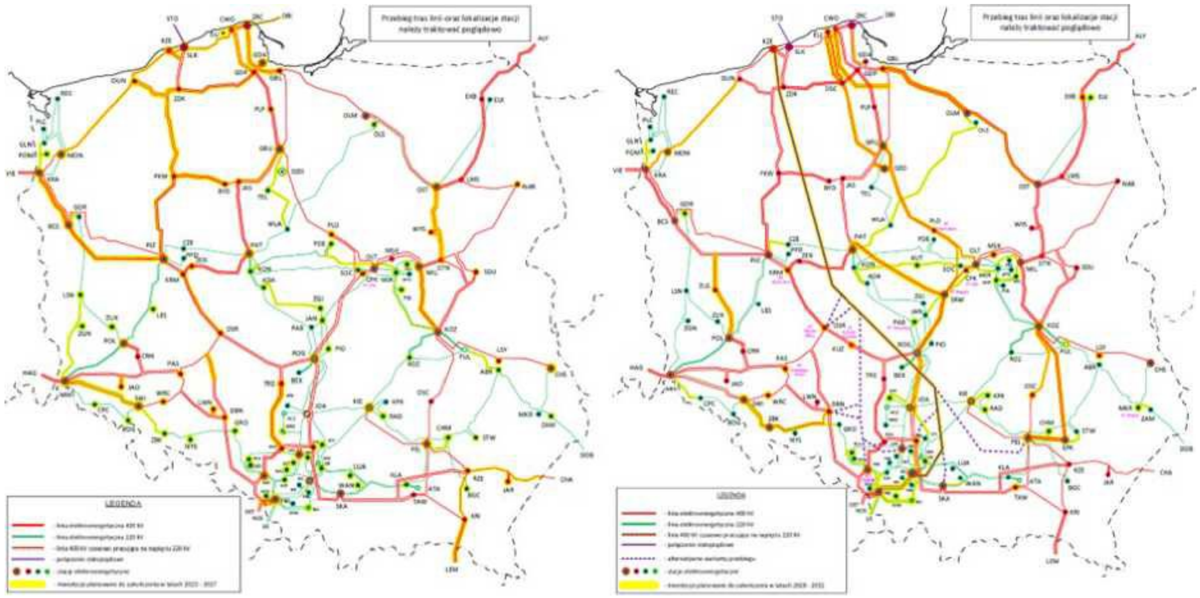


Figure 2.28. Grid diagram, investments for 2023-2027 (left) and 2028-2032 (right)
Source: Transmission System Development Plan 2023-2032, PSE S.A.

The plan identifies 105 investment measures for network expansion and upgrade, which are in the process of being implemented and a further 146 actions planned for the period up to 2032. The plan also included 56 tasks for investment in ICT transmission networks, as well as 29 investment activities in buildings and constructions and regulation of real estate.

All these actions will result in:

- 775 km of new HVDC fixed-current lines,
- 4 875 km of new 400 kV lines,
- 233 km of new 220 kV lines,
- 1 820 km of upgraded 400 kV lines,
- 1 334 km of upgraded 220 kV line,
- 4500 MVA of new 400/220 kV transformation capacity,
- 23220 MVA of new 400/110 kV transformation capacity,
- 11155 MVA new transformation capacity 220/110 kV,
- 2100 mVaR of new reactive power compensation capacity.

In addition to the commissioning of new infrastructure elements, the oldest equipment will be decommissioned. The investment expenditure estimated by PSE S.A. is expected to amount to more than PLN 32 billion. Of this sum approximately PLN 14.2 billion will be used for the continuation of the tasks foreseen in the previous Transmission System Development Plan and PLN 13.1 billion is expected to be needed to carry out the new tasks resulting from the system.

Distribution System Operators also presented their Development Plans for the coming years. These plans do not provide information on the projected investment outlays, but the scope of the planned upgrades and expansions of the network is presented.

PGE Ddistribution S.A. plans to reach 30 % of cable networks in SN's network by 2027. As of 2023, the company identified 1672 tasks relating to the connection of new customers and 1460 tasks relating to the connection of new sources to the distribution network.

Tauron Dystribucja S.A., as part of its development plan, envisages several tens of thousands of investment tasks, ranging from connecting new customers and generators to upgrading existing network infrastructure to continuing the process of replacing smart meters.

Energa Operator S.A. presented in its document plans to connect 917 new customers and 395 new generation sources. The Development Plan also lists 559 investment tasks related to the modernisation and restoration of network assets.

ENEA Operator Sp. z o. o. under the Development Plan identified the need to connect 953 new customers and 192 new generation sources. 733 investments related to the restoration and modernisation of network assets were also identified.

All distribution companies are also obliged by energy law to install AMI-class electricity meters by 2028 for at least 80 % of their customers connected at low voltage.

5.2.2. Natural gas

The operator of the natural gas transmission system in Poland is the company OGP GAZ-SYSTEM S.A. The transmission pipeline operator was designated by decision of the President of the ERO in 2006. Its main tasks are: managing the national transmission network, operating the liquefied natural gas terminal in Świnoujście and ensuring continuous reliable transmission of gas between sources and customers in Poland. The licence of the transmission system operator GAZ-SYSTEM S.A. shall be valid until 6 December 2068.

In 2023, GAZ-SYSTEM S.A. operated a transmission pipeline network with a length of more than 12 thousand km. In the transmission system, 66 entries (gas supply points from mines or compressor stations) and 880 exits from the system (mainly connections to distribution systems and gas collection points by final customers) were handled in the transmission system.

Table 2.74. Technical characteristics of the National Transmission System

Transmission System Component	Unit	2011	2015	2020	2023
System pipelines	km	9 853	10 996	11 056	12 121
System nodes	unit	57	58	34	36
Gas stations		869	881	864	828
Compressor stations		14	14	15	14

Source: GAZ-SYSTEM S.A.

The transmission system consists of two cooperative systems:

- The Transit Gas Pipeline System;
- The national transmission system consisting of two natural gas systems:
  - high-methane E;
  - nitrogen-rich Lw.

The nitrogen-rich natural gas transmission system covers parts of the West Poland in 3 voivodships: Lubuskie, Wielkopolskie and Dolnośląskie. It is supplied from deposits located in the Polish Lowland by the Kościan-Brońsko, Białcz, Radlin, Kaleje (Mchy) and Roszków gas fields. In addition, the system is supplied with gas from the Wielichowo mine, which, in order to achieve the gas parameters of the Lw sub-group, needs to mix high-methane gas in the Grodzisk Wielkopolski gas mixing plant.

High-methane gas storage facilities are an important element of gas infrastructure. There are currently seven natural gas storage facilities in Poland. Their technical characteristics are set out in the table below (Table 2.77).

Table 2.75. Maximum storage capacity in 2023/2024

Group of installations	Warehouse	Active capacity		Max. injection power		Max. take-off power	
		million m³	GWh	million m³/day	GWh/d	million m³/day	GWh/d
GIM Kawerna	KPMG Mogilno	585,4	6 521,4	9,60	106,9	18,00	200,5
	KPMG Kosakowo	239,4	2 669,3	2,40	26,8	9,60	107,0
GIM Sanok	KPMG Husów	500,0	5 650,0	4,15	46,7	5,76	64,6
	KPMG Strachocina	360,0	4 078,8	2,64	29,7	3,36	37,9
	KPMG Swarzów	90,0	1 013,4	1,00	11,2	0,93	10,4
	KPMG Brzeźnica	100,0	1 126,0	1,44	16,2	1,44	16,1
GIM Wierzchowice	KPMG Wierzchowice	1 300,0	14 729,0	9,60	107,5	14,40	158,4
SUM		**3 327,72**	**37 510,9**	**32,03**	**358,98**	**53,47**	**595,2**

Source: Gas Storage Poland sp. z o.o.

Forecasts for the development of the natural gas transmission network are prepared by GAZ-SYSTEM S.A. as part of the National Ten-Year Transmission System Development Plan. The latest version of this document covers the period 2024-

2033.

5.2.3. Oil and liquid fuels

Domestic oil reserves cover only a few percent of the annual demand for this raw material (between 3.5 % and 4 % of oil demand in the period 2020-2022). For many years, most of the imported crude oil came from the east. At present, as a result of the consistent implementation of the strategy for diversifying the supply of this raw material and international events, oil from Russia is no longer imported into Poland. Instead, Saudi Arabia became the main import destination in 2023, followed by Norway.

The change in the direction of meeting national demand has been made possible thanks to extensive infrastructure, mainly thanks to the oil terminal in Gdańsk, whose capacity (36 million tonnes of oil and 4 million tonnes of petroleum products per year) is sufficient to fully cover the Polish refineries' needs.

The national oil and fuel storage capacity is around 10 million m³ and is sufficient to maintain emergency stocks as well as to cover the commercial and operational needs of market operators.

The oil infrastructure consists of three sections:

1) The eastern section of the 'Przyjazń' pipeline connects the Adamów reservoir, located at the border with Belarus, with the Raw Material Base in Miszewk Strzałkowski near Płock. This section has a capacity of 50 million tonnes of oil per year.
2) The Western section of the 'Przyjaźń' pipeline connects the Raw Material Base in Miszewk Strzałkowski with the MVL tank located in Schwedt. This part of the bus is fed into the raw material for two German refineries: PCK Raffinerie GmbH Schwedt and TOTAL RaffinerieMitteldeutschland GmbH in Spergau. The Western section of the 'Przyzhń' pipeline achieves a production capacity of 27 million tonnes of oil per year.
3) The Pomorski pipeline connects the Manipulation Database in Gdańsk with the Raw Material Base in Miszewk Strzałkowski. Through this route, PERN secures the transport of raw material from maritime supplies via the Port of Gdańsk (Naftoport). Through the Pomorskie pipeline, the raw material can be transported in two directions. On the Gdańsk-Płock route, its capacity is approx. 30 million tonnes of oil per year, while in the opposite direction the pipeline is efficient about. 27 million tonnes per year.

PERN S.A. also has a network of product pipelines for transporting petroleum products in three directions:

1) Płock – New Wieś Wielka – Reiowiec (direction: Bydgoszcz – Poznań):
   (a) On the route from Płock to New Wield, 2.8 million m³ of fuels may be transported annually. 2.2 million m³ of fuels per year can be shipped to the Porttainer by extending the pipeline.
2) Płock – Mościska – Emilianów (direction: Warsaw)
   (a) This pipeline can be transported from Płock to Mościsk about 2.1 million m³ and to Emilianov about 1.5 million m³ of fuels per year.
3) Płock – Koluszki – Boronów (direction: Łódź – Częstochowa)
   (a) Trasa Płock – Koluszki has an annual throughput of 4.9 million m³ of fuels and its extension from Koluszek to Boronowa approximately 2.4 million m³ of fuels per year.

Figure 2.29. Illustrative layout of PERN S.A. product pipelines (as of 2023)

Source: PERN S.A.

In the crude oil processing process, the production of liquid fuels is mainly carried out in refineries belonging to the ORLEN Group. In 2022, the LOTOS Group, the PGNiG Group, merged with the ORLEN Group, creating the largest fuel and energy entity in Central Europe.

The total capacity of the ORLEN Group refineries is around 45 million tonnes per year, with around 27 million tonnes being produced in the Polish refineries in Płock and Gdańsk:

- The ORLEN refinery in Płock – is one of the most up-to-date production plants in Central and Eastern Europe with a capacity of 16.3 million tonnes/year
- The ORLEN refinery in Gdańsk – as a result of the merger of the ORLEN group with the LOTOS group – became owned by ORLEN and Saudi Aramco. The total capacity of refineries is around 10.5 million tonnes/year and is distributed between the two owners.
- ORLEN South refineries in Trzebini and Jedli are specialised in the production of biocomponents, oil bases, fuel oils, hydrotreated paraffins and regenerate the oils worked.
- The ORLEN Lietuva refinery in Moldova (Lithuania) is the only plant of this type in the Baltic States with a capacity of 10.2 million tonnes/year.
- The ORLEN Unioetrol refinery in Kralupe and Litvinova (Czech Republic) has a total capacity of 8.7 million tonnes/year.

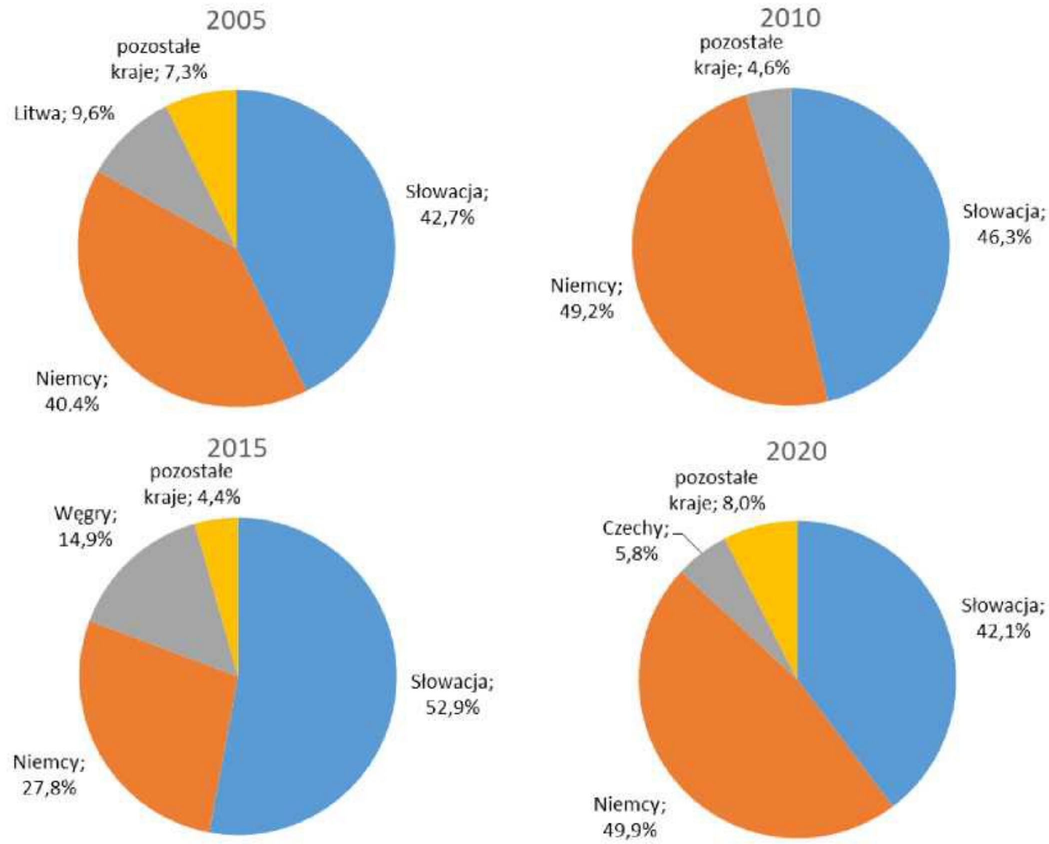


Figure 2.30. Directions of imports of petrol in 2005, 2010, 2015 and 2020
Source: ARE S.A. database.

The production of petrol, diesel and fuel oil in Poland covers to a very large extent the domestic demand for these types of fuel.

The retail trade in petrol, diesel and auto-gas is carried out at service stations and auto-gas stations. The number of service stations increased in 2020 compared to 2015. 7739 service stations (in 2015 there were about 6 601).

Given the number of service stations operated, PKN ORLEN S.A., which has around 1811 stations. The second Polish operator in terms of the number of service stations used in 2020 was Grupa Lotos S.A., which had a total of approx. in 2020. 513 stations throughout Poland. However, as a result of the merger of the LOTOS and ORLEN groups, the company's petrol stations were sold to foreign entities in order to avoid the concentration of the service station sector detrimental to competitiveness.

Foreign companies held approximately in 2020. 1569 service stations. The leaders in this respect are BP, Shell and CircleK. Independent (non-attached) operators owned approximately in Poland. 3659 service stations. Stations in independent operators' networks with more than 10 service stations are approx. 1181 sites. There was also a slight increase in the number of shop stations. Today, the number of such service stations is close to 190 facilities.

The presence of franchise stations is also noticeable, as a result of the fact that many private operators, and often hypermarkets, cooperate with a strong brand partner and a stable market position.

The price of liquid fuels is not regulated by the President of the ERO. They are market-based – they are essentially determined by global oil prices, excise and VAT rates and fuel charges, as well as the USD exchange rate.

5.3. Electricity and natural gas market, energy prices

Current situation in electricity and natural gas markets including energy prices

Electricity market

During the period under review, national electricity production has been on an increasing trend reaching 179.7 TWh in 2022, which is the highest hitherto in Poland's electricity history. Over the years, there is also an increase in electricity consumption, which in 2022 was around 1.7 TWh below production, i.e. 0.9 % (Figure 2.40). The structure of electricity production shows a slow change in the energy mix, due to changes in legal and market conditions (Figure 2.41). It is still based on coal, but to a lesser extent than in 2005-2015, which sends a positive signal in the context of EU climate policy. In 2020, the share of coal in the production structure was lower than in 2022, due to the need to shut down or reduce the capacity of many coal blocks. Between 2005 and 2022, there was a significant increase in the amount of energy produced from RES, from 3.8 TWh in 2005, to 37.7 TWh in 2022.

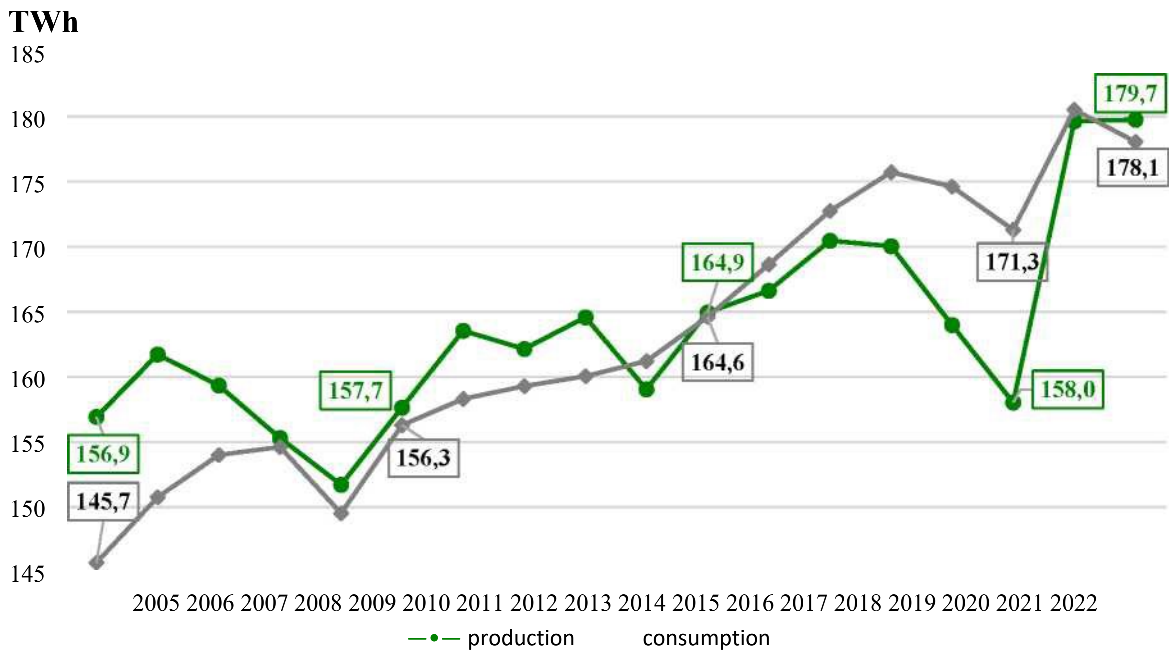


Figure 2.31. Total electricity generation 2005-2022

Source: ARE SA

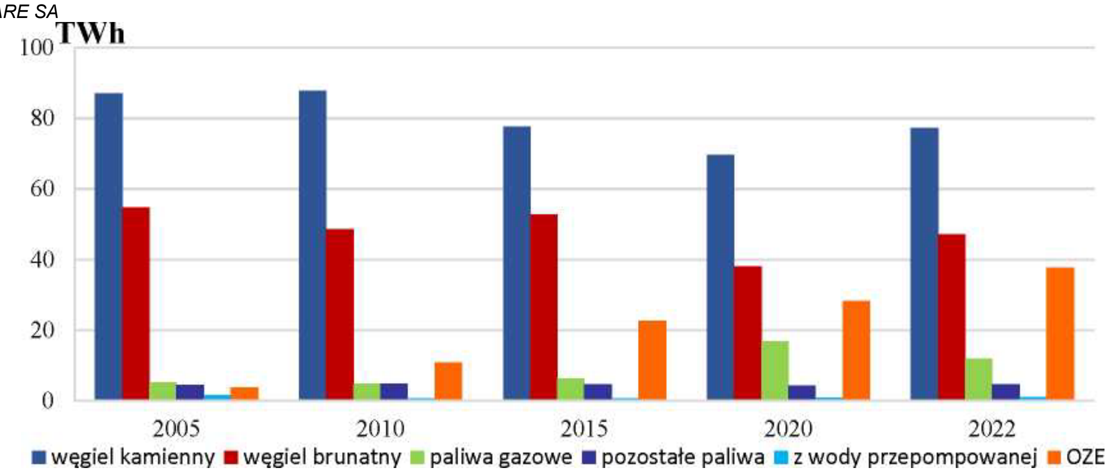


Figure 2.32. Electricity production by energy carrier in 2005, 2010, 2015, 2016

Source: ARE S.A.

The structure of the wholesale electricity market was presented on the basis of an analysis of the directions of energy sales.

In 2022, professional power generators sold a total of 124.6 TWh of energy, i.e. about 11.2 % more than in 2020 (112.0 TWh), and the main form of wholesale electricity trading in power plants and power plants was sales on regulated markets, where the energy exchange and sales to trading companies were the predominant. The increase in popularity of the exchange-trade in electricity in Poland was mainly affected by the 2018 amendment to the Energy Law Act, which raised the so-called stock exchange list from 30 % to 100 % in 2019-2022. The obligation did not apply to electricity produced from, inter alia, renewable energy sources, cogeneration, self-consumption and units with an installed electricity capacity of no more than 50 MWe. In 2022, the stock exchange listing obligation was abolished.

The main channel for the sale of electricity by generators in 2022 was once again Comwarowa KBC S.A., with a share of more than 74.3 % of total turnover. By comparison, the market share of the stock exchange was 0.7 % in 2005, 4.2 % in 2010, 48.2 % in 2015 and 63.0 % in 2020. 15.7 % of electricity was sold to trading companies (PO) in 2022, and the share of this direction in energy sales by generators decreased by 9.4 percentage points compared to 2020, and by 27.9 percentage points compared to 2015. The remaining sales were predominantly made on the balancing market (7.6 %), including for the security of operation of the national electricity system and only to a small extent to end-users and exports.

The structure of electricity sales is shown in the table below (Table 2.78).

Table 2.76. Structure of sales of electricity in commercial thermal power plants

Years	Total	Turnover undertakings [1)]	TGE stock market	of which: forward market %	SPOT	end recipients	balancing market
	Sales of electricity			of which:			
	GWh						
2005	145 031,0	87,32	0,72	.	.	3,59	8,37
2010	141 253,1	88,05	4,21	1,12	3,10	1,85	5,87
2015	146 588,5	43,65	48,17	45,21	2,94	2,41	5,39
2020	111 989,0	25,07	63,03	58,56	4,47	2,31	7,56
2022	124 577,5	15,71	74,35	69,11	5,24	1,30	7,59

In 2005 it includes sales to PSE S.A. Source: ARE S.A.

The retail market from the demand side is the market of the final customer. ‘Final customer’ as defined in the EP (amendments that entered into force on 11 March 2011) is a customer purchasing fuel or energy for his own use; self-consumption does not include electricity purchased for consumption for the generation, transmission or distribution of electricity.

In addition to final customers, retail market participants include electricity sellers and distribution system operators (DSOs). Distribution system operators are electricity distribution undertakings responsible for the secure and reliable operation of the distribution system while guaranteeing effective and non-discriminatory access to that system for all market participants.

Electricity sales to final customers during the period under review are shown in the table below (Table 2.79).

Table 2.77. Electricity sales to final customers

Breakdown		2005		2010		2015		2020		2022	
		quantity	p.m. Price	quantity	p.m. Price	quantity	p.m. Price	quantity	p.m. Price	quantity	p.m. Price
		GWh	EUR 2020 /MWh	GWh	EUR 2020 /MWh	GWh	EUR 2020 /MWh	GWh	EUR 2020 /MWh	GWh	EUR 2020 /MWh
Thermal power plants PW[1)]		5 359	38,1	1 363	65,2	2 856	53,1	1 897	57,5	1 725	89,9
of which: customers with comprehensive contracts		1 025	45,5	388	67,2	2 232	53,9	1 769	56,4	1 622	88,9
EC. Independent		—	—	1 501	64,7	1 057	54,4	1 218	65,2	1 120	106,5
of which: customers with comprehensive contracts		—	—	—	—	836	53,6	700	60	547	93,8
Turnover companies of the OP		3 969	36,8	6 308	61,8	13 907	52,8	21 045	68,3	28 661	119,1
customers with comprehensive contracts		—	—	—	—	10	55,9	3 134	82,1	3 480	98,5
customers with sales contracts		3 969	36,8	6 308	61,8	13 898	52,8	17 911	65,5	25 181	122,2
of which:	— on WN+NN	2 752	36,8	2 218	60	2 073	45,3	4 555	53,3	5 099	145,2
	— on SN	1 213	36,4	3 764	62,3	7 874	53,5	10 345	65,5	16 437	120,4
	— per nN	3	107,4	325	68,7	3 950	55,5	3 011	73,9	3 645	114,6
Turnover companies of PO_{SD}		98 705	40,3	108 954	68,5	107 517	58,7	113 003	69,2	106 759	101,4
customers with comprehensive contracts		95 531	40,3	86 802	70,1	60 512	64,8	56 761	72,7	54 174	100,6
	— on WN+NN	14 311	36,6	7 588	62,3	3 629	50,4	2 153	60,9	1 876	132,3
	— on SN	33 392	38,1	27 439	69,9	16 400	58,9	13 312	73,2	12 109	110,5
	— per nN	47 796	43	51 775	71,4	40 484	68,5	41 296	73,1	40 190	96,2
customers with sales contracts		3 174	36,2	22 152	62,2	47 005	50,9	56 242	65,7	52 585	102,2
	— on WN+NN	3 139	36,2	12 965	59,7	16 849	43,6	17 728	58,2	15 837	106,6
	— on SN	35	36,5	7 328	65,2	21 080	53,4	27 742	68,4	27 524	100,9
	— per nN	—	—	1 858	67,7	9 076	58,5	10 773	71	9 224	98,5
TOTAL [2)]		**108 036**	**40**	**118 126**	**68,1**	**125 339**	**57,9**	**137 197**	**68,9**	**138 313**	**101,2**

1) — in 2005 including independent
2) — including professional hydropower plants Source: Are SA based on test results 1.44.02

Sales of electricity to final consumers in the country are steadily increasing. An increase of more than 28 % was recorded in the period presented (from 2005 to 2022). The main energy seller remains the incumbent trading companies created after the separation of the distribution system operator from former distribution companies, which account for 77 % of the total sales contracts. The other independent electricity trading companies gain an increasing share of sales to final customers. The sale of energy is carried out under both comprehensive and sales contracts. During the period presented, there was a sharp increase in the share of TPA consumers in the energy market. In 2005, it stood at 7 %, while in 2010 24 % exceeded 56 % of total electricity sales in recent years.

Natural gas market

In December 2012, an important step was taken towards the liberalisation of the Polish gas market through the launch of a gas exchange on the Commodity Energy Exchange. This was the implementation of Article 49b of the Energy Law Act, which obliged energy companies trading in gaseous fuels to sell part of methane-rich natural gas entered into the transmission network in a given year on commodity exchanges. In 2013 this obligation it amounted to 30 % of the volume of gas injected into the transmission network by a natural gas trader. Since 2015, the quantity has been increased to 55 %, while the 2022 Regulation of the Minister for Climate and the Environment set a level of not less than 30 %. TGE S.A. carried out in 2022 on the market for the sale of gaseous fuels: The market for Current Day, the Next Day Market and the Commodity Market.

On 1 January 2017, the provisions of the Energy Law Act abolishing the supervision of the President of the ERO on tariffs for the sale of gas to wholesale customers, for the sale of LNG and CNG gas, for the sale of this fuel to final customers purchasing it at a virtual point and in the form of tenders, auctions and public procurement, entered into force. On 1 October 2017, the obligation to submit tariffs for the sale of high-methane and nitrogen-rich natural gas to non-household final customers for approval was abolished. Until the end of 2027, the President of ERO will supervise tariffs (i.e. maximum prices) for network gas sold to households.

The gas market in Poland operates at two levels:

- **wholesale market** – sales of gas to large customers connected to the transmission network or to distribution companies or trading companies (at the end of 2022, there were 176 entities holding licences for trading gaseous fuels on the wholesale market, 89 of which were actively involved in the trading of natural gas),
- **retail market** – sale of gas to final customers connected to the distribution network.

In 2022, gas sales to final customers continued to be dominated by companies in the ORLEN group (formerly PGNiG S.A.) and the share of alternative sellers on the retail market decreased. The share of the ORLEN group in gas sales to final customers was just over 89 % (compared to 86 % in 2020). The remaining sales of gas to final customers were made by other trading companies selling domestically. In 2022, gas undertakings sold 181 905 GWh of natural gas to final customers, in 2 020.197120 GWh (Table 2.80).

Table 2.78. Natural gas sales (GWh)

	2005	2010	2015	2020	2022
Total sales	153 200	157 211	150 192	197 120	181 905
Industrial customers	93 504	95 816	95 390	132 138	105 451
Households	41 698	45 788	40 783	49 640	56 066

Source: ARE S.A.

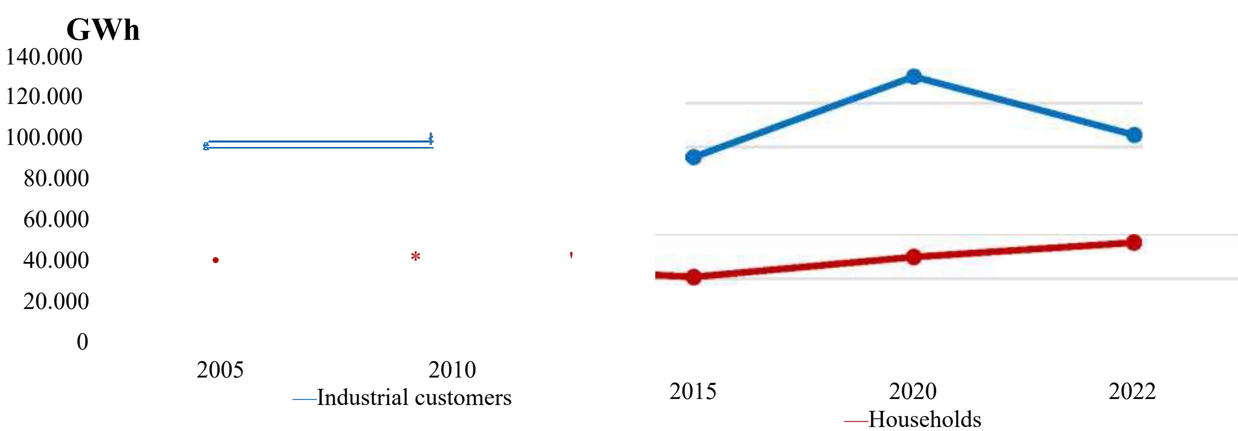


Figure 2.33. Sales of natural gas to industrial customers and households in 2005, 2010, 2015, 2020, 2022 (GWh)

Source: ARE S.A.

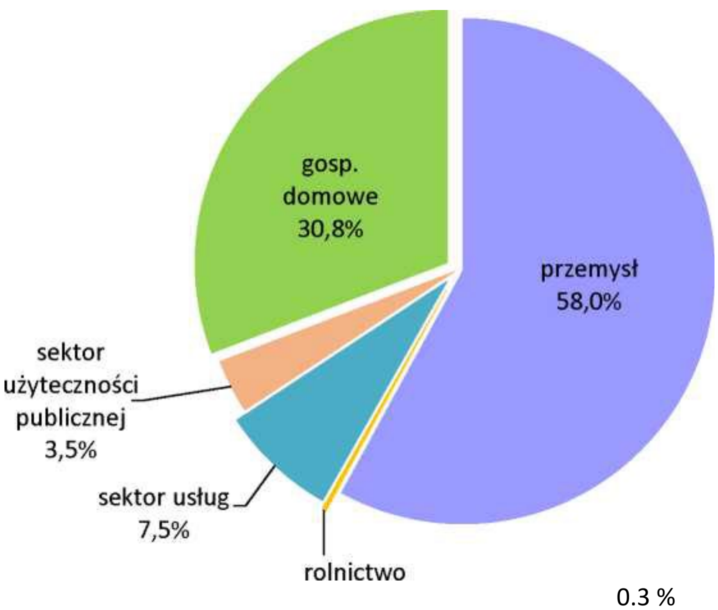


Figure 2.34. Structure of gas sales to final customers by sector (GWh) – end of year 2022

Source: ARE S.A.

Domestic natural gas production amounted to 42 225 GWh in 2022 (43 653 GWh in 2020). Total imports of natural gas, i.e. the sum of imports and intra-Community acquisitions, amounted to 164 364 GWh in 2022, compared to 187 000 GWh in 2020.

Table 2.79. Extraction and import of natural gas in 2005, 2010, 2015

	2005	2010	2015	2020	2022
	GWh				
National production	50 194	47 414	47 591	43 653	42 225
Total imports	110 708	115 162	129 123	187 000	164 364
Imports from the east	101 382	103 204	93 731	102 497	31 926
Intra-community acquisitions	3 929	11 958	34 013	42 227	65 123

Source: ARE S.A.

6. Dimension research, innovation and competitiveness

6.1. Current situation of the emission-reducing technology sector and its position on the global market

The chapter assesses the competitiveness of strategic net-zero technologies as defined in the European Union Act: The Green Deal Industrial Plan for Net-Zero Industry. It provides an overview of the evolution of technologies and markets to achieve the objectives of the European Green Deal and the REPowerEU Plan. The proposed Net-Zero Industry Paper sets out eight strategic net-zero technologies to achieve the 'Fit for 55' target for 2030 of reducing net greenhouse gas emissions by at least 55 % compared to 1990 levels. These are solar energy technologies (PV and solar thermal technologies), onshore wind and offshore renewable generation technologies, electrolysers and fuel cells, battery storage technologies, sustainable biogas/biomethane technologies, carbon capture and storage technologies, heat pumps and geothermal technologies, and grid technologies. In the proposed act, the EU sets out an overall headline benchmark for each of the listed strategic net-zero technologies, which aims to ensure that, by 2030, the Union's manufacturing capacity of strategic net-zero technologies approaches or reaches at least 40 % of the Union's annual deployment needs.

Photovoltaics

Photovoltaics are the fastest growing power generation technology. It provides cheaper electricity than fossil fuel power plants in most countries. It plays a key role in all scenarios for achieving a climate-neutral energy system. In 2022, solar PV already generated 7 % of the total installed capacity of 212 GWp in the EU. The EU Solar Energy Strategy aims to reach 720 GWp installed by 2030, a fourfold increase from 2021 levels. The PV value chain is dominated by Asian countries, in particular China. However, the European Solar Photovoltaic Industry Alliance launched on 9 December 2022 aims to increase the EU's production capacity to reach at least 30 GWp across the supply chain by 2025. However, there is strong international competition to attract productive investments.

Photovoltaic installations rely to a very large extent on crystalline silicon (polysilicon) technology, which continues to increase energy conversion efficiency and reduce material consumption. In 2022, the commercial modules provided an average efficiency of 21.1 % and a maximum of 24.7 %. Innovative materials, such as Perovians, offer an opportunity to further increase the efficiency of energy conversion. In May 2023, the Perovt-Silicon tandem device established a new efficiency record of 33.7 %. The pilot lines of these tandems are under development, including in the EU, but commercial products are not yet available.

In 2022, EU companies were active in the production of silicon, ingots/plates, cells, modules and inverters and offered commercial products. Inverter production remains by far the largest segment in solar energy production in the EU, with production capacity reaching almost 70 GW, about 5 GW more than in 2021. The EU also has one of the main polysilicon producers that exports mainly to China. At the beginning of 2023, nominal module production capacity in the EU amounted to 8.28 GW per year, for cells to 0.86 GW per year and 1.4 GW per year for ingots and wafers. In 2022, it is estimated that Union producers assembled modules with a capacity of around 4 GW (10 % of the market), mainly from imported cells.

In 2022, Chinese companies provided at least three quarters of the global production capacity at all stages of the PV supply chain and were the main exporters of wafers, cells and modules. Moreover, Chinese companies account for more than 80 % of the world's polysilicon production. PV prices remained broadly stable in 2022, with the price of the main modules at EUR 0.35/W, but started decreasing again in the first half of 2023 due to massive competition and excess supply of components along the value chain. In September 2023, the price reached a record low of almost EUR 0.22/Wp, making it difficult for Union producers to produce cost-effectively.

The PV market continued to grow significantly in 2022, with a global installed capacity of 1185 GWp (an increase of 230 GWp year-on-year). China was the largest single market with a capacity of around 90 GWp. This was a record year for the EU, with installed capacity of 41 GWp (18 % share). This was mainly driven by Spain (8.1 GWp), Germany (7.5 GWp), Poland (4.9 GWp) and the Netherlands (3.9 GWp). The residential sector, with a share of over 50 %, was particularly strong. High electricity prices have contributed to the competitiveness of PV electricity (the industrial-scale averaged cost of use being the lowest for any technology in almost all markets).

Solar Thermal

As stated in the EU Solar Energy Strategy, solar thermal energy can make a significant contribution to the decarbonisation of the energy system. Solar thermal technologies use little or no critical raw materials at all and can achieve a high degree of recycling.

Concentrated solar power plants (CSP) with a total capacity of 6.4 GW are active worldwide. Spain is almost entirely responsible for a capacity of 2.4 GW in the EU. New power plants are being built in the United Arab Emirates, China and South Africa, which could increase capacity by 1.8 GW by 2025. No new power plants have been operational in the EU since 2014, but Spain plans to increase capacity by at least 2 GW by 2030.

There are a number of applications of solar heating and cooling technologies in buildings, district heating networks and industrial processes. Current average costs for heating/cooling (EUR 20 to EUR 110/MWh in Europe) can be competitive with gas heating, especially in areas with significant solar energy resources. The overall EU market share is still small at 0.678 TWh (0.1 %), compared to a total derived heat demand of 651 TWh in 2021. According to the reported information, the EU transparent shielded collector sector grew by 10 % in 2022. This is a positive indicator, albeit below the level needed to triple production capacity between 2021 and 2030, as proposed in the EU Solar Energy Strategy. Solar thermal systems feed district heating systems in 264 large and small cities in Europe (representing less than 5 % of the 6000 grids in use). EU companies are responsible for a large share of the supply and export of solar water heaters in the EU market. In 2022, these companies faced significant supply chain disruptions.

Onshore and offshore wind

Wind energy plays an important role in achieving EU carbon neutrality. The REPowerEU plan calls for a faster installation of wind capacity to deploy 510 GW of wind capacity by 2030. The share of wind energy in electricity generation capacity in the EU is projected to be 31 % in 2030. At the same time, the EU's wind energy sector faces a number of challenges. To address these issues and increase the EU's competitiveness in the wind energy sector, the Commission adopted an action plan on wind energy.

In 2022, the total installed capacity in the EU was 204 GW (189 GW onshore; 16 GW in offshore energy). 16.2 GW (15 GW onshore) were installed in 2022; GW in offshore energy), which represents an increase of almost 50 % compared to 2021. Industry plans to install 20 GW of wind capacity per year in the EU over the next 5 years, below 30 GW/year needed to meet the 2030 targets. Overall, China remains the leader in wind power, with a total capacity of 334 GW (31 GW offshore), with 37.6 GW added in 2022, including 5 GW in offshore energy. The EU is in second place and the US is in third place with a total capacity of 144 GW. The new global total wind capacity installed in 2022 was 68 GW of onshore and 9 GW of offshore energy. In January 2023, EU Member States concluded non-binding agreements on offshore renewable energy targets per sea basin, with a total EU capacity of 109-112 GW by 2030, 215-248 GW by 2040 and 281-354 GW by 2050.

The EU wind sector remains one of the strongest players in the global market. In 2022, EU producers accounted for 85 % of the EU wind market and 30 % on the global market, down from 42 % achieved in 2019. In particular, for the maritime sector, EU companies held 94 % of the EU installation market share in 2022.

Batteries

Batteries play a key role in the clean energy transition, both in transport and stationary applications. As part of the EU's objectives such as the transition to zero-emission new light-duty vehicles only by 2035, increasing global competitiveness, meeting EU policy objectives and preventing new dependencies on fossil fuels. The EU is significantly increasing domestic battery production.

EU battery production is expected to reach 458 GWh by 2025 and 1 083 GWh by 2030 to meet projected EU demand. The European Battery Alliance plays a key role in this context, and in 2022 the European Battery Industrial

Network increased from 750 to 800 members from the whole value chain. To date, the European battery ecosystem is responsible for investment commitments, mainly private, worth around EUR 180 billion.

Despite an overall decline in the EU car market in 2022, sales of fully battery electric vehicles (BEVs) in the EU increased by 28 % compared to 2021, corresponding to 12.1 % (1.12 million) from 9.1 million vehicles sold on EU markets. Together, BEVs, plug-in electric vehicles and hybrid electric vehicles accounted for 44.1 % of car sales in the EU in 2022. The upward trend continues, with BEVs alone sold 819000 and 1.288 million of all plug-in electric vehicles in the EU-27 in October 2023. Globally, this trend indicates 14 million vehicles by the end of 2023 (+ 35 % compared to 2022), which could represent 18 % of total car sales in 2023.

While most batteries will end up in the automotive sector, stationary storage is also growing exponentially. By the end of 2023, energy storage systems with a capacity of 154 GWh are expected to be installed globally, 102 % more than in 2022, of which around 10 % are expected to be installed in the EU.

While global production increased by 180 % compared to 2017, the very high global demand for lithium in 2022 exceeded supply once again. In 2022, approximately 60 % of the demand for lithium, 30 % of the demand for cobalt and 10 % of the demand for nickel concerned electric vehicle batteries (15 %, 10 % and 2 % respectively in 2017). After ten years when prices mainly decreased, despite an increasing share of cheaper chemicals such as lithium-iron phosphate (LFP), average prices for lithium ion battery packs (LIB) reached EUR 136/kWh in 2022, an increase of 7 % compared to 2021. In Europe, due to higher production costs, average prices in 2022 were EUR 152/kWh, 24 % higher than in the US and 33 % higher than in China. According to BloombergNEF, Europe's share of global announcements of investment in lithium-ion battery (LIB) production capacity fell from 41 % in 2021 to 2 % in 2022. It should be borne in mind that such announcements of large investments are usually 'flat-rate' and not in line with the linear pattern. According to mid-2023 forecasts, the United States will ahead of the EU's battery manufacturing capacity in 2031. While the US added 436 GWh (57.9 % increase) to drafts since the Inflation Reduction Act came into force, the EU added only 25 GWh (3 %). Given the support provided by the Inflation Reduction Act and lower energy prices in the US, the actual price of batteries in the EU would be 40 % higher than in the US, which means up to EUR 4000 higher costs for European BEV batteries, a price gap that could have a negative impact on the deployment of production capacity in the EU.

The EU market for stationary batteries is also growing steadily. In the first quarter of 2023, the installed energy storage base in energy networks (except pumped storage) in the EU was around 11 GW/14.7 GWh of storage facilities, of which ~5.3 GW/55.6 GWh were installations connected to the distribution or transmission grid. At least ~19 GW/42.3 GWh of storage facilities connected to the distribution or transmission network is currently under development. However, in order to achieve the EU's objectives of the "Fit for 55" and REPowerEU package, the deployment of stationary energy storage needs to be swiftly deployed to reach the projected demand of 200 GW by 2030.

The EU demand for lithium batteries is currently estimated to be around 1 TWh by 2030. While China still covers most of the excess demand in the EU, EU private investment in local battery production will drive companies to build facilities close to electric vehicle production lines to reduce transport costs. Despite the potential negative impact of the Inflation Reduction Act on the development of battery value chains in the EU, the pace of construction of battery factories across Europe is increasing and is expected to meet most of the demand in the EU by 2030.

Heat pumps

The European Commission is preparing an EU Action Plan to accelerate the deployment of heat pumps. In eighteen EU Member States covered by the European Heat Pump Organisation (EHPA), there were 17.4 million individual heat pumps, mainly dedicated to heating, at the end of 2022. Their sales increased by 41 % to 2.75 million units in 2022. In the first half of 2023, sales of heat pumps in the EU continued to increase, while in some countries, such as Italy, sales fell compared to the first half of 2022 due to changing national support schemes and unfavourable electricity-to-gas price ratios. Model-based decarbonisation scenarios have shown high growth potential. For example, according to the JRC POTEnCIA model, the number of individual heat pumps mainly used for heating in the EU (13 million in 2020) is expected to increase 2.5-fold by 2030 and almost 10 times by 2050. The power of appliances is expected to halve by 2050 thanks to better insulation of buildings; this is in line with the REPowerEU ambition of installing at least 30 million heat pumps by 2030.

District heating can be the preferred heating option in densely populated urban areas where large heat pumps can source solar, geothermal or excess heat from industrial or urban processes. The draft European Warming Action Programme estimates a potential market share of 50 % for district heating in Europe by 2050, with around 25-30 % of the generation capacity based on large electric heat pumps. This could cover up to 38 % of total heat production in district heating.

The technical potential of industrial heat pumps varies from sector to sector, ranging from around 65 % of process heat in the paper industry, 40 % in the food industry to 25 % in the chemical industry. In Europe alone, heat pumps with a total capacity of 15 GW could be deployed in almost 3000 installations.

In 2021, it is estimated that the EU's production capacity covered 75 % of EU demand for individual water heat pumps. Water heat pump producers are investing at an unprecedented scale and pace in Europe's production capacity, investing almost EUR 5 billion between 2023 and 2026, as well as in a new platform to promote the deployment of heat pumps created to accelerate their deployment. For large heat pumps for commercial and network applications, European industry has a dominant market position. Also for industrial heat pumps, there are 17 EU producers, 8 from Norway and only 3 non-European producers (all based in Japan). Their main components (e.g. compressors) are produced locally.

Geothermal energy

Deep geothermal energy has the highest capacity utilisation rate from all renewable energy sources (which may exceed 80 %), low operating costs and an extensive production base. Deep-sea geothermal power in 2022 reached 16.1 GWe worldwide, of which 877 MWe in the EU. No new plant was launched in Europe in 2022 and the global growth of 286.4 MWe, mainly in Kenya, Indonesia and the USA, was below the 3 % annual pre-pandemic trend. It is more promising that the direct use of geothermal heat in the EU has seen a steady increase of 9 % since 2010, especially in district heating and cooling. There are currently 261 systems using geothermal heat directly, with 12 new systems added in 2022 (5 in France alone).

Geothermal turbines are mainly produced by several large, mostly non-European, industrial corporations such as Toshiba (JP), Fuji Electric (JP), Mitsubishi Heavy Industries (JP), Ormat Technologies (US/IL) and Ansaldo Energia (IT), with some notable exceptions in Italy. The market for the construction of geothermal facilities involves many companies from the public and private sectors. In district heating, geothermal suppliers for underground parts of installations are mainly active in the oil and gas industry. Pumps, valves and control systems are usually imported from the USA and Canada. Drilling activities, which entail high costs for geothermal projects at large depths, are dominated by several specialised companies outside Europe.

Electrolysis of water for the production of renewable hydrogen

Water electrolysis is currently the only key technology for large-scale renewable hydrogen production. It can contribute to the decarbonisation of hard-to-abate sectors, such as industry, heavy-duty, maritime and aviation, or to other applications such as energy storage (especially seasonal).

In the EU, the revised Renewable Energy Directive sets specific sub-targets for the use of renewable fuels of non-biological origin for the production of renewable hydrogen in industry (42 %) and transport (1 % RFNBOs and 5.5 % in combination with advanced biofuels) by 2030. The new Delegated Regulation on the definition of renewable fuels of non-biological origin sets requirements for the production of renewable fuels of non-biological origin, including renewable hydrogen, such as temporal and geographical correlation and the additionality principle.

The global installed electrolyser capacity is expected to reach around 2 GW by the end of 2023 compared to the range of 600-700 MW at the end of 2022 and 500 MW at the end of 2021. Most of these capacities estimated between 50 % and 75 % are alkaline, the remainder being almost entirely composed of proton exchange membrane (PEM) electrolysers. In terms of installed capacity, China is a leader with expected installed capacity of around 1 GW by the end of 2023, with the world's largest 260 MW project launched in 2023, up from 204 MW already installed in 2022. It is followed by Europe (EU-27, EFTA, UK) with a projected capacity of 500 MW by the end of 2023 (one quarter of global capacity), up from 162 MW in operation (August 2022). For the United States, there is insufficient detailed data and the capacity installed in 2022 was estimated at 19 MW. By the end of 2022, global electrolyser capacity was estimated to be around 13-14 GW/year, of which around 3.3 GW/year in Europe.

Industry initiatives, such as the European Clean Hydrogen Alliance under the auspices of the European Commission to promote industrial leadership in renewable and low-carbon hydrogen and the Electrolysers Partnership, aim to achieve an annual electrolyser capacity of 25 GW by 2025. China has the largest production capacity, which generates at least half of the global volumes and focuses almost exclusively on alkaline electrolysers. Production capacity in North America is similar to that in Europe and is now more concentrated on PEM electrolysis. In terms of cost competitiveness, the price of electricity is one of the main drivers of the final cost of hydrogen produced by water electrolysis, and its weight increases with the number of full load hours of the electrolyser. US sources estimate that electricity prices at around USD 30/MWh (EUR 28.4/MWh) would result in a hydrogen price of USD 2/kgH2 or around EUR 1.9/kgH_2.

In Europe, the Clean Hydrogen Joint Undertaking is investing EUR 2.4 billion in the entire hydrogen value chain. Investments supported by Important Projects of Common European Interest in the field of hydrogen have enabled several producers to build new electrolyser plants in Europe, increasing the EU's technological autonomy, industrial know-how and creating jobs. The production of hydrogen from renewable sources poses some challenges. The issue of energy efficiency loss arises, which means that production must be combined with significant renewable electricity generation. In addition, access to fresh water resources should be taken into account when launching new water electrolysis projects that may exacerbate local water stress in the EU and in third countries, in order to avoid a shortage of another element essential to human life.

Renewable hydrogen and its derivatives are not yet traded globally, despite the increase in projects to transport hydrogen worldwide from regions rich in renewable energy but with relatively low demand to high-demand regions such as Europe and Japan. There is no specific commercial code for renewable hydrogen yet. Some voluntary certification schemes have been notified to the Commission.

Building production capacity in Europe must be linked to adequate recycling infrastructure. Additional research and investment on recycling will be needed, including the critical raw materials needed to produce electrolysers. A new challenge will be to develop substitute materials for membranes with a level of durability and performance comparable to that provided by the current state of the art, typically based on perfluoroalkyl and polyfluoroalkyl substances. Research is needed to find satisfactory alternatives.

Sustainable biogas and biomethane technologies

Sustainable biogas and biomethane make an important contribution to the swift and cost-effective achievement of the EU's energy autonomy and climate neutrality. Under REPowerEU, the Commission proposed a Biomethane Action Plan supported by the Biomethane Industrial Partnership, which aims to replace around 10 % of natural gas per year with sustainable biomethane production by 2030. Renewable gas and natural gas markets and the EU hydrogen regulation will facilitate efforts to integrate biomethane into the EU gas network.

The commercial technology for biogas or biomethane production is anaerobic digestion, but biomethane performance is low. Innovative biomethane production technologies, such as biomass residues and waste gasification and biomethanisation of biogas, are close to market readiness. Innovative pathways based on both thermochemical and biological processes are also being developed. The current trend towards increasing biomethane production is the construction of new plants and the conversion of existing biogas plants producing combined heat and power into biomethane plants.

EU public funding for biomethane technologies for research and innovation between 2014 and 2021 amounted to EUR 77 million, making the EU a leader in high-value inventions worldwide. Between 2010 and 2022, the EU was by far the leader in scientific publications, and China ranked third in 2022.

In 2022, the EU was the largest producer of biogas, accounting for over 67 % of global biogas production. Of this, 53 % was produced in Germany, followed by North America (around 15 %), while China provides incentives to produce biogas to increase its production. Many European companies play an important role in the market for the production of biogas plant equipment and the overall design and construction of plants. The turnover of the EU biogas sector in 2021 was EUR 5 530 million, of which 60 % in Germany and 12 % in Italy, with 47100 direct and indirect jobs.

Biogas feedstocks are diversified and sourced locally in Europe, without risk of dependence on imports. The EU is at the forefront of the technological development of the sector, but will have to face the challenges of scaling up due to high capital and operational costs, cost competitiveness vis-à-vis natural gas and access to the gas grid. Currently, biomethane production costs range from EUR 40 to 120 per MWh; however, technological innovation, the replication of first-of-a-kind innovative biomethane technologies and market-based incentives with EU support in the form of a stable regulatory and investment framework could reduce production costs by 25-50 %. This could boost the EU's competitiveness in this sector. Switching to waste residues and raw materials reduces availability but also reduces input costs. Current installations are small and medium-sized due to the availability of raw materials, logistics and costs. Modernising existing biogas installations to switch to biomethane requires small operators (farmers or SMEs) high investment costs of EUR 1-2 million, which means that incentives for companies are needed. Injection into the grid is not always possible as power plants are built where raw materials are available and the gas grid is not well developed in all regions of the EU, which requires supporting access to the gas grid. Currently, about half of all biomethane production facilities are connected to the natural gas grid.

Total biogas and biomethane production from anaerobic digestion in the EU in 2021 represented 4.4 % of natural gas consumed, i.e.: Billion cubic metres (bcm). Of this, 3.5 bcm of biomethane was produced in 1067 industrial plants from upgraded biogas and 14.9 bcm biogas in 18843 industrial plants using anaerobic digestion. The EU is the world's largest producer of biomethane. At the end of 2020, there were 1161 biogas processing plants worldwide with a production capacity of 6.7 billion cubic metres per year. Achieving the REPowerEU target of 35 bcm in 2030 would require both the construction of new installations and the upgrade of biogas power plants to switch to biomethane or about 5000 smaller additional biomethane production installations. Potential production could reach 165 bcm by 2050. The production of liquefied biomethane for transport is growing rapidly in the EU, with 15 plants with a capacity of 1.24 TWh per year in 2021 (0.12 bcm/year). Potential capacity by 2025 can reach 12.4 TWh per year in 104 plants.

Carbon capture and storage (CCS)

The Commission's scenarios for achieving climate neutrality by 2050 show that the EU will require capturing up to 477 million tonnes of CO2. The highest CO2 capture efficiency will be provided by cement, solid biomass and waste incineration plants.

The Commission already supports and regulates the deployment of CCS through an enabling legislative framework, including the CCS Directive and the EU ETS Directive. The Commission also provides direct project funding, mainly through the Innovation Fund and the Connecting Europe Facility. A Regulation of the European Parliament and of the Council on establishing a framework of measures for strengthening Europe's net-zero technology products manufacturing ecosystem is currently under preparation, which sets an EU target of at least 50 million tonnes of CO2 injection capacity per year by 2030, with an obligation for EU oil and gas producers to contribute to this objective. To support the emerging CO2 value chain with a comprehensive long-term policy framework, the Commission published a Communication on Sustainable Carbon Cycles in 2021 and a proposal for a Regulation on an EU certification framework for carbon removals in 2022. In the first quarter of 2024, the Commission also plans to publish a Communication on an Industrial Strategy for Carbon Management (ICM), including CCS, Carbon Capture and Utilisation (CCU) and industrial carbon removals.

The reports on the implementation of the CCS Directive submitted in 2023 show a growing interest in CCS from market participants across the EU. However, the Directive is currently not applied uniformly across all EU Member States and there are no harmonised rules for CO2 transport and storage infrastructure. One of the objectives of the ICM strategy is to address this problem. The EU is relatively well placed to capture CO2 and many companies provide different capture technologies (before, post-combustion and oxy-fuel technology) on commercial terms. However, they are currently not being implemented on a large scale. The cost of CCS varies significantly depending on site-specific factors, technology development, access to finance, economies of scale generated by common infrastructure, as well as across sectors and technologies. In conclusion, the costs of technology are still significant. The indicative unit costs in EUR/tonne of CO2 are EUR 28-55/tonne of CO2 for capture, EUR 4-11 per tonne of CO2 for transport and EUR 8-30/tonne of CO2 for storage.

By developing full industrial carbon management value chains, the EU lags behind other economies such as the US and Canada. According to the Global CCS Institute, 196 CCS facilities were in preparation worldwide in September 2022, 73 of which are located in Europe. At the end of July 2023, there were no existing CO2 storage projects in the EU and business models are still in their inception phase. There are a number of projects to capture and use CO2 in industry and agriculture, but the amount of CO2 captured is limited.

The demand and supply of materials required in the CCS and CCU value chains are an area requiring further research. However, CCS is less exposed to CRM risks than other technologies. In 2022, the global CCS market was worth USD 6.4 billion (EUR 6 billion). The United States recorded the highest revenues in this value chain, reaching EUR 1 945 billion in 2021, largely due to the use of underground CO2 injection to increase hydrocarbon recovery. By comparison, Europe's total revenue amounted to EUR 92 million.

The market investigation identified 186 key CCS companies worldwide. 24 % of these are European entities or active in this sector through European subsidiaries. There are several oil and gas operators in the EU with a long history of pipelines, wells and significant geological competence, which will be useful for the development of CCS infrastructure projects. The information gathered in the reports on the implementation of the CCS Directive shows a growing interest from potential infrastructure providers, in particular in the field of storage: in total, seven exploration permits and two storage permits have been issued, with more than 10 storage permit applications announced by 2028. In addition to oil and gas companies, new players specialising in different parts of the CCS value chain are emerging. For example, shipping companies expand their activities to transport CO2 and engineering suppliers are developing capture solutions for external issuers.

CCS is a range of projects and technologies deployed. However, CCS is still very costly and many uncertainties remain. However, CCS needs to be deployed on a large scale to contribute to climate neutrality by 2050. Further research and innovation is still needed to improve available technologies or develop new innovative solutions. The main barriers to CCS deployment are high initial investment and operational costs, a fragmented regulatory framework, the complexity of full chain infrastructure projects, as well as public awareness. With the Innovation Fund, the Commission is already supporting the annual capture of more than 10 million tonnes of CO2 from 2026 onwards, with financial support for selected projects amounting to more than EUR 2.5 billion. As a result, public funding – at both EU and national level – will be needed to attract private capital.

6.2. Current level of public and private research and innovation spending on low-carbon-technologies, current number of patents, and current number of researchers

Research is the main driver of innovation, and the monitoring of R & D expenditure and its intensity (R & D expenditure as a percentage of GDP) are considered as two key indicators used to compare countries in terms of the weight they attach to technological development. Developing an effective R & I pathway is also crucial for a competitive clean energy industry. The EU remains at the forefront of clean energy research, retains a strong position in internationally protected patents and plays a leading role in renewables and energy efficiency. Stepping up efforts to make synergistic use of Union and national programmes and setting clear national R & I targets until at least 2 030 are still essential to develop this successful R & I pathway.

The EU's R & I policy shapes the direction of innovation and the portfolio of clean energy technologies. The world's largest R & I programme, Horizon Europe (with its budget of EUR 95.5 billion dedicated to R & I in 2021-2027), and other EU funding programmes (e.g. the innovation fund and the cohesion policy funding) are intended to strengthen the EU R & I's ecosystem and help achieve the EU's policy objectives. Together with joint and coordinated efforts by Member States (notably under the Strategic Energy Technology Plan (SET-Plan), R & I activities increase the resilience of the EU clean energy sector.

Most EU Member States increased their public R & I investment on the Energy Union priorities in 2020, with more than EUR 4 billion reported so far. In 2021, more than half of the EU Member States that provided data increased their public R & I investment on the Energy Union priorities compared to 2020, with EUR 5.4 billion reported so far. Since 2020, Horizon 2020 and its successor, Horizon Europe, has provided more than EUR 2 billion per year to fund Member States' national programmes, a significant increase in R & I investment.

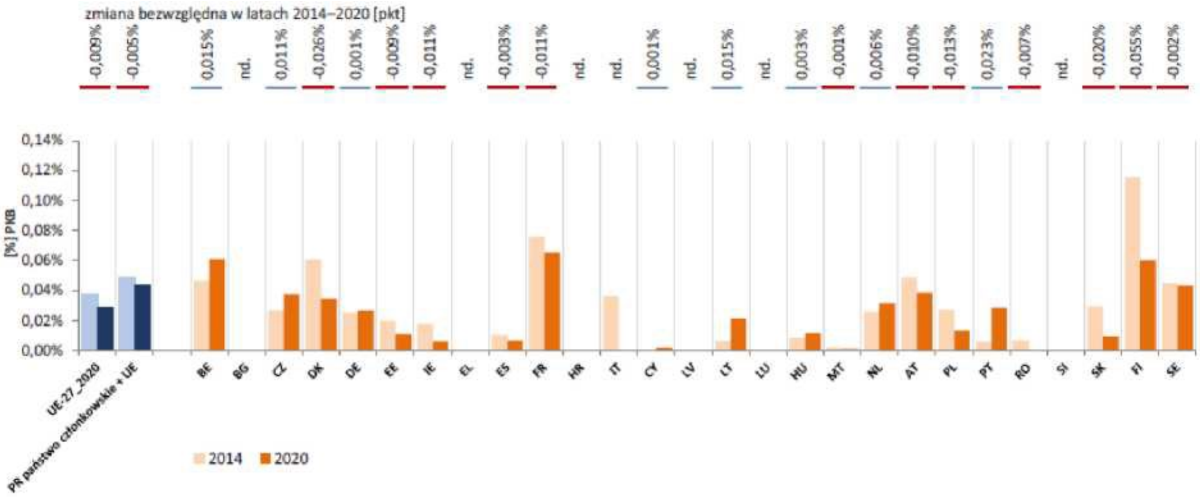


Figure 2.35. Public investment in clean energy research and innovation in EU Member States as a share of GDP since the start of Horizon 2020

Source: JRC based on IEA

While the national contributions of large economies themselves remain low, after taking into account Horizon 2020, the European Union was at the top of the ranking of large economies, in terms of public sector investment in research and innovation on the Energy Union priorities. In absolute expenditure, this expenditure amounted to EUR 8.2 billion, ahead of the United States, with an investment of EUR 7.7 billion, an improvement compared to 2020. The European Union was also the second largest share of GDP (0.047 %, after Japan with 0.057 %). Despite this, investment in public research and innovation at national and EU level, measured as a percentage of gross domestic product (GDP), remains below 2014 levels (Figure 2.46). The other major economies also followed the same trend. The European Union's target for 2030 is to spend total R & D expenditure at 3 % of the EU's total GDP.

According to global assessments, the private sector invests at least three times more in clean energy research and innovation than government budgets. EU business sector investments account for 80 % of R & I spending under the Energy Union research and innovation priorities. In 2019, the estimated private R & I investment amounted to 0.17 % of GDP (Figure 2.46), which also represents 11 % of total R & D expenditure in the business and business sector. Since 2014, estimates for the EU, the United States and Japan show comparable amounts in absolute terms in the respective R & I areas (between EUR 18 billion and EUR 22 billion per year). However, in terms of GDP, private R & I investment in the EU is higher than US spending, but lower than in other major competitive Asian economies (Japan, Korea and China). With 19 % of global Venture Capital investments in clean energy technology firms, the EU ranked third in 2022, behind the US and China.

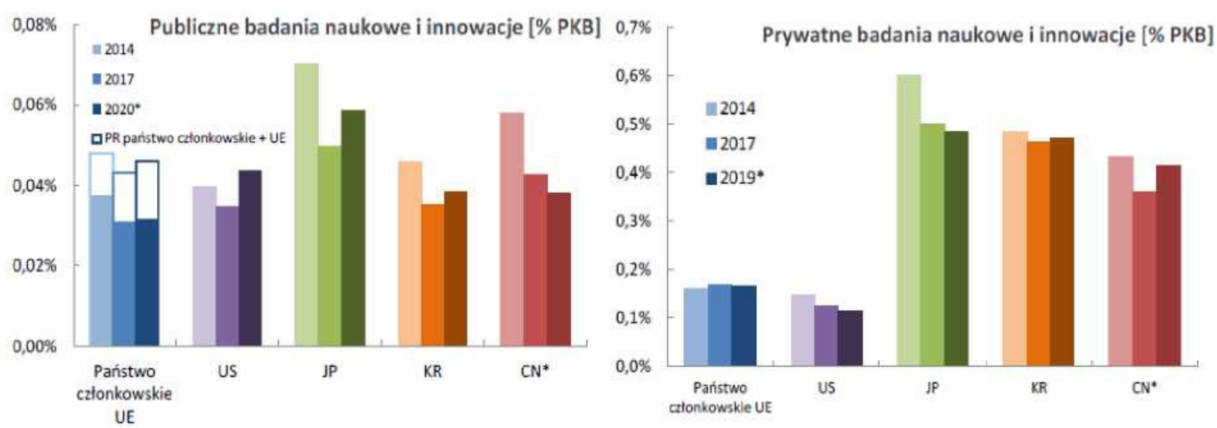


Figure 2.36. Public and private R & I financing in Energy Union R & I priorities in major economies as a share of GDP

Source: JRC based on IEA, 2023

EU research and innovation programmes on the Energy Union priorities focused mainly on low-carbon energy solutions. In 2020, EUR 31 billion was invested in Energy Union Energy Technology Research and Innovation Priorities. Around 78 % of these funds came from the private sector, while the rest came from public funding from

Member States (15 %) and the EU (7 %). Overall, these investments have increased by EUR 2 billion over the last 3 years, i.e. by 7.5 % on average per year.

For sustainable transport, the private sector in research and innovation generated almost 90 % of the funding, while for most of the remaining priorities more than two thirds of the funding. There are two exceptions – investments in nuclear safety, which is mainly publicly funded (national) and Carbon Capture and Use (CCUS), which receives almost equal shares from public and private R & I investments.

The industry with the highest share of R & I investment, sustainable transport remained in all 2020 priorities, attracting 45 % of total R & I investment and 54 % of private investment. The next priority was energy efficiency, which raised 18 % of total funding and smart systems (17 % of the total envelope).

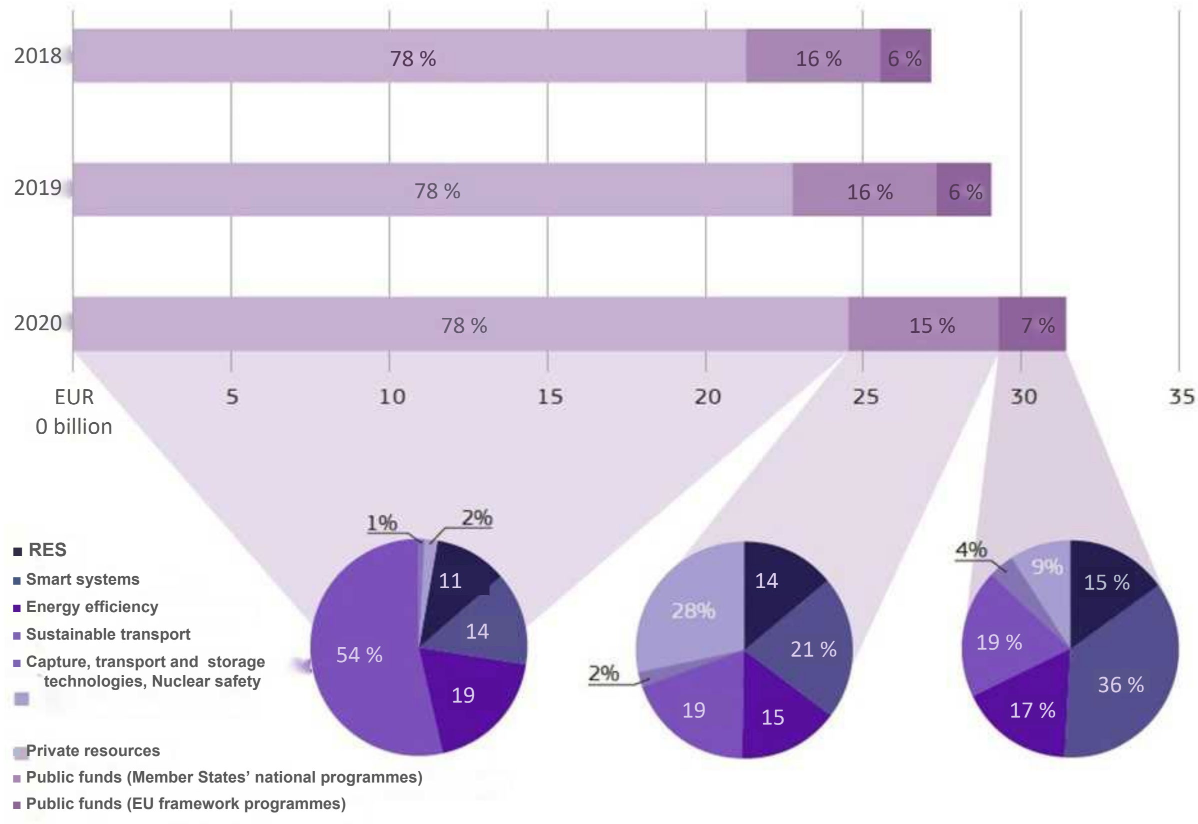


Figure 2.37 Investments in research and innovation priorities in the EU Energy Union (2018-2020), [billion Euro]

Source: European Commission, PROGRESS REPORT 2023 Coordinated energy research and innovation for a competitive Europe, 2023

In the EU, in the R & I and Competitiveness agenda, 20 Member States reported measures to achieve objectives and policies under the European Strategic Energy Technology Plan. Most Member States reported comprehensive research funding programmes that support the development of technologies covered by the WGs on the implementation of the plan. As regards public spending on R & I, 19 Member States provided information on measurable national targets and 5 reported them against target. Out of the 13 Member States that reported data for 2020 and 2021, 12 recorded an increase in R & I investments (AT, CZ, DE, ES, FR, LT, MT, NL, AT, PT, FI, SE) and only one recorded a slight decrease (EL).

Patenting innovation in the Energy Union

Since 2014, half of the EU Member States have increased their patenting activity in line with the Energy Union R & I priorities, with green innovation champions such as Germany and Denmark performing strongly both in absolute numbers and in the share of green patents in their overall innovation portfolio. Since 2014, the number of EU patent applications under the Energy Union R & I priorities has increased on average by 5 % per year. While there are significant differences in patenting trends both between Member States and with regard to specific technologies, the EU overall maintains a strong position in the area of internationally protected patents. Overall, between 2014 and 2020, the EU ranked second in international patent applications after Japan, was the leader in renewables (29 %) and ranks first in energy efficiency with Japan (24 %), mainly thanks to the EU's specialisation in materials and technologies for buildings. Data on patents filed by EU operators also show its leadership in renewable fuels, batteries and e-mobility and carbon capture, storage and utilisation technologies. By contrast, it loses slightly in smart systems (17 %) and ranks fourth among major economies.

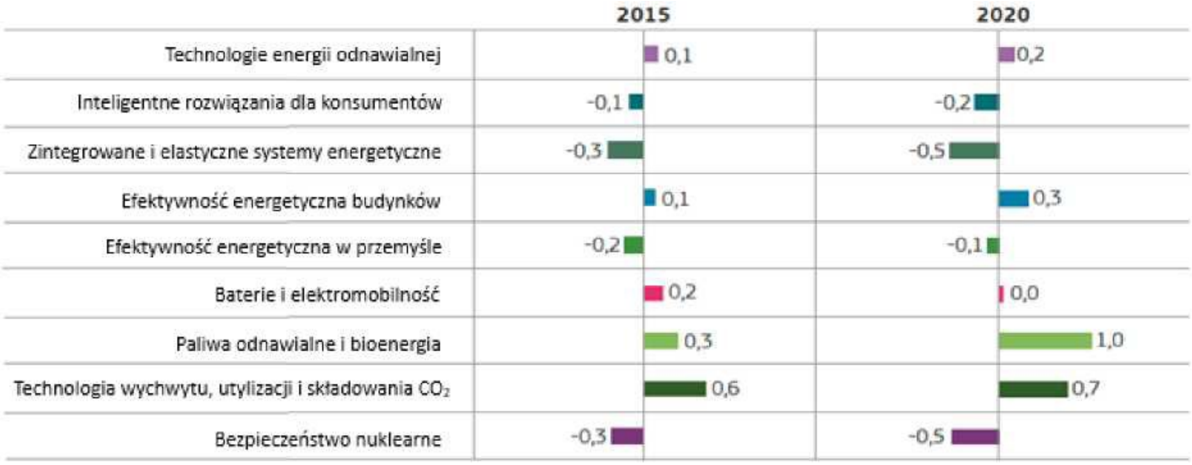


Figure 2.38 Change in the EU specialisation indicator for patent applications in SET Plan activities in 20152020

Source: European Commission, PROGRESS REPORT 2023 Coordinated energy research and innovation for a competitive Europe, 2023

Worldwide, there were slightly fewer scientific publications addressing low carbon energy technologies in 2020 than in 2016-2019. In the EU, this number increased more modestly in 2016-2019 (when compared to the global average), and declined more strongly in 2020. The EU contributed just over 16 % of scientific articles worldwide, but did continue to produce more than twice the global average number of publications per head of population. This trend is mostly due to the increasing number of scientific publications in other domains and to the fact that high-income economies no longer seem to dominate in topics related to clean energy and innovation. The EU was leading in energy research 10 years ago, but the massive improvement in the quantity and quality of Chinese output in energy research has pushed the EU down into second position. Chinese researchers are in the lead when it comes to the most cited publications related to energy (with a 39 % share). Nevertheless, EU researchers are co-creating and publishing clean energy work internationally to a level well above the global average. In addition, there is more intense cooperation between the public and private sectors in this area in the EU. The Horizon 2020 R & I framework programme, the European Regional Development Fund and the seventh framework programme for R & I were ranked among the global top 20 acknowledged funding schemes supporting clean energy science in the period 2016-2020.

As highlighted in the 2022 Competitiveness Progress Report and the Guidance for Member States for the Update of the National Energy and Climate Plans 2021-2030, an effective R & I pathway requires an adequate number of experts and entrepreneurs supported by the coordinated use of EU, national and regional programmes. This also requires clearly defined national R & I targets and targets at least until 2030, enhanced cooperation between Member States and continuous monitoring of national R & I activities. Joint and coordinated efforts across Member States, in particular through the revised Strategic Energy Technology Plan (SET-Plan) and National Energy and Climate Plans (NECPs), also provide a unique opportunity to deepen the dialogue between the EU and its Member States on clean energy research and innovation and competitiveness.

National R & D expenditure

Gross domestic investment on R & D activities in 2022 amounted to PLN 44.7 billion and increased by 18.6 % compared to the previous year. The R & D intensity indicator, representing the share of internal R & D expenditure as a share of GDP, has gradually increased from around. 0.5 % of GDP in 2005, 2010 – 0.7 % of GDP, 2015, around 1 % of GDP, to around 1.39 % of GDP in 2020 and 1.46 % of GDP in 2022.

Figure 2.39 Gross Domestic Expenditure on Research and Development (GERD) as a percentage of GDP in Poland 2000-2022

Source: Eurostat

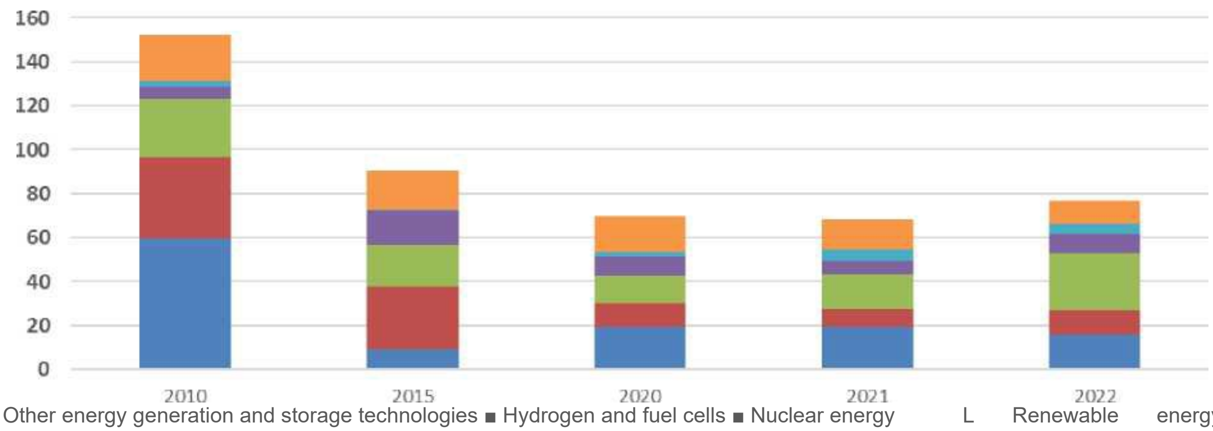
As in previous years, in 2022, the main R & D funding sectors in Poland were the enterprise and government sectors. As in the rest of the Community and Poland, capital expenditure in the private sector is higher than that of public funds. These financing sectors accounted for 54.8 % and 33.5 % of all internal R & D expenditure respectively (compared to 50.9 % and 37.4 % in 2021). The executive sector with the highest internal R & D expenditure was the business sector, which spent PLN 29.5 billion in 2022 (an increase of 23.9 % on the previous year). In 2022, they accounted for around 66 % of total expenditure, compared to around 63 % a year ago. According to Eurostat data, Poland is the country that has made the most progress in this field (in addition to Cyprus), with only 28.1 % of research funding from companies' own resources in 2011. The share of funds coming from the European Commission has also increased since 2016. Although it is not as high as before the end of spending under the 2007-2013 financial perspective (14.6 % in 2015), it accounted for almost PLN 3 billion in 2022, or 6.7 % of total expenditure, benefiting as many as 19.1 % of operators.

National innovation investments in Energy Union priorities

Many ministries and government bodies are involved in the definition and implementation of Polish R & D policy in the field of energy. There is no single entity responsible for energy R & D. The main responsibility for energy-related research lies with the Ministry of Science and Higher Education. The Ministry of Climate and the Environment is responsible for innovation policy for the energy sector and for most programmes financing energy-related demonstration and development projects.

National statistics shall provide information on total R & D expenditure, without detailing data for low-carbon technologies or individual Energy Union priority areas. The development of innovation in renewable sources according to IEA data accounted for 34 % of public funding, i.e. around EUR 26.3 million, and energy efficiency improvements of 20.3 % of the budget. Of the total amount of expenditure, only 6.2 % of public funding for energy research has gone to hydrogen and fuel cell technologies (EUR 4.8 million), which can play a key role in the decarbonisation of industry, energy, heating and transport, as an important element of the energy transition.

≠80 [min Euro]



Other energy generation and storage technologies ■ Hydrogen and fuel cells ■ Nuclear energy L Renewable energy sources

■ Fossil fuels ■ Energy efficiency

Figure 2.40 Breakdown of public funds earmarked in Poland between 2010 and 2022 for R & D in the field of energy

Source: International Energy Agency, 2023

Support programmes for green projects and energy R & D programmes

The European Union's research and innovation funding programmes are an important source of funding for energy R & D in Poland. Under***Horizon 2020***, a total of EUR 743 million was allocated to R & D in Poland between 2014 and 2020, of which more than EUR 178 million for energy and climate-related R & D, including EUR 50 million for advanced manufacturing and processing, EUR 47 million for safe, clean and efficient energy, EUR 41 million for smart, green and smart transport, and EUR 40 million for climate action, the environment and the efficient use of resources and raw materials. In February 2021, the EU Framework Programme for Research and Innovation, ***Horizon Europe***, was launched for the period 2021-27. It aims to provide EUR 95.5 billion of R & D funding for projects across the EU and will continue to support energy-related R & D and set targets for increased international R & D cooperation. Since the start of Horizon Europe, Poland has received a total funding of EUR 207.35 million, representing 1.48 % of the funds allocated to EU Member States. From this programme, 472 projects are currently being implemented in Poland and the total number of participants from Poland is 319. In Poland, EU funds cover most of the R & D expenditure of the National Centre for Research and Development (NCBR), which provides a wide range of services to raise funding from Horizon Europe and is one of the key sources of R & D funding in the country.

European funds for Infrastructure, Climate, Environment 2021-2027 (FEnIKS)

Its main objective is to improve the conditions for the country's development by building technical and social infrastructure in line with the objectives of sustainable development. The FEnIKS programme was adopted by the EC on 6 October 2022. It is an extremely important tool for implementing Poland's energy, climate and environmental policies. The new fund will support, among other things, energy efficiency, reduction of greenhouse gases and adaptation to climate change. The total budget for investments and projects amounts to almost EUR 29.3 billion. The EU funding available under FEnIKS 2021-2027 for the energy sector amounts to EUR 6 079 million and for the environment sector EUR 3 667 million.

The Minister for Climate and the Environment of Poland will be responsible for implementing two priorities (Priority I and Priority II), totalling EUR 9.75 billion (i.e. approx. PLN 46 billion). This amount represents as much as 40 % of the total EU allocation of the programme. Under Priority I and II, support will target the decarbonisation of the economy and the transition to a green and circular economy. Compared to the previous programming period (2014-2020), the funding available for these policies increased by more than 50 %.

The proportions between different sectors have also changed: the energy sector, i.e. energy efficiency in different types of buildings, RES (including biomethane production installations) and electricity and gas infrastructure, is twice as many as EUR 6.08 billion (ca. PLN 29 billion). This is an increase commensurate with the scale of the challenges in the sector resulting from the economic and political circumstances resulting, inter alia, from the war in Ukraine. More funding is also available for climate change adaptation and environmental projects – currently EUR 3.67 billion (approximately PLN 17 billion).

EU Smart Growth Operational Programme

It is another important source of EU funding for R & D in Poland. It provides funding to entrepreneurs and researchers to support R & D projects aimed at commercialising technologies, products and services. Between 2014 and 2020, the programme allocated around EUR 8.31 billion to innovative projects in Poland. Poland also receives R & D support from the programme of the European Environment Agency and Norway Grants (supported by Norway, Iceland and Liechtenstein), which has provided around EUR 150 million in R & D funding since 2012.

Norwegian and EEA Funds – Environment, Energy and Climate Change Programme

The Programme aims to mitigate climate change and reduce vulnerability to climate change. Support shall focus on measures to improve air quality (including the development of district heating systems and cogeneration), to increase the production of renewable energy, including geothermal energy and energy from small hydropower plants, and to combating climate change or improving the environment and protecting nature. The funds will also be used to support pilot projects in the field of energy use of biomass. The programme for “Renewable Energy, Energy Efficiency, Energy Security” has the largest envelope of EUR 112 million. It is divided into two components: Improving energy efficiency and security’ and ‘Increasing renewable energy production’.

The total amount of funds involved in the implementation of the Programme in the environment sector will be around EUR 156 million. The main source of funding for the Environment, Energy and Climate Change Programme is one of the financial mechanisms called the Norwegian and EEA Funds, i.e.: European Economic Area (EEA) Financial Mechanism. The support is complemented by the national budget.

New Energy Programme

It has a budget of around EUR 550 million for 2021-26 to support innovative green energy projects in several areas, including energy clusters, smart cities, hydrogen technologies, multi-fuel energy storage systems and carbon-free energy production. The scheme is run by the National Fund for Environmental Protection and Water Management and uses a competitive bidding process to allocate funds.

New Energy Technologies are a funding programme run by the NCBR to help achieve climate neutrality in Poland by developing solutions to increase energy security and competitiveness of the Polish economy. Its main purpose is to: increasing the potential of the renewable energy industry, including self-consumers; development of smart energy grid infrastructure; reduce the emission intensity of the energy sector by increasing the use of biodegradable raw materials and waste products. The programme has a budget of EUR 176 million to support technology readiness level 8-9 projects related to solar, onshore and offshore wind, hydrogen production and use, energy storage, micro-grids for energy and heat, waste-to-energy and geothermal energy.

The***Green Technologies Accelerator*** – is an innovation programme run by the Ministry of Climate and the Environment aimed at driving the domestic and international commercialisation of advanced green technologies developed by Polish entrepreneurs. Its main objective is to help Polish small and medium-sized enterprises to establish international contacts and to provide them with the necessary tools to enable them to thrive.

The Polish public procurement strategy ***“Saper Innovation”*** supports innovative projects that, by attracting the market, address the key challenges of energy security and the energy transition. Through the Innovation Team, the NCBR has launched several projects supporting Poland’s energy transition in line with the EU’s climate and energy objectives, in particular on renewable heating and cooling. Projects under the Innovation Team Programme are funded by a budget of EUR 46 million from the EU’s Smart Growth Operational Programme.

The ***‘Electricity storage’*** project aims to develop recyclable primary cells with high energy density and long lifespan, the production of which will rely as much as possible on national resources. The project aims to implement a demonstration battery and a demonstration system for electricity storage. The ‘Heat and Cool Storage’ project aims to develop high-efficiency storage systems that maximise the use of renewable energy sources for both heating and cooling in domestic and industrial applications.

The Ministry of Climate and Environment is involved in a number of international initiatives supporting energy innovation, including the European Clean Hydrogen Alliance and the Research and Innovation Accelerator for Science and Society. Poland participates in only one of the 38 IEA technological cooperation programmes. Poland became a member of the Ministry of Clean Energy in 2021 and supports its initiatives on nuclear innovation and electric vehicles.

The NCBR is developing international cooperation with partners from different countries and regions, including: with the People's Republic of China, Iceland, Israel, Liechtenstein, Norway, Singapore, South Africa, Türkiye and the United States. In May 2021, the Polish and Japanese governments signed an Action Plan for the implementation of their Strategic Partnership 2021-25 to strengthen cooperation in the energy sector, with a focus on e-mobility, clean transport based on electricity and hydrogen, and exchange of information on the development of national hydrogen strategies.

R & D staff

In 2022, R & D staff comprised 321.4 thousand people, 5.2 % more than last year. More than half of R & D staff worked on R & D activities carried out by businesses (53.1 %). Their actual involvement in R & D projects in full-time equivalents was 195.1 thousand. FTEs increased by 5.3 % on an annual basis. The structure of R & D staff was dominated by internal staff, representing 81.8 % of R & D staff measured in persons and 84.1 % in FTEs (81.5 % and 83.7 % respectively in 2021). In 2022, the share of employees in R & D in terms of total employment, on a full-time equivalent basis, was 1.20 % (FTE), compared to an equivalent rate of 1.48 % for the European Union as a whole.

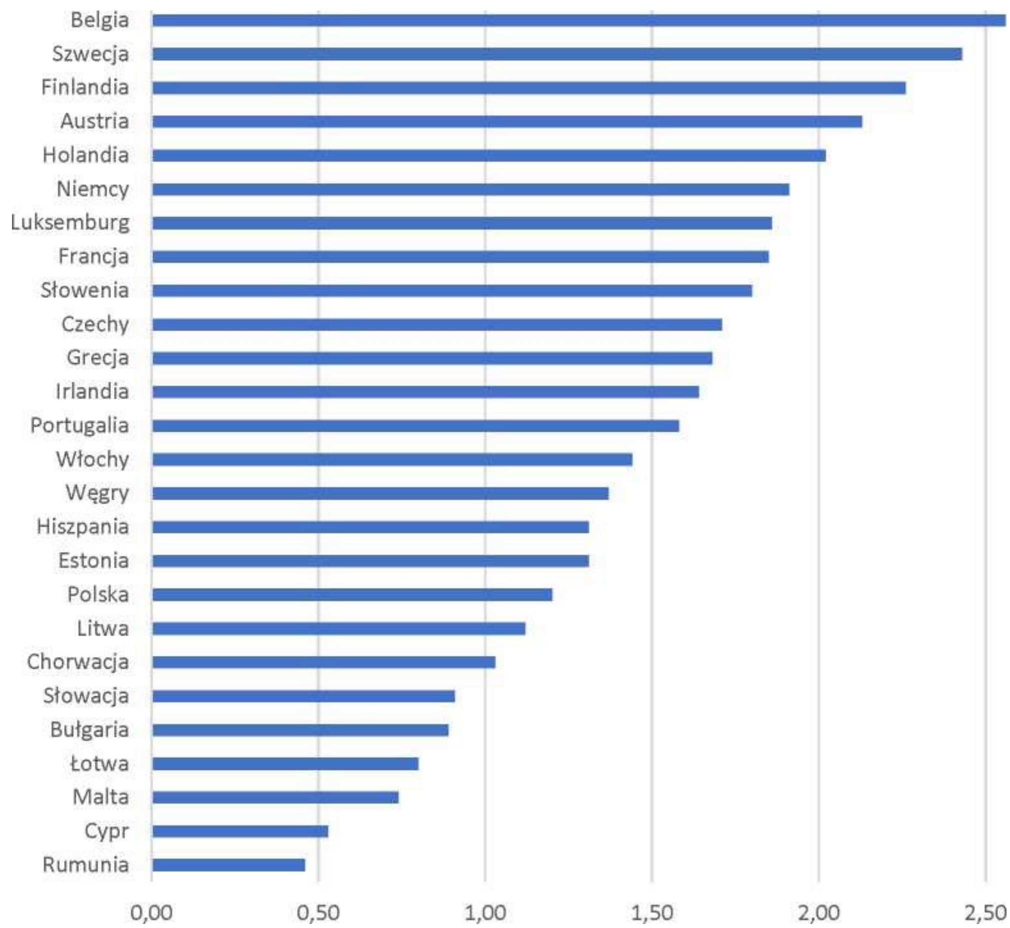


Figure 2.41 Share of employees in R & D in relation to total employment in EU countries, on a full-time equivalent basis in 2022

Source: Eurostat

In 2021, Poland was ranked 18 in the European Union in terms of full-time equivalent employment in R & D (FTE) relative to total employment.

Patents in Poland

In 2022, 3323 national and foreign applications for inventions were made at the Patent Office of the Republic of Poland, a decrease of 4.7 % compared to the previous year. In 20152022, the total number of applications for inventions was 3.5-4.5 thousand per year. In 2022, 3233 applications for inventions by national entities were registered at the Polish Patent Office, i.e. 4.2 % less than in the previous year. Among national applicants, 40.1 % of applications for inventions were registered by economic operators, 37.5 % by universities and 6.8 % by research institutes. The rest of the inventions were reported by individuals (13.9 %) and scientific bodies (1.7 %).

On the basis of data from the Polish Patent Office, 60 patents have been granted to national entities in fields of technology compatible with the development of renewable energy sources. On the other hand, in the field of ‘environmental technologies’, 87 patents were granted to national operators. In 2021, foreign entities did not apply for protection of inventions in this category. In the fields of technology converging with the development of hydrogen technologies, 102 applications for protection of inventions have been submitted by national entities. This is a record increase compared to 182 patents obtained in 2020. In the same category, foreign entities did not apply for patent protection in 2021. On the other hand, in the fields of technology for environmentally friendly transport solutions (e-mobility), national entities filed 107 applications and obtained 116 patents. In Poland, in 2021, 35 % of the patents granted concerned inventions in nine fields of technology, in line with the development of technologies that could support the green transition of companies and are consistent with the areas of national smart specialisations (KIS).

6.3. Description of energy subsidies, including for fossil fuels

Subsidies play a key role in accelerating the deployment of clean energy and energy efficiency solutions and reducing fossil fuel consumption. Subsidies may serve economic, environmental or social welfare purposes. Poorly designed subsidies can distort competition, act against the energy transition and reduce the carbon price signal.

The energy crisis, which started in 2021 and exacerbated the Russian aggression against Ukraine in 2022, has had serious consequences for energy-related subsidies. These consequences can be seen in the amount of these grants, their distribution between technologies and beneficiaries and the instruments used to award them. Russia's use of energy supplies as a political weapon and the gradual cuts in Russian gas supplies required a strong EU policy response, including short-term measures, to ensure energy affordability for vulnerable consumers and industries across Europe.

In 2021, energy subsidies followed a gradual upward trend (Figure 2.52), while they increased sharply in 2022. Total energy subsidies in the EU increased from EUR 177 billion in 2015 to EUR 216 billion in 2021 and reached an estimated EUR 390 billion in 2022.

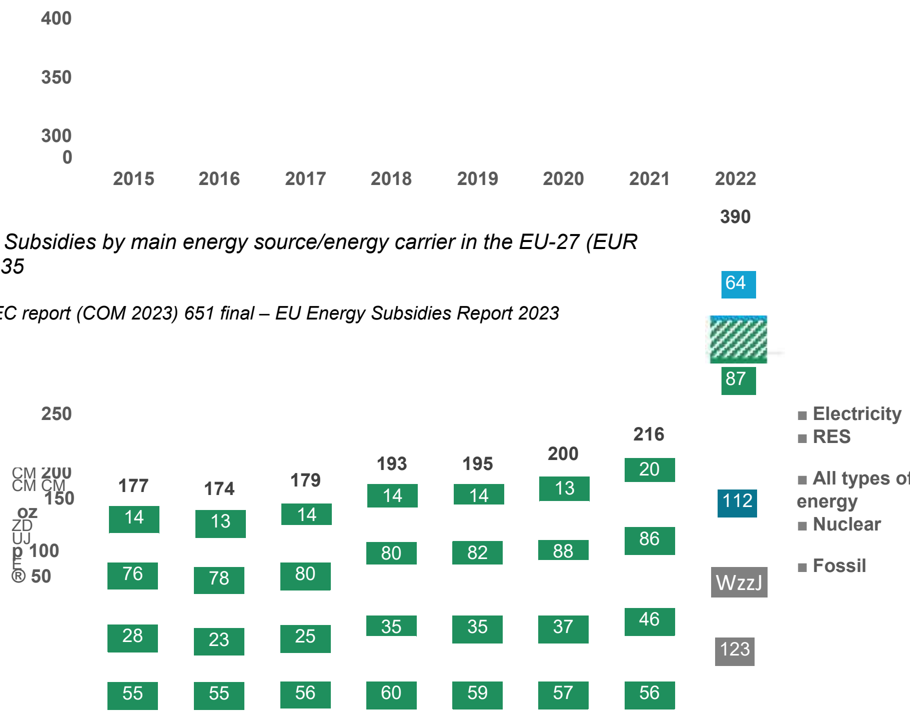


Figure 2.42. Subsidies by main energy source/energy carrier in the EU-27 (EUR billion 2022)35

Source: The EC report (COM 2023) 651 final – EU Energy Subsidies Report 2023

The 202235figures, with a ranged area, cover around EUR 44 billion and represent 12 % of the total amount included in the 2022 grant list.

The downward trend of fossil fuel subsidies continued until 2021, when they amounted to EUR 56 billion, before rising sharply to an estimated EUR 123 billion in response to the crisis in 2022. While in 2022, most fossil fuel support was allocated to oil and refined products (EUR 56 billion) (Figure 2.53), between 2021 and 2022, natural gas-targeted subsidies tripled to EUR 46 billion. Support to coal and lignite remained the same at EUR 8 billion, while EUR 13 billion was allocated to all other types of fossil fuels, including peat.

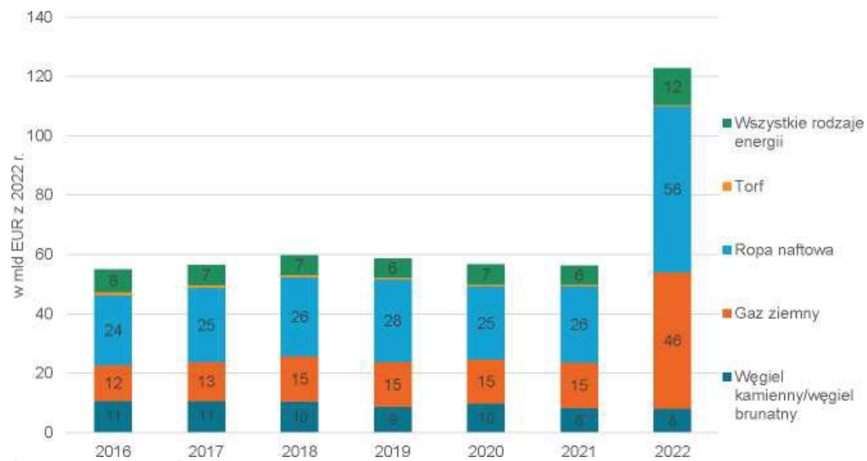


Figure 2.43. Fossil fuel subsidies by fuel type

Source: EC report (COM 2023) 651 final – 2023 report on energy subsidies in the EU

Data (Figure 2.54) show that fossil fuel subsidies were higher in eleven Member States than in Poland. Almost all fossil fuel subsidies in the EU were assessed as environmentally harmful subsidies.

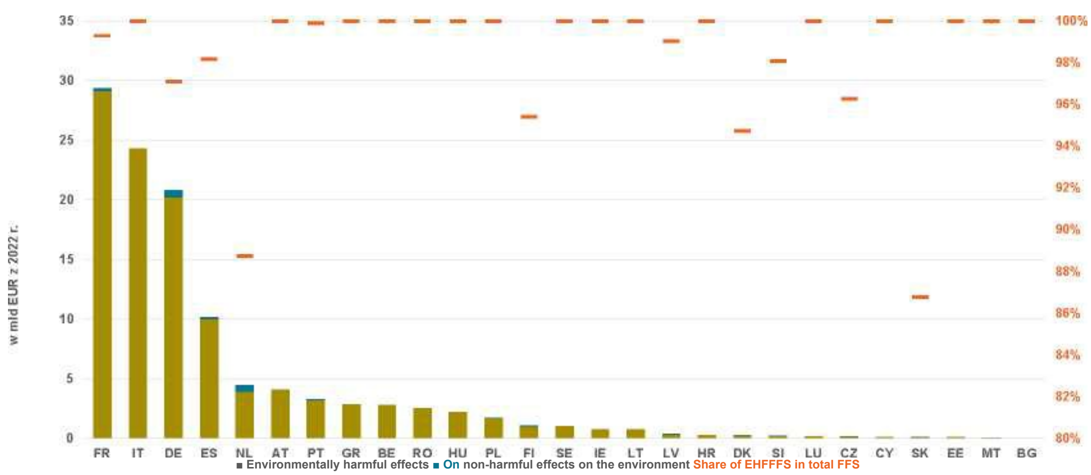


Figure 2.44. Fossil fuel subsidies by Member State and by environmental impact

Source: EC report (COM 2023) 651 final – 2023 report on energy subsidies in the EU

Subsidies dedicated to renewables in 2021 decreased for the first time in many years (Figure 2.54) to EUR 86 billion (-1.3 billion or -1.5 % compared to 2020). This decrease was mainly due to an increase in wholesale prices in the electricity market, leading to a reduction in payments under support instruments that complement market prices. The reduction in the amount of subsidies allocated to renewable energy also occurred despite the increase in installed and supported RES generation capacity. In 2022, the amount of RES subsidies increased slightly to EUR 87 billion and for the first time since 2015 was below the level of fossil fuel subsidies.

Support for renewable technologies varies widely across the EU (Figure 2.55) and reflects national priorities and potential for RES. In 2022, the largest amount of subsidies in all Member States was allocated to solar energy (both photovoltaic and concentrated solar energy) (EUR 25 billion), followed by wind and biomass (EUR 15 billion each). The smallest financial support was allocated to hydropower (EUR 1.5 billion in 2022). Subsidies that were not targeted at any specific renewable energy technology (EUR 24 billion) were also widely used.

In 2021, almost 90 % of RES subsidies in Poland were non-technology-specific subsidies, while the remaining share was spent on photovoltaic energy and biomass.

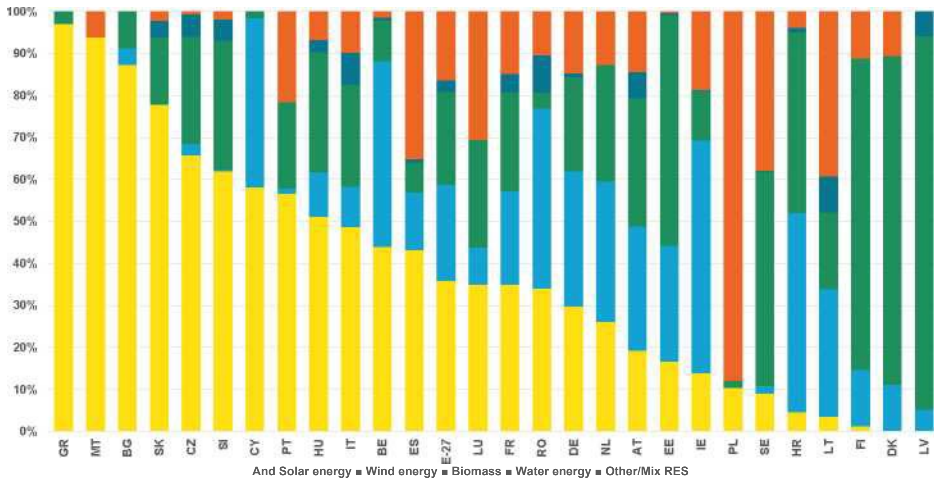


Figure 2.45. Share of RES subsidies by technology for selected Member State (2021)

Source: EC report (COM 2023) 651 final – 2023 report on energy subsidies in the EU

The European Commission is working with Member States to address the energy crisis. This cooperation shall include measures to secure alternative energy supplies, reduce energy demand to compensate for the lack of gas supply from Russia, increase the use of renewable energy sources and increase energy efficiency. In addition to the implementation of measures that have been taken at EU level or enabled by an EU framework, Member States have also adopted measures tailored to their national needs to protect their citizens and economy from harmful energy prices (Figure 2.56).

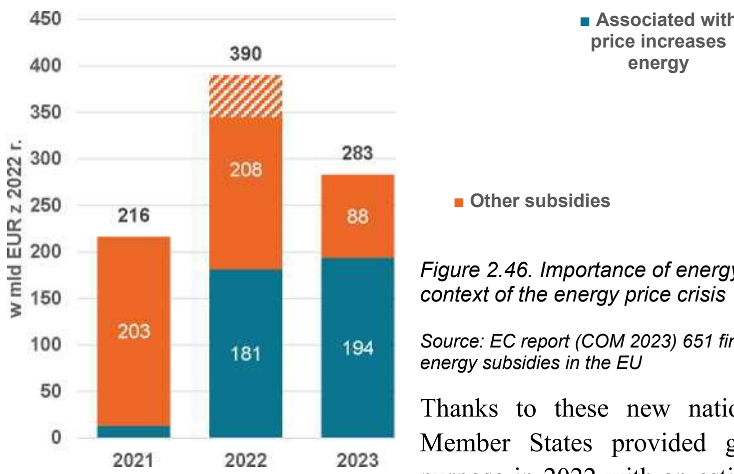


Figure 2.46. Importance of energy subsidies in the context of the energy price crisis

Source: EC report (COM 2023) 651 final – 2023 report on energy subsidies in the EU

Thanks to these new national measures, Member States provided grants for this purpose in 2022 with an estimated value of around. EUR 181 billion, representing almost 50 % of all energy subsidies in the EU-27 in 2022. The initial figures for 2023 show a continuation of this support, but only in the medium term. Almost 80 % of disbursements under these measures are planned to be completed before 2025, while 20 % of disbursements are planned to be completed after 2025 or not at all.

Subsidies for measures related to the energy crisis accounted for around 1.1 % of EU GDP in 2022. To this end, Poland spent less than 1.0 % of its GDP, which was about EUR 6 billion, less than the subsidies introduced for seven Member States (Figure 2.57).

Source: EC report (COM 2023) 651 final – 2023 report on energy subsidies in the EU

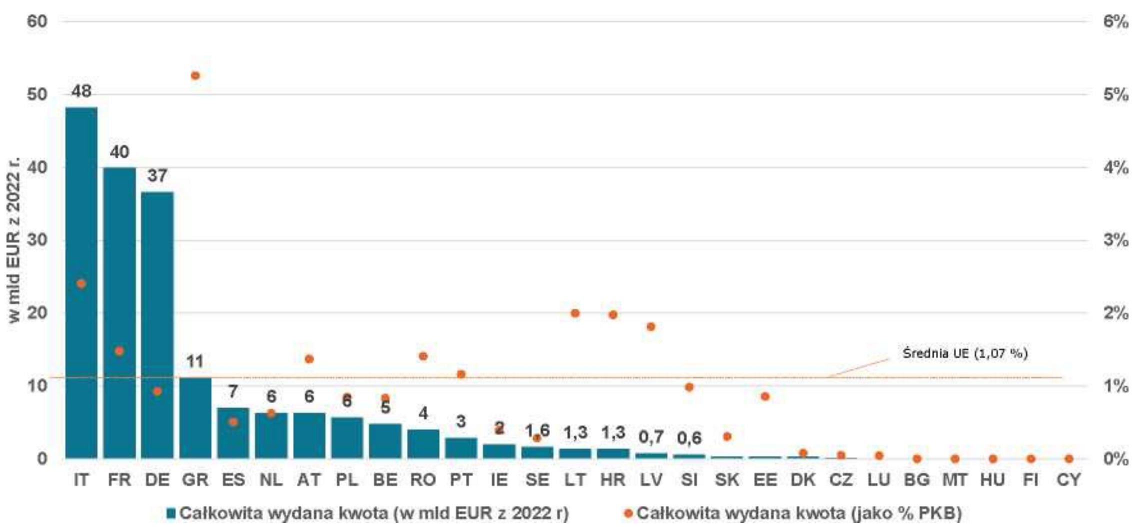


Figure 2.47. Subsidies to address rising energy prices by country in 2022

6.4. Current level of wholesale and retail electricity prices compared to regional and EU average countries

Between 2015 and the first quarter of 2021, wholesale electricity prices in EU countries were similar, not exceeding EUR 100/MWh (Figure 2.58). The subsequent price hikes were due, among other things, to a significant increase in power demand, linked to the increase in the energy intensity of national economies after phasing out against the spread of the SARS-CoV-2 virus, lockdowns. 2022 saw the largest increase in wholesale electricity prices, driven by an increase in demand for fossil fuels not originating in Russia. However, the smooth diversification of the supply lines of coal and gas and the increase in the share of RES in energy production have contributed to lower wholesale prices to levels before Russia's war of aggression against Ukraine. In 2023, the EU average price decreased to around EUR 97/MWh, while the average wholesale prices in Poland were EUR 112/MWh (Figure 2.59).

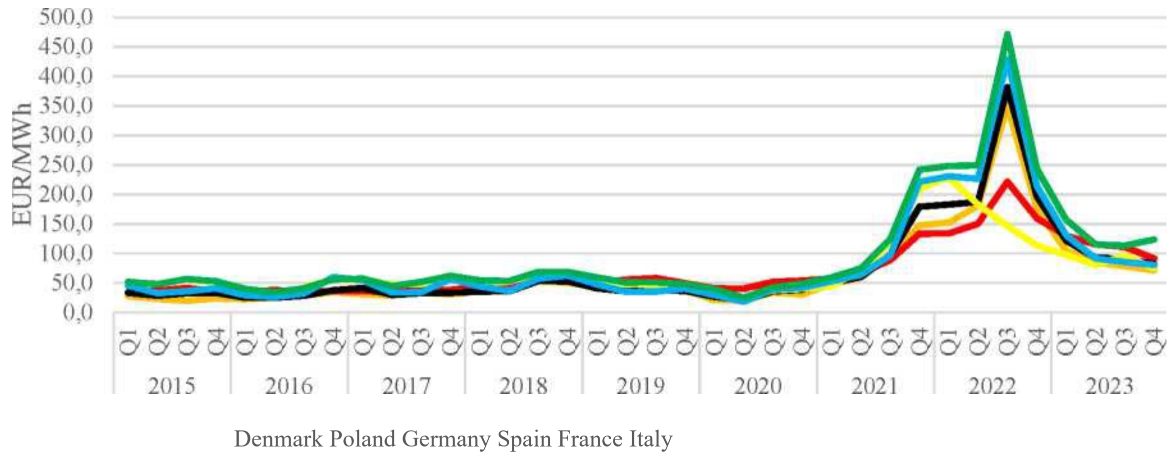
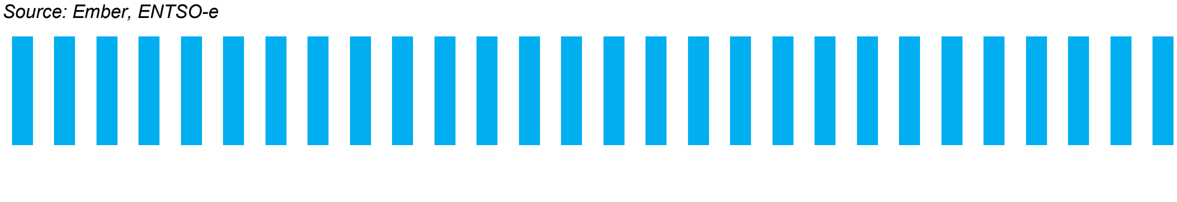


Figure 2.48. Wholesale electricity prices from the next day market in selected EU countries 2015-2023

Source: Ember, ENTSO-e

Figure 2.49. Wholesale electricity prices from the next day market in EU countries in 2023

Source: Ember, ENTSO-e



The figures below show the ranking of EU countries in terms of price levels, based on the example of electricity prices expressed in EUR/MWh in the first half of 2023 for three categories of industrial consumers, with different levels of annual consumption. These drawings illustrate the variation in energy prices both between countries and between industrial consumers within a single country, depending on the level of consumption. Electricity prices (excluding taxes and levies) in Poland are below average EU prices for each consumption band. However, prices including all taxes and charges (including VAT and excise duties) in Poland are higher than average prices in the EU.

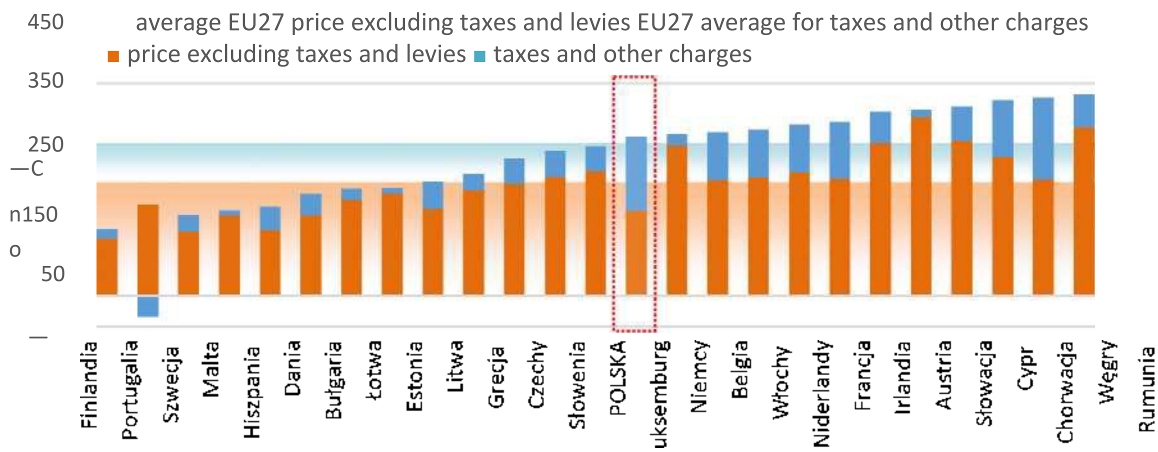


Figure 2.50. Industrial electricity prices for the first half of 2023 – category IC (500 – 1999) MWh)

Source: Eurostat

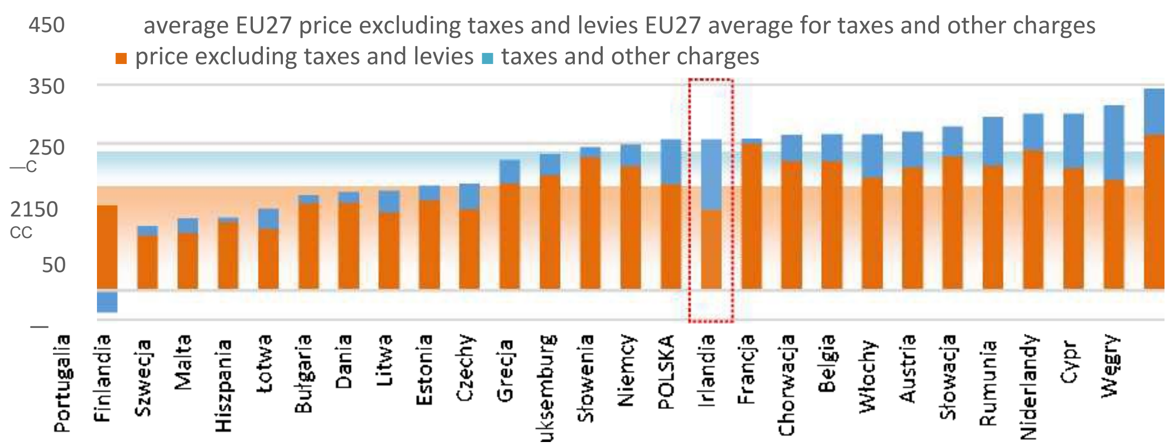


Figure 2.51. Industrial electricity prices for the first half of 2023 – category ID (2000 – 19999) MWh)

Source: Eurostat

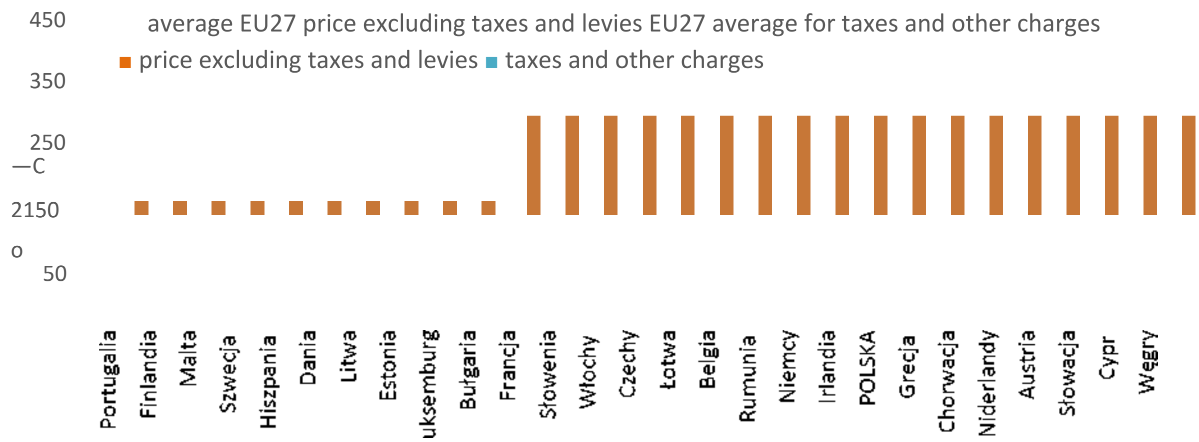


Figure 2.52. Industrial electricity prices for the first half of 2023 – category IE (20000 – 69999) MWh)

Source: Eurostat

By contrast, the following figures show the ranking of EU countries in terms of electricity price levels for three categories of household consumers, with different levels of annual consumption. Electricity prices (taxed) in Poland are, for each consumption band, lower than the average EU prices.

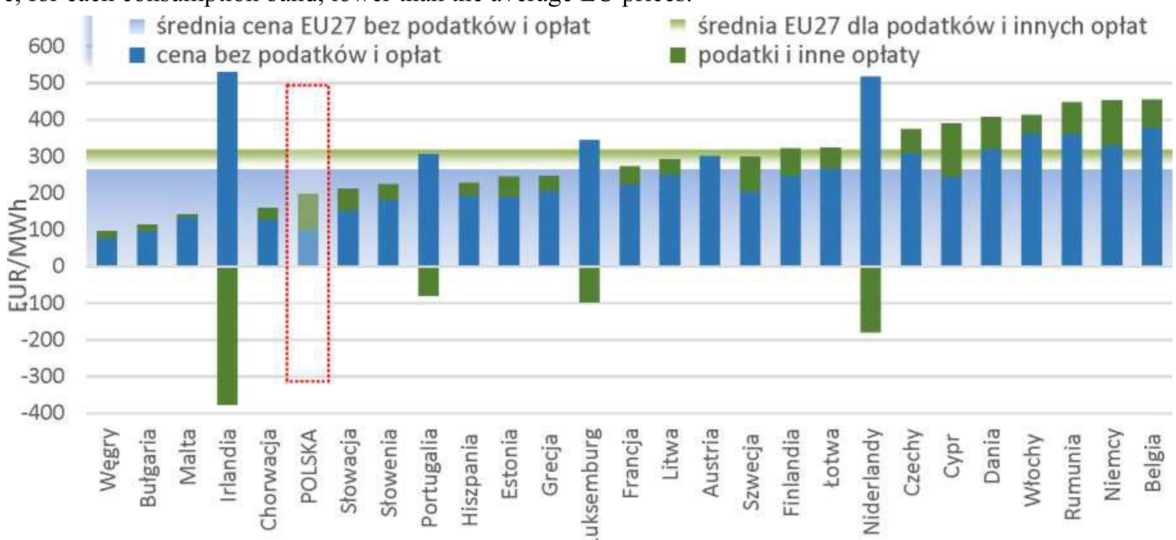


Figure 2.53. Electricity prices for household consumers for the first half of 2023 – DB category (1000 – 2 499 kWh)

Source: Eurostat

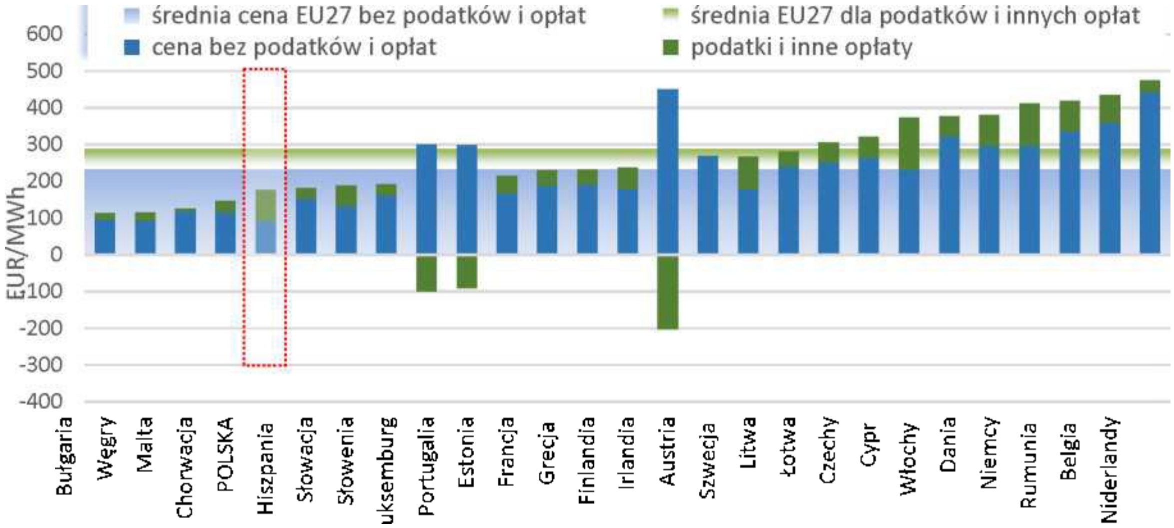


Figure 2.54. Electricity prices for household consumers for the first half of 2023 – category DC (2500 – 4 999 kWh)

Source: Eurostat

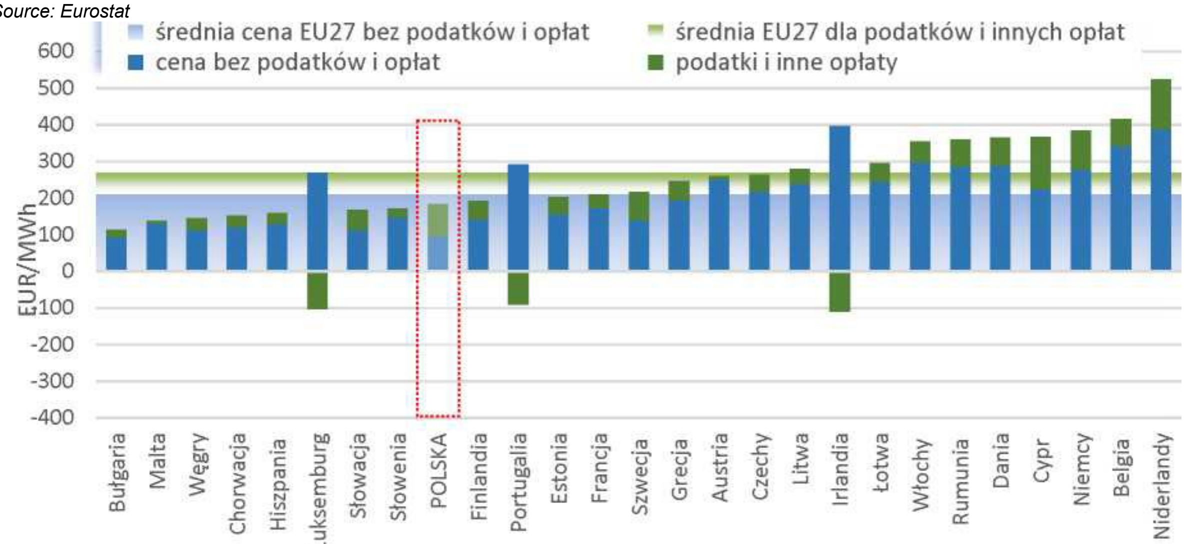


Figure 2.55. Electricity prices for household consumers for the first half of 2023 – category DD (5000 – 14 999 MWh)

Source: Eurostat

For some countries, the negative tax figures are due to the introduction by the national authorities of allowances and discounts which exceed the sum of taxes and other charges related to the purchase of electricity by end-users.

6.5. Forecasts for the development of R & I investments in existing policies and measures

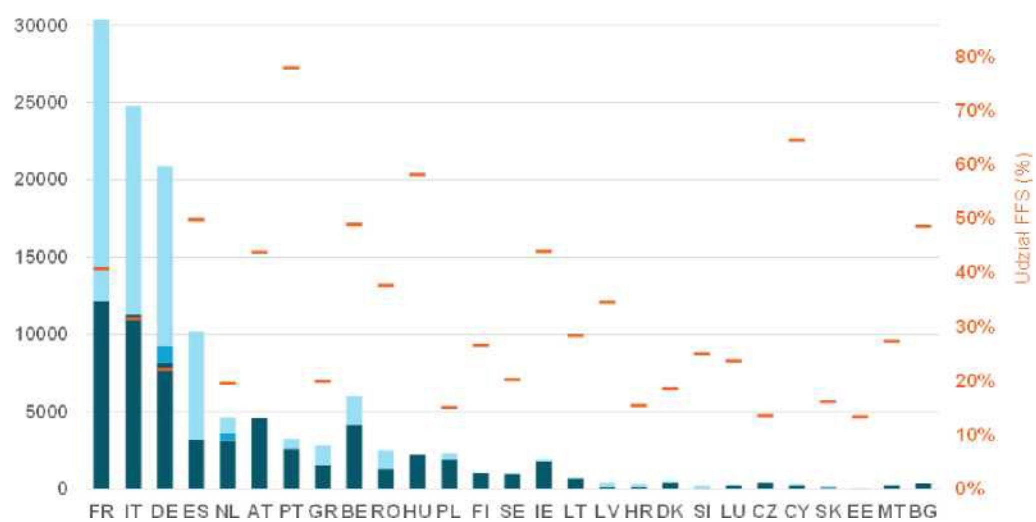
In line with the objectives of the EU's Europe 2020 strategy, investment in R & D should reach 3 %. The GDP of the European Union. According to Eurostat's 2022 data, four countries recorded R & D intensity as a percentage of GDP among the EU members, above 3 %. The highest R & D intensity was recorded in Belgium (3.44 %), followed by Sweden (3.40 %), Austria (3.20 %) and Germany (3.13 %). In contrast, eight EU countries reported R & D intensity below 1 %: Romania (0.46 %), Malta (0.65 %), Latvia (0.75 %), Cyprus and Bulgaria (both 0.77 %) recorded the lowest shares, followed by Ireland, Slovakia and Luxembourg with a share of close to 1 %. Poland was among the five countries that recorded a significant increase in R & D intensity over the last decade. However, they are still below the EU average in our country. In Poland, the R & D intensity rate was 1.46 % in 2022. According to the Strategy for Responsible Development, 2.5 % of GDP in 2030 is assumed to be spent on R & D.

According to a study by the consultancy firm Bain & Company, firms' R & D expenditure will increase on average by 10 % per year until 2026, despite high inflation and uncertainty in the market. Companies invest in R & D with the aim of deploying modern technologies and bringing products to the market faster. The biggest challenge remains the lack of skilled staff. By 2026, firms' annual R & D expenditure will reach EUR 2.72 trillion, compared to 1.85 trillion in 2022, almost half the increase. The forecast reflects a trend already observed in previous years. Between 2016 and 2021, R & D expenditure, measured as a percentage of revenue, increased by 23 %. The increase in R & D expenditure is most often reported by representatives of the automotive, aviation and defence and energy sectors.

National plans for energy subsidies

The General Union Environment Action Programme to 2030 requires the Commission and the Member States to phase out environmentally harmful subsidies, and in particular fossil fuel subsidies, by "setting a deadline for phasing out fossil fuel subsidies, in a manner consistent with the objective of limiting global warming to 1.5 °C".

Based on 2022 data (Figure 2.66), 47 % (EUR 58 billion) of total fossil fuel subsidies (EUR 123 billion) had a planned completion date before 2025. Only around 1 % (EUR 1.7 billion) of fossil fuel subsidies have an end date in the medium term (2025-2030). For the remaining 52 % (EUR 64 billion) there is no end date yet, or the agreed end date is after 2030.



Planned completion date before 2025
■ Planned completion date 2025-2030
■ Planned end date after 2030 or no deadline
—Part of the FFS in the total amount of energy subsidies (right-hand axle)

Figure 2.56 Fossil fuel subsidies by end date and as a percentage of total energy subsidies (%) in 2021

Source: EC report (COM 2023) 651 final – 2023 report on energy subsidies in the EU

Almost all EU Member States intend to move away from fossil fuels. However, in most Member States this intention has not been translated into concrete plans. The energy sector is the sector for which Member States have the most concrete plans to reduce their dependence on fossil fuels, in particular coal. Eight Member States also set deadlines for phasing out fossil-based heating in buildings. For the other economic sectors (industry, transport and agriculture), there are almost no deadlines for ending fossil fuel use.

In addition, while the amount of fossil fuel subsidies more than doubled in 2022 compared to 2021 due to support measures in response to the energy crisis, the vast majority of these measures are temporary and due to end in the near future. The energy crisis is unlikely to reverse the actions taken so far by Member States to reduce fossil fuel subsidies.

In the longer term, the energy transition will enable the support from subsidies to environmentally harmful fossil fuels to be increasingly redirected towards energy efficiency and renewable energy technologies.

This will be done, inter alia, by existing national support programmes from European Union funds. The European Funds for Infrastructure, Climate, Environment (FEnIKS) 20212027 programme is the largest financial and number of areas of support to support businesses in implementing green solutions such as modernising and upgrading energy infrastructure, investing in renewable energy sources, optimising energy consumption and reducing greenhouse gas emissions. This programme may support, inter alia, energy efficiency for housing companies and cooperatives in the form of a financial instrument (loan with cancellation) from the budget of PLN 705 million. EU financial support for companies is eligible for energy modernisation of plant buildings, energy efficiency of manufacturing processes, increasing the energy efficiency of the plant's media systems, transport routes and increasing the energy efficiency of ancillary systems, including, for example, boiler plants, systems for heat recovery from industrial processes or lighting, and the installation of RES equipment, installations and equipment for the production, storage, refuelling or transport of hydrogen. For housing cooperatives, financial support from EU funds is available for measures relating to thermomodernisation of buildings, the use of heat recovery technologies, connection to district heating or limited gas networks, the installation of new low-carbon or renewable heat or electricity sources for their own use, including home-based energy storage and heat pumps, the replacement of lighting with more energy-efficient lighting, the installation of devices enabling the costs of the heat or cooling supplied to be settled individually, equipped with remote reading features and the use of building energy management systems (BMS) and modernisation of ventilation and air conditioning systems.

Under the measure on the development of renewable energy sources (RES), funding may be granted from the FEnIKS programme for the construction, conversion, modernisation and extension of renewable energy sources for the production of biomethane with connection to the gas grid, the construction or expansion of renewable energy sources for the production of electricity and/or biogas heat, together with energy storage facilities operating for the RES source and connection to the grid, including infrastructure enabling the use of heat generated by cogeneration. The maximum EU co-financing rate for this project is 79.71 % of the call budget of PLN 300 million.

There are also a number of available financial support programmes for the development of RES, mainly for photovoltaic projects offered by the Polish government and local government units. The list of national financial support for PV may include programmes such as: Agro-energy, clean air, EnergiaPlus, EEA, RES Grant, Business Guarantee, Feng Greening Business Scheme).

6.6. Projection of investment in research into emission reduction

R & D expenditure shows an increasing trend in Poland. Between 2005 and 2015 it increased from around 0.5 % to approx. 1 %. In line with the Strategy for Responsible Development and the Europe 2020 Strategy, it is assumed that R & D expenditure will increase further to 1.7 % of GDP in 2020, as defined in these documents. The analysis assumes that R & D expenditure would remain at 1.7 % of GDP by 2040.

Table 2.80. R & D expenditure (million EUR'2016)

	2005	2010	2015	2020	2025	2030
Inputs (million EUR'2016)	1 711	2 798	4 250	9 371	11 044	12 716

Source: CSO: http://stat.gov.pl/wskazniki-makroekonomiczne/

Table 2.81. R & D expenditure by sector-specific emission reduction technology sector (million EUR'2016)

	2005	2010	2015
Energy efficiency	b.d.	49,23	17,45
Fossil	b.d.	30,78	30,12
Renewables	b.d.	22,18	19,50
Nuclear energy	b.d.	4,58	1,07
Hydrogen and Fuel Cells	b.d.	1,80	1,94
Other technologies in energy and energy storage	b.d.	17,25	17,06
Other interdisciplinary energy technologies	b.d.	0,92	1,08
	2005	2010	2015
Total R & D budget of the emission reduction sector	b.d.	127	88

Source: MAE

The forecast of R & D investment in the emission-reducing sectors assumes that the R & D growth rate in 2015-2030 is commensurate with that of total R & D expenditure.

Table 2.82. Forecast of total expenditure on research to reduce emissions by 2030 (million EUR'2016)

	2005	2010	2015	2020	2025	2030
Total R & D budget of the emission reduction sector	b.d.	127	88	195	229	264

Source: IEA, ARE SA

6.7. Overview of investment needs

6.7.1. Financial risk factors

Key risks for financing energy investments include the creation of the Net Zero Banking Alliance (NZBA) on the first April 2021 by 43 financial institutions from around the world, which brings together more than 100 members, representing 40 countries and more than 43 % of global banking assets. The institutions affiliated to the organisation have committed to achieving net-zero GHG emissions in their credit portfolios by 2050. Financial institutions shall apply the following criteria when applying the Net Zero Standard:

- operational and financial activities generating greenhouse gas emissions should be in line with the global net zero objective;
- financial institutions should align funding provision activities not only with the net zero objective, but also with the SDGs;
- financial institutions should use their skills to influence and engage non-financial companies and focus on financing activities that support economy-wide decarbonisation and the green transition;

The ongoing plans to shift banks towards a new approach to financing investments, inter alia, in the energy sector, will have a significant impact on companies' investments, channelling them into sustainable solutions and technologies that are essential for the Union to reach its 2030 and 2050 climate targets. Ensuring an adequate level of these investments will be particularly challenging in the short term in a context of higher interest rates and a possible recession.

The 2018 European Action Plan for Financing Sustainable Growth and the Renewed Sustainable Finance Strategy recently adopted by the European Commission introduced a series of new regulations for participants in the Polish capital market. Obligations such as: reporting on environmental impacts, decarbonisation strategies and potential climate risks implies not only additional costs but also significant organisational changes in financial institutions and public companies. The Ministry of Finance will also not overlook the challenges, as the state budget will also have to adapt to the principles of the European Takstomy.

The main instrument that will influence decision-making on the financing of energy investments will be the taxonomy, which is the common name of Regulation (EU) 2020/852 of the European Parliament and of the Council of 18 June 2020 on the establishment of a framework to facilitate sustainable investment and amending Regulation

(EU) 2019/2088. It is a set of pan-European rules and technical indicators that reflect the EU's climate objectives and ambitions for the different areas of the economy. The Regulation sets out the overarching conditions that an economic activity must fulfil in order to qualify as environmentally sustainable activities. The conditions that allow an activity to be considered sustainable shall be the following:

- the activity carried out contributes significantly to one or more of the six environmental objectives;
- does not significantly harm any of the environmental objectives;
- the activity is carried out in accordance with minimum guarantees;
- the activities carried out shall comply with the technical screening criteria established by the Commission.

It is worth recalling that the main environmental objectives recognised by the European Union are:

1. climate change mitigation;
2. climate change adaptation;
3. sustainable use and protection of water and marine resources;
4. transition to a circular economy;
5. pollution prevention and control;
6. protecting and restoring biodiversity and ecosystems.

The Taxonomy Regulation was published in the Official Journal of the European Union on 22 June 2020 and entered into force on 12 July 2020. It should be borne in mind that, as regards regulations and decisions, individual EU countries are obliged to apply them from the date of entry into force. The obligation to apply the criteria under Taksonomy and to indicate them in non-financial reports and product information for environmental purposes entered into force on 1 January 2022. At the time of entry into force of the Regulation, the obligation to report non-financial information on the basis of EU Taxonomy was required to entities that publish non-financial statements or reports on non-financial information, as required by the Accounting Act of 29 September 1994. The provisions of the Accounting Act on non-financial reporting implement Directive 2014/95/EU of the European Parliament and of the Council of 22 October 2014 as regards disclosure of non-financial and diversity information by certain large undertakings and groups (NFRD). The reporting obligations introduced in the taxonomy concern:

- financial sector entities (covered by SFRD – Regulation (EU) 2019/2088 on sustainability-related disclosures in the financial services sector) that offer 'green' financial products and services – these entities are required to disclose to what extent the activities contribute to the stated objectives and what percentage of the investment (turnover, CAPEX or OPEX) is compliant with its requirements;
- listed companies (covered by the NFDR – Directive 2014/95/EU on non-financial disclosures) – these public interest entities are required to disclose whether and to what extent their business activities are in line with the assumptions of Taksonomy by indicating what percentage of turnover, CAPEX and OPEX in a given year has contributed to the objectives specified in Taksonomy.

As of 1 January 2023, companies are required to disclose all quantitative information required by the Annexes to the Delegated Regulation (including, but not limited to, the proportion of taxonomy-aligned economic activities – i.e. environmentally sustainable – in total turnover, capital and operating expenditure in many presentation sections).

On 27 June 2023 (2023/2485), Commission Delegated Regulation (EU) amending Delegated Regulation (EU) 2021/2139 establishing additional technical screening criteria for determining the conditions under which certain economic activities qualify as contributing substantially to climate change mitigation or climate change adaptation and for determining whether those activities cause no significant harm to any of the other environmental objectives was adopted.

In accordance with the supplementary delegated act, in the case of natural gas, the gas installation must: emit no more than 270 g CO2per 1 kWh of energy on average over the life cycle; emit no more than 550 kg CO2per 1 kW power per year for at least 20 years; be built in a location where another installation was previously in place; have a power of 15 % less than its predecessor; have emissions ofnot more than 55 % of the emissions of the previous installation; set up before 31 January 2030.

In the case of nuclear power, future nuclear power plants have been subject to a construction permit by 2045. Furthermore, such investments must comply with nuclear and environmental safety requirements. From 2025, they must use accident-resistant fuel. It will also be necessary to demonstrate that nuclear waste will be properly disposed of, i.e. without harming the environment.

The reporting obligations under Regulation (EU) 2020/852 of the European Parliament and of the Council of 18 June 2020 will be extended to a much larger number of entities in the coming years:

- as of 1 January 2024, the reporting obligation for undertakings subject to the Non-Financial Reporting Directive (NFRD) that already prepare non-financial reports today;
- from 1 January 2025, the reporting obligation for large undertakings that are currently not subject to the NFRD;
- from 2026, reporting obligations for listed SMEs and small and non-complex credit institutions and captive insurance companies.

In practice, corporate taxonomic reporting is intended to enable financial institutions to lend their investment activities to provide information on whether or not an entity or investment project meets the taxonomy. The information obtained will have a decisive influence on the assessment of individual inversion projects. The taxonomy regulation is primarily aimed at the financial sector, but energy companies will have to deal with it as listed companies when preparing non-financial reports and as investors seeking financing on the market for new power units. The rules introduced by the Taxonomy Regulation will require an analysis of companies' activities in terms of compliance with the taxonomy and the guidelines it contains for energy. Thus, energy companies will have to indicate what proportion of turnover, capital expenditure and, where justified, operating expenditure are compatible with the taxonomy.

On the basis of the taxonomy, it will therefore be possible to determine whether an investment can be regarded as 'sustainable'. If an investment task is classified as unsustainable, it will not be able to obtain EU funding and capital market financing will be hampered and, if possible under very unfavourable financial conditions, significantly worse than the market. As a result of the work carried out in the Commission, Poland obtained conditional classification of nuclear power plants and gas-fired power plants as transitional.

7. Description of the forecasting methodology

The general scheme of the calculation procedure used for the work is shown in the figure (Figure 4.1).

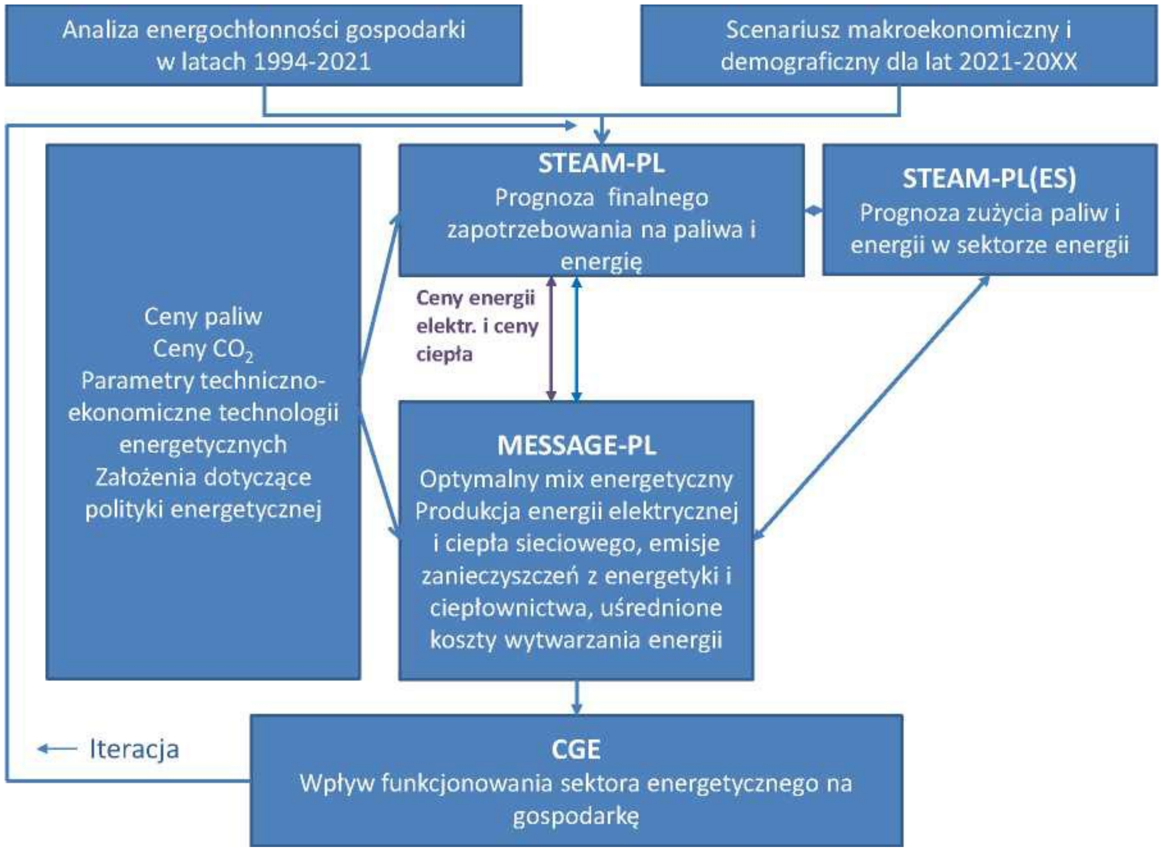


Figure 4.57. Diagram of the calculation procedure used for the work

The starting point of the calculation methodology used for the work was an analysis of the energy intensity of the economy between 1994 and 2022, based on that analysis, the energy consumption was broken down by sector and sub-sector and then into different directions of use (heating, lighting, technological processes, etc.) within the subsectors defined in the dedicated model. The relationship between the different components of the system and the environment, the strength of the links has been studied and the extent to which changes in one part of the system affect changes in other areas. Subsequently, on the basis of the projections for the country's economic and demographic development, a coherent scenario was built which would form the basis for calculating the future level of fuel and energy demand over the relevant time horizon. The first step in the calculation methodology was to determine the future level of energy demand in the country.

According to the methodology used, the main factors influencing future energy demand were: the rate of economic growth described by a number of macroeconomic indicators (GDP and added values in individual sectors of the national economy), demographic processes, projected changes in society's lifestyles, technological progress and processes to improve energy efficiency. The projections of electricity demand are based on the bottom-up approach used in the STEAM-PL (Set of Tools for Energy Demand Analysis and Modelling) model. The STEAM-PL model is a tool developed in ARE SA, fully adapting its relationships and equations to the changing conditions for the functioning of energy markets, including the expected technological progress. The projections generated by the model are constructed on the basis of a coherent scenario comprising macroeconomic, demographic, projected technological progress and the associated rate of improvement in energy efficiency. Fuel prices in this model are exogenous data. The base year is 2012. The calibration of the model was carried out on the basis of statistical data for the period 2000 to 2020. The STEAM-PL model generates results in fuel and energy demand forecasts, covering all current and forward-looking fuels and energy carriers in all sectors and sub-sectors of the national economy (taking into account the assumed rate of development of distributed energy). The use of appropriate metrics makes it possible to estimate in that model the total pollutant emissions corresponding to the consumption of specific fuels in the economic sector concerned. The simulation approach, for the manufacturing sector covered by the EU ETS, has been further complemented by optimisation methods that are better suited to analysing CO2 emission reductionstrategies (MESSAGE-PL_Ind). The STEAM-PL(ES) model sets the future volume of fuel and energy demand in the energy sector, i.e.: in mines, coking plants, refineries, gas plants, etc. The results obtained from the STEAM-PL model36 have been compared with those of the MAED and BALANCE models developed and developed in the Argonne National Laboratory, Chicago Illinois (USA), which are part of the ENPEP – Energy and Power Evaluation Program energy sector analysis package. Their description can be found in many national and foreign studies.

The projections for electricity and district heating demand were used as input to the MESSAGE-PL (Model for Energy Supply Strategy Alternatives and their General Environmental Impacts (IIASA) model, which, on the basis of the volume of demand obtained, determines the optimal structure of the generation sector and the required output from individual generation units. The selection of the economically optimal generation structure (mix of energy) in the MESSAGE model is based on minimising the total discounted system costs over the whole period considered, subject to top-down constraints arising from climate and energy policy, technical, logistical and raw material conditions. On the basis of the electricity and district heating production volumes calculated in this model for the different generation technologies, the total pollutant emissions from the sector, as well as the LCOE, which were the basis for determining retail prices, were calculated using appropriate indicators. In order to examine the economic impact of the functioning of the fuel and energy sector as part of Stage II, the CGE general equilibrium model is envisaged.

Description of analytical models used

STEAM-PL model

STEAM-PL is an end-use model dedicated to the national fuel and energy system, reflecting in detail the technical aspects of energy use in the various economic sectors. It is an integrated hybrid model that can simultaneously determine the future level of useful energy demand (using the classic ‘bottom-up’ approach) and the means of covering it (using a top-down approach). The model is based on a computational algorithm that simulates the behaviour of energy consumers responsive to changes in fuel and technology price relationships, which allows the substitution of energy technologies and energy carriers to be analysed on the basis of the costs associated with the supply of certain energy services (market share algorithms). For this purpose, the model uses

36Squierz S. ‘bottom-up’ energy demand model, taking into account technological progress and changes in price ratios. Energy Market Agency S.A./Politechnika Warszawska, Warsaw 2017.

econometric modelling of market shares in the form of logit functions (market share alghoritm – a mathematical approach used in, inter alia, BALANCE/ENPEP37 and WEM models38).

STEAM-PL has a modular structure, i.e. each sector of the national economy defined therein is dedicated to an appropriate module, taking into account in its calculation algorithms a number of characteristics distinguishing the sector (Figure 4.2).

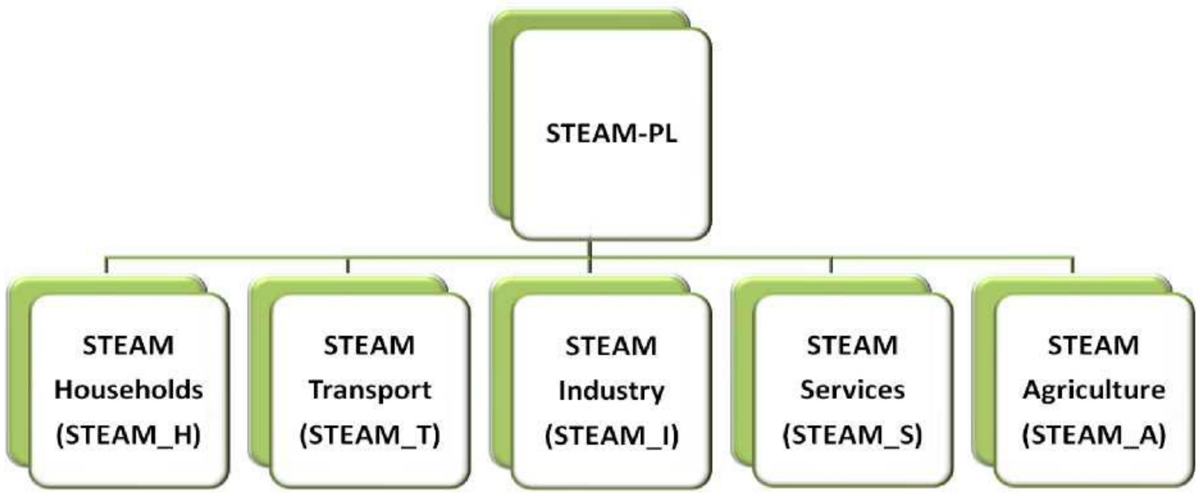


Figure 4.58. Breakdown of the structure of the STEAM-PL model into modules

The model uses the following breakdown of sectors of the national economy into sub-sectors, allowing to capture the specific features of the functioning of each economic area (Table 4.1):

Table 4.83. Sectoral structure of the STEAM-PL model

Sector	Subsector
Households	Urban households
	Rural households
Transportation	Passenger transportation
	Freight
Industry	Manufacture of metals and foundry of metals
	Non-ferrous metals output
	Manufacture of chemical and petrochemical products
	Manufacture of non-metallic mineral products
	Manufacture of paper and paper products, printing, manufacture of wood products
	Manufacture of food products, beverages and tobacco products
	Manufacture of other industrial products (manufacture of textiles, apparel, leather and related products, manufacture of machinery and equipment, manufacture of motor vehicles, trailers and semi-trailers, manufacture of other transport equipment, manufacture of machinery and equipment, mining of metal ores, other mining and quarrying, construction, other manufacturing).
Services	Non-commercial services
	Commercial services

Within each sector and subsector, the following directions of energy use (Table 4.2) are defined:

37https://ceeesa.es.anl.gov/projects/Enpepwin.html
38 World Energy Model documentation. International Energy Agency, October 2021. https://iea.blob.core.windows.net/assets/932ea201-0972-4231-8d81-356300e9fc43/WEM_Documentation_WEO2021.pdf

Table 4.84. Breakdown of directions of use used in the STEAM-PL model

Sector	Subsector
Households	Electrical equipment
	Lighting
	Air conditioning and ventilation
	Preparation of meals
	Space heating
	Preparation of the CWU
Transportation	Transport work (passenger transport)
	Transport work (freight transport)
Industry	Electric drives
	Lighting
	Heating and ventilation of the accommodation
	Furnace heat
	Technological pair
Services	Room lighting
	Street lighting
	Ventilation
	Air-conditioning
	Space heating
	Preparation of the CWU
	Electric drives
	Technological equipment
	Office electrical equipment
	Refrigeration
	Preparation of meals
Agriculture	Motor fuels
	Other fuel
	Electric take-offs

The calculation procedure used in the model can be characterised as follows: the model first determines the level of energy demand that is useful on the basis of the pace of economic development of the country and social, technical and regulatory factors.

As drivers of39 changes in demand in individual sectors and directions of use (Table 4.3):

Table 4.85. Drivers of sector-specific demand developments

Sector	Direction of energy use	Subsector
Households	Electrical equipment	Disposable income at home
	Lighting	Number of households, useful floor area
	Air conditioning and ventilation	Disposable income, number of houses
	Preparation of meals	Population, number of homes.
	Space heating	Useful floor area
	Preparation of hot water	Population, number of homes.
Transportation	Passenger transport work	Disposable income at home
	Freight transport work	GDP, added value in industry and construction
Industry	Electric drives	GDP, added value in industry and construction

39identified factors that most determine the extent and pace of changes in energy demand

	Lighting	
	Heating, room ventilation	
	Furnace heat	
	Technological pair	
Services	Lighting	Useful floor area of the premises, added value in services
	Space heating	
	Ventilation	Number of facilities, number of persons using the facilities, number of persons employed per category of activity and value added to the service
	Air-conditioning	
	Preparation of the CWU	
	Electric drives	
	Technological equipment	
	Office electrical equipment	
	Refrigeration	
	Preparing meals	
Agriculture	Electric take-offs	Added value in agriculture
	Motor fuels	
	Other fuel	

The next step is to identify a set of technologies and devices to cover the demand for individual energy services. The following were used to determine the baseline state: the results of the three-yearly cyclical survey of fuel and energy consumption in households[40], the results of the 'Fuel and Energy Budgets' statistical survey[41], as well as the results of analyses carried out by recognised research centres and industry institutions. The final energy consumption is calculated on the basis of the forecast quantity of equipment, its technical and economic characteristics and the expected intensity of use. Improving the energy efficiency of electrical appliances is taken into account through assumptions linked to technological developments (energy classes). The rate of replacement of existing equipment with new appliances of a higher energy efficiency class is taken on the basis of an analysis of historical trends, as a predictive result obtained from the relevant econometric models and on the basis of sales data obtained from manufacturers, for each individual appliance (an indicator of the rate of replacement of old with new equipment may also be determined by the user). The breakdown by energy classes is used for all defined electric appliances model (e.g. 72 different types of everyday electrical appliances are defined in a household module + 6 types of air-conditioning and ventilation equipment). For energy uses such as: heating and domestic hot water preparation, the aforementioned market share algorithm is used to determine how to cover energy needs.

In the manufacturing sector, the model follows a slightly different approach to services and households, namely, first, the production projections for energy-intensive industrial products are prepared (as exogenous data resulting from economic strategy and from dedicated economic models) and then, on the basis of historical data, energy intensity indicators are determined for the product groups concerned. These indicators are extrapolated as an element reflecting the evolution of energy efficiency improvement processes (the values of these indicators can be shaped in any way by a user based on historical data, as well as data on future technological

40'Energy consumption in households' – Central Statistical Office, Warsaw, 2002, 2009, 2012, 2015

41G-02b (balance sheet of energy carriers and district heating infrastructure), G-03 (Report on fuel and energy consumption) developments). The level of energy demand thus obtained is then divided into different directions of use in which, by means of a market share algorithm, simulated the means by which the various groups of dedicated technologies described in a series of technical, raw materials and environmental constraints are met.

Figure 4.3 shows the model diagram and the individual elements defined in the STEAM-PL model.

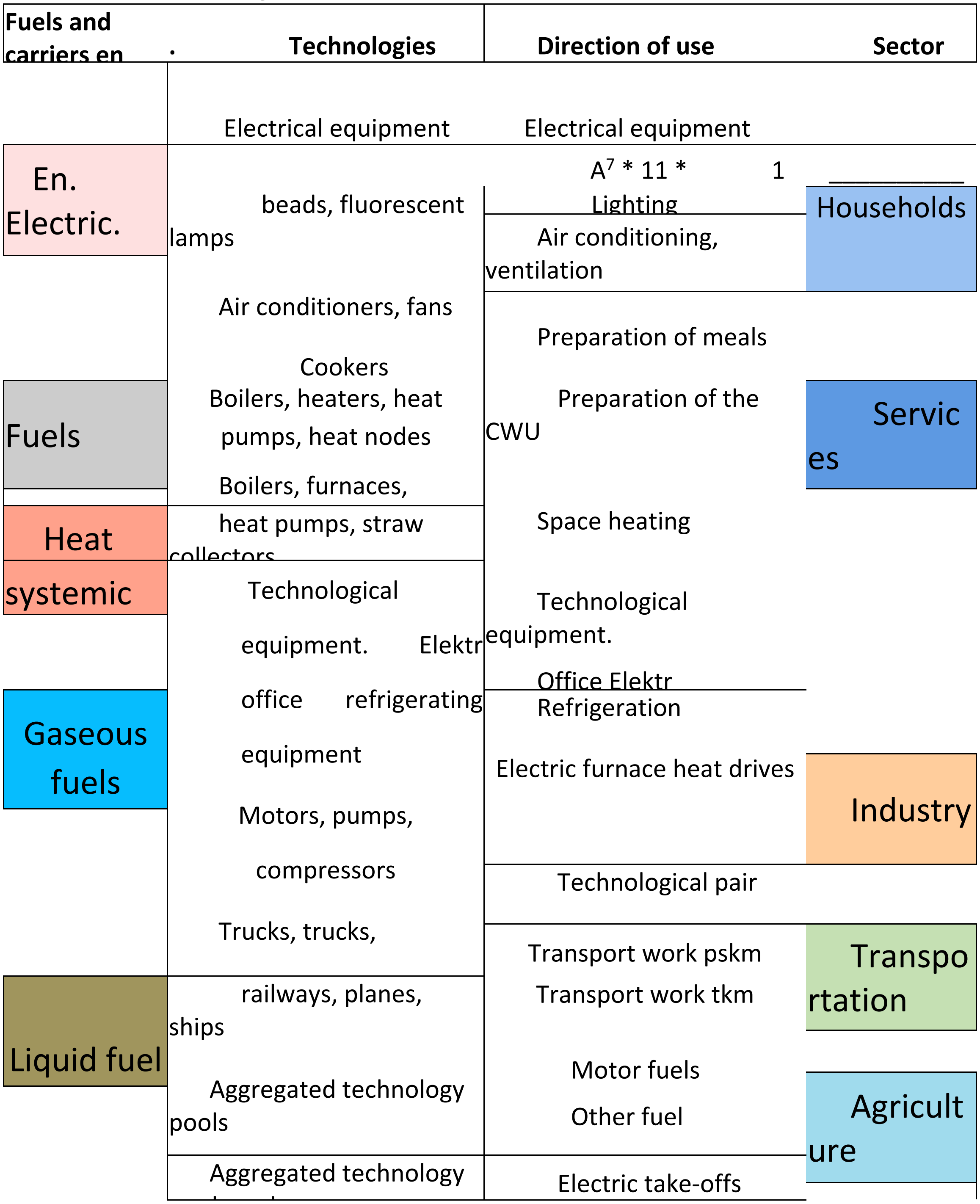


Figure 4.59. General diagram of the STEAM-PL model

Energy demand useful for directions of use: electrical equipment, lighting, air conditioning and ventilation, meal preparation, office electrical equipment and refrigeration equipment shall be calculated on the basis of the number of appliances of the type concerned and the intensity of their use (defined as the product of the average annual utilisation time and power or annual energy consumption):

$$ZEU = LUO * IWU \tag{3.1}$$

where:

Zeu – useful energy demand

Luo – Number of reception devices

IWU – consumption intensity of the receiving device (number of the average annual time of use and power of the device or average annual energy input)

The number of reception facilities and the intensity of their use is most often derived from the expected number of households, the number of entities carrying out a given service activity, the size of the population and the degree of prosperity of the population as measured by the GDP/resident indicator or the level of disposable income. Where data are available, sales data directly from suppliers shall also be used.

In other directions of use, the energy demand is calculated on the basis of the expected level of activity and the energy consumption per unit of that activity:

$$ZEU = A * AND \qquad (3.2)$$

where:

Zeu – usable energy

A – activity level

I – Energy intensity

$$ZEF = \text{ZEU} * \ | \text{“\_BLANK”} \ (3.3)$$

where:

ZEF – final energy

η – efficiency

The market share alghoritm*(MAP)*algorithm is used to determine how to cover useful energy demand identified in previous steps, for uses where there is competition between different technologies and energy carriers (e.g. space heating, meal preparation, domestic hot water preparation, para-technological).

The transport sector specific module (STEAM_T) allows analysis by transport: passenger and freight, and broken down within these two categories, modes of transport and vehicle types. The structure used makes it possible to reflect in detail the functioning of the national transport sector (Figure 4.4; Figure 4.5; Figure 4.6; Figure 4.7; Figure 4.8).

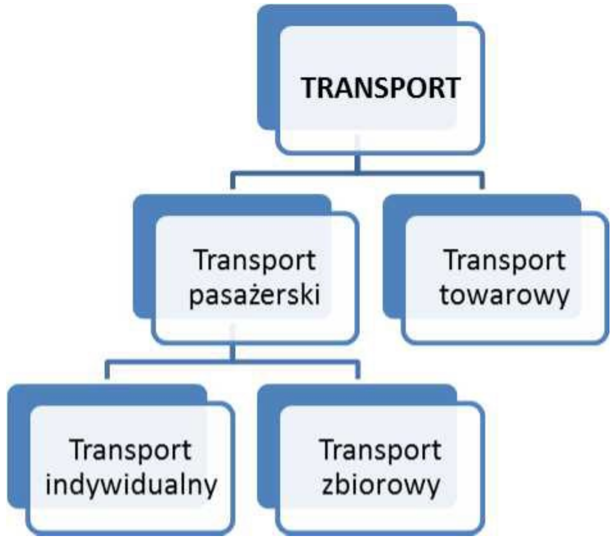


Figure 4.60. Structure used in the module STEAM_T

For personal passenger transport, the following vehicle groups are specified: existing passenger cars, new passenger cars, imported cars, as well as motorcycles, scooters and bicycles. In the category of passenger cars, the following vehicle types are defined according to the type of fuel used (petrol, diesel, LPG, compressed natural gas CNG, electricity, other) and the cylinder capacity of the engine (&1.4 dm^3, 1.4-1.9 dm^3, > 2.0 dm^3), (Figure 4.5).

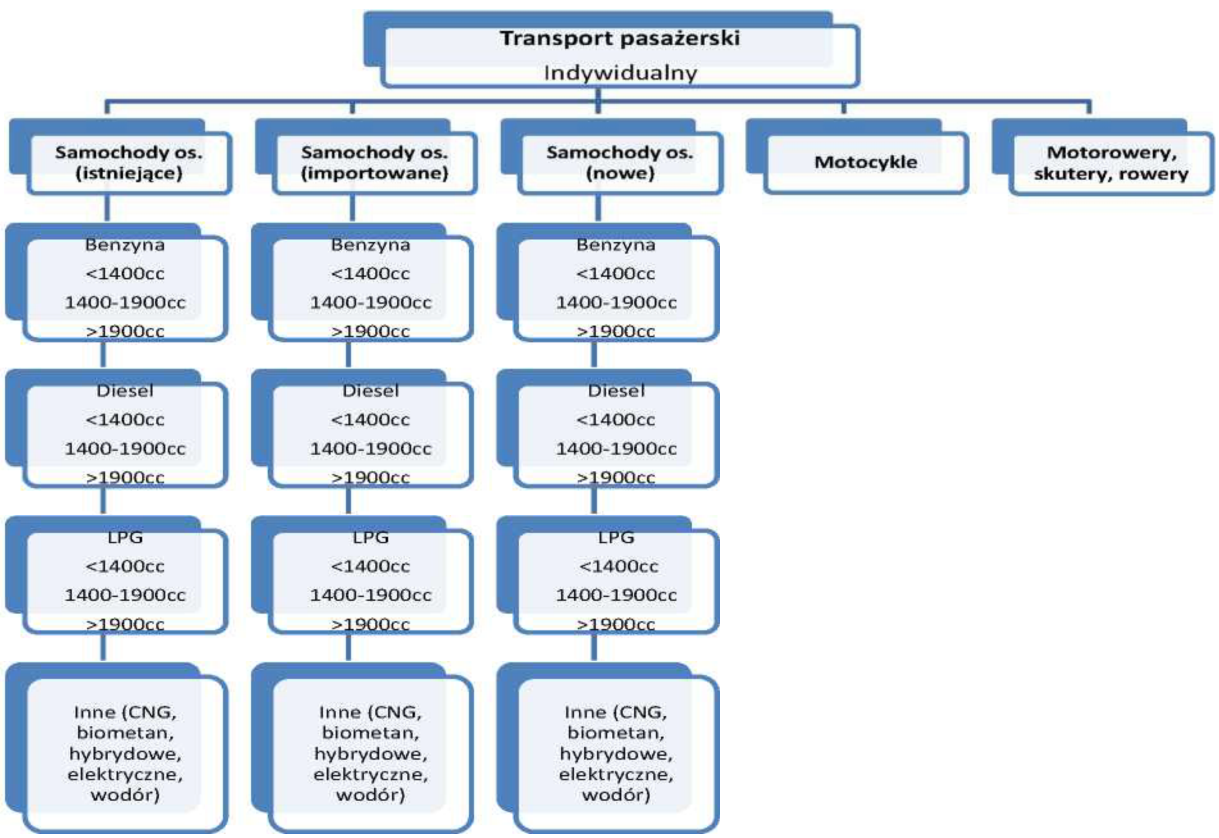


Figure 4.61. Structure used in the module STEAM_T – Individual passenger transport

In collective passenger transport, four main modes of transport have been identified, i.e.: road transport (including urban and interurban bus transport), rail transport with specific types of rail vehicles (combustion, electric, metro trains and tramways), air transport and waterborne transport. Public transport includes buses powered by diesel (ON), compressed natural gas (CNG), electricity and other fuels (e.g. hydrogen, ethanol). In extra-urban (interurban and international) traffic, five types of bus vehicles have been adopted: ON-powered buses > 3.5 t and & 3.5 t, buses powered by petrol & 3.5 t and CNG buses up to 3.5 t (Figure 4.6).

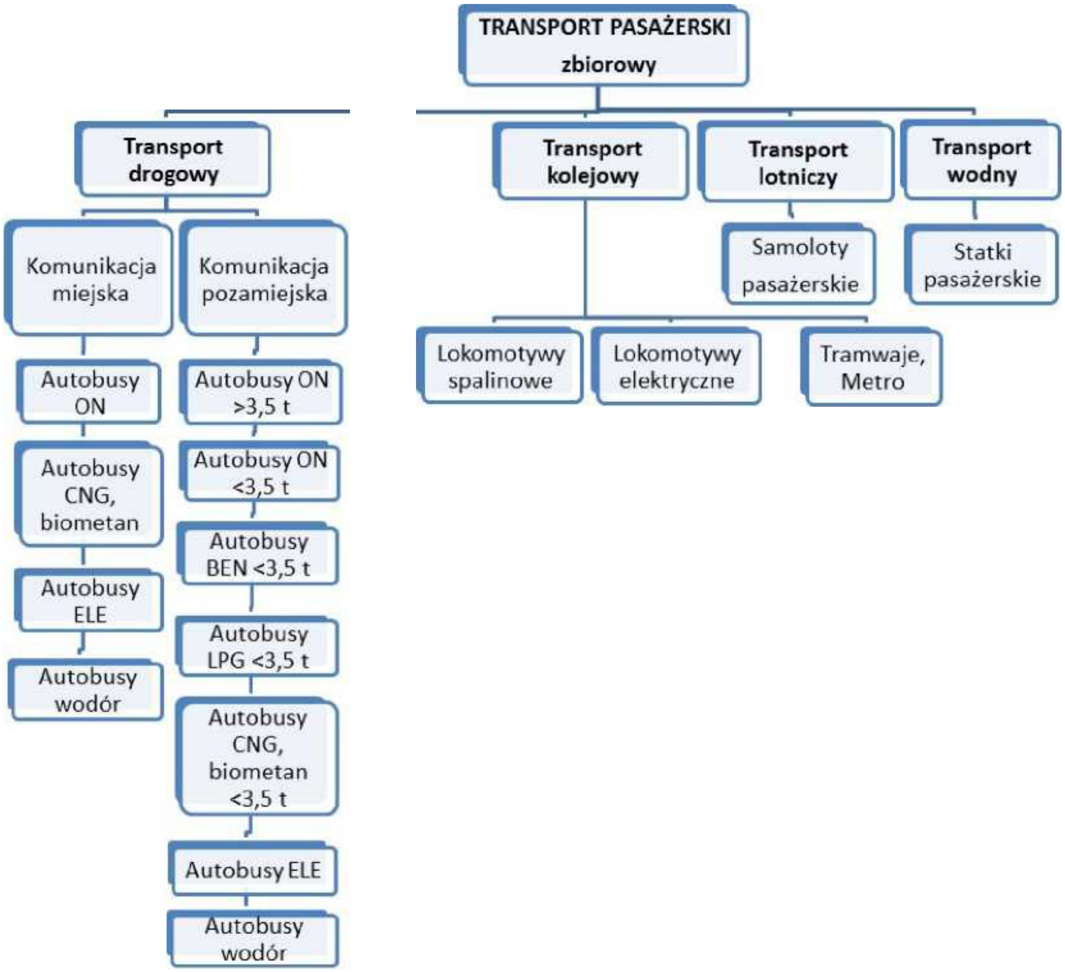


Figure 4.62. Structure used in the module STEAM_T – Collective passenger transport

In freight transport, four main branches were specified, namely: road transport, which is represented by trucks with a vehicle mass up to 3.5 tonnes and more than 3.5 specific fuel used, rail transport (combustion and electric locomotives) and air and water transport (freight ships, barges), (Figure 4.7).

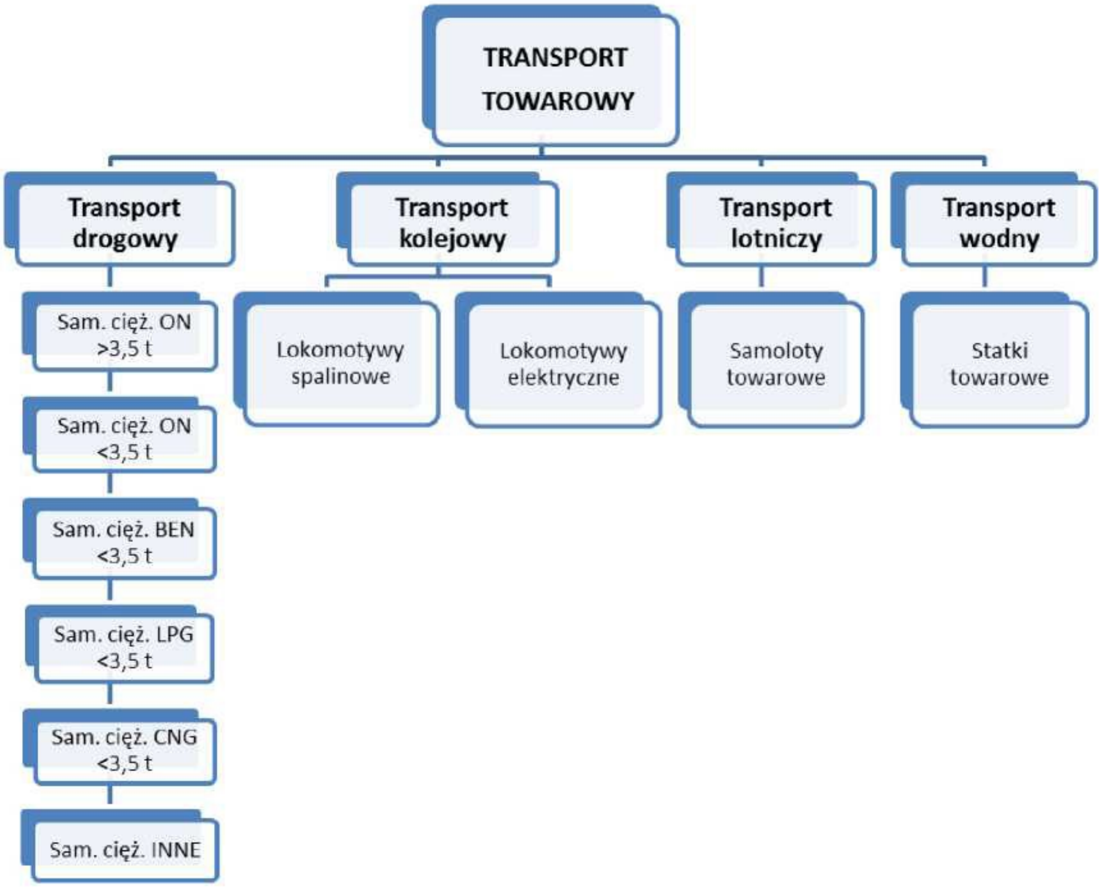


Figure 4.63. Structure used in module STEAM_T – Freight transport

The projection of fuel demand in this sector is based on the product of the expected number of transport vehicles, the forecasts of their average annual mileage and the average fuel consumption per 100 km of mileage:

$$EF = LP * SRP * SZP \quad (3.4)$$

where:

EF – Final energy

LP – number of transport vehicles

SRP – annual average runs

SZP – average fuel consumption per 100 km of mileage.

MESSAGE-PL model

The model of alternative energy supply strategies and their overall environmental impact (MESSAGE) has been designed as an optimisation model for medium and long-term energy system planning, development scenarios and energy policy analysis. The MESSAGE[42] model was created and is still being developed at the Institute of Applied System Analysis in Laxenburg (IIASA, Austria). The International Nuclear Energy Agency (IAEA) took over the MESSAGE model in 2000, where it is continuously updated and improved to support detailed analyses of alternative energy strategies, including the use of nuclear technologies. The Special Agreement between the IIASA and the IAEA allows for its application in countries that have signed the relevant agreements – Poland is a member of such States. In ARE S.A., the MESSAGE model was adapted to Polish conditions.

The methodology used in the MESSAGE model is based on optimising the function of the target with resource constraints, fuel availability and trade, new investments, market saturation of new technologies, pollutant emission standards and waste production, in order to formulate and assess alternative energy supply strategies for a given amount of energy demand.

The objective function is defined as minimising the total discounted system costs over the whole period considered and the entire supply chain, using linear programming methods or, for certain tasks, (e.g. selection of specified capacity aggregates – large carbon and nuclear units) total-numerical programming.

The Message operates on grid users' defined energy flows, starting from the extraction or supply of primary energy, through transformations (e.g. electricity and heat generation), transmission and distribution to final customers (Figure 4.8).

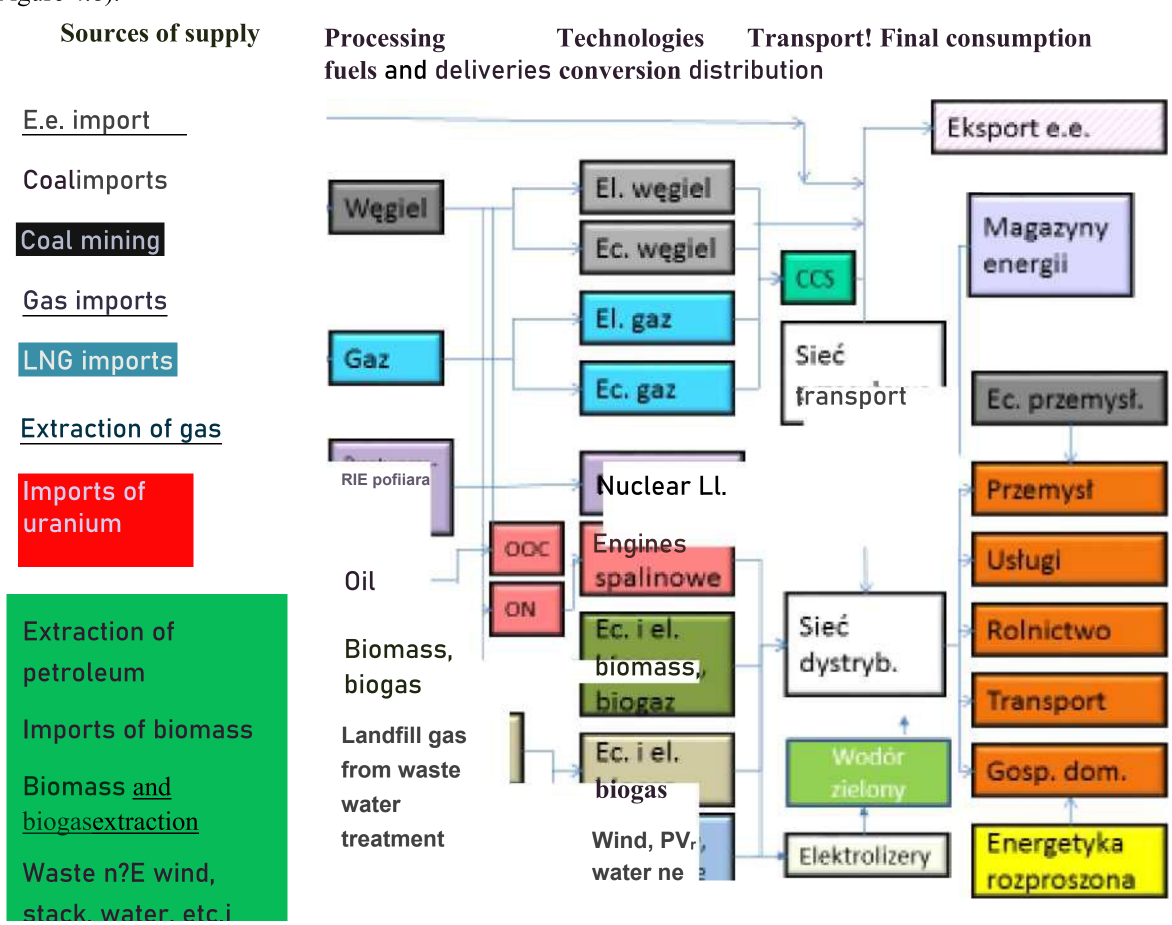


Figure 4.64. Simplified design of the electricity and heating system in the MESSAGE model

Both existing technologies and new generation units are part of the network. Currently, the model contains around 100 existing generation units and new types of technologies (e.g. high-efficiency coal and gas technologies with CO_2 capture, renewable energy technologies, nuclear power plants, cogeneration technologies, energy storage, electrolysers, DSR services). The model takes into account long-term objectives for air pollutant emissions and CO2 emissions(including emission allowance limits under the European Emissions Trading System) and State policy instruments promoting RES and combined heat and power generation.

An important advantage of the MESSAGE model is the possibility of differentiating the level of demand for a given energy carrier according to the season, type of day and daytime. This information is the basis for determining the technological mix and the operating mode of the units installed (base work, sub-peak and load peak). The equivalent load curve used in the MESSAGE model in the KSE (Figure 4.9) is created on the basis of data from PSE S.A. on the level of load for historical periods and forecasts of changes to this curve produced by ARE SA.

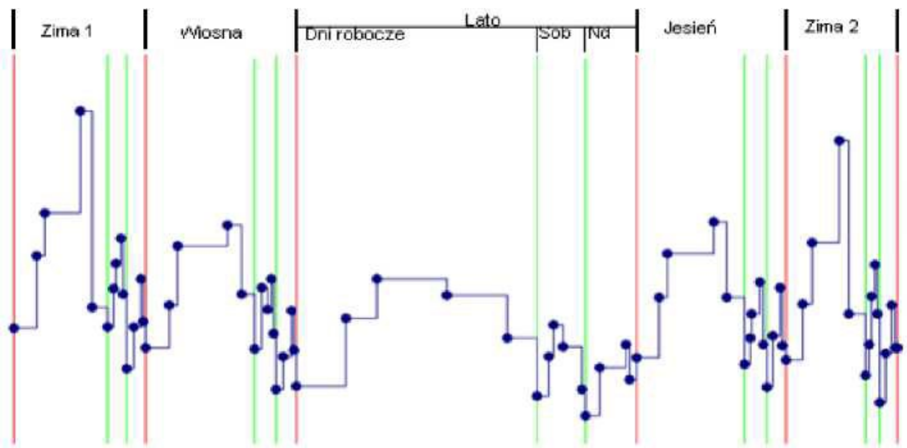


Figure 4.65. Equivalent load curve used in the MESSAGE model

On the basis of the optimal structure of the generation sector determined using the MESSAGE model and the required production demand from individual generation units, the unit average costs of electricity generation in Poland over the relevant time horizon are determined.

Definitions

District heat	heat**in** hot water, steam or other media intended for sale and delivered to customers through district heating networks.
DSR CED *Demand Side Response*	— a physical unit supplying power to the system by temporarily limiting the consumption of electricity from the electricity grid.
Energy efficiency	— the ratio of results, services, goods or energy obtained to the energy input.
Main Activity Producer CHP Plants	— undertakings or territorially and organisationally separated parts of undertakings whose principal activity is the production of electricity and heat from cogeneration.
Autoproducer CHP plants	— a combined heat and power plant producing electricity and heat in the form of process steam and/or hot water for the purposes of the industrial plant to which it belongs.
Electro-intensity of GDP	— the ratio of domestic electricity consumption to Gross Domestic Product.
Final energy intensity of GDP	— the ratio of final energy consumption to Gross Domestic Product.
Primary energy intensity of GDP	— ratio of primary energy consumption to Gross Domestic Product.
EUA CED *European Union Allowance*	— basic unit to account for emissions of one tonne of $CO2_{equivalent}$ to the atmosphere.
Energy intensity of GDP	— final energy consumption for energy calculated according to the Eurostat/IEA methodology. Final consumption in industry does not include the energy transition sector. Transformation in blast furnaces is accounted for using the actual transformation efficiency.
Cogeneration	— simultaneous generation of heat and electricity or mechanical energy during the same technological process.
LCP CED *Large Combustion Plants*	— Directive 2001/80/EC on the limitation of emissions of certain pollutants into the air from large combustion plants.
Number of heating degree days	**the** product of the number of heating days by the difference between the average temperature of the heated space and the average outdoor temperature. The number of degree-days Sd in a given year is calculated according to Eurostat methodology.
Small installation (RES)	— an installation of a renewable energy source with a total installed capacity of more than 50 kW and less than or equal to 1 MW connected to the electricity grid with a rated voltage of less than 110 kV or a combined heat output greater than 150 kW and less than 3 MW, where the combined electrical capacity is greater than 50 kW and equal to or below 1 MW.

Micro-installation (RES)

an installation of a renewable energy source with a total installed capacity of less than or equal to 50 kW, connected to the electricity grid with a voltage rating of less than 110 kV or a combined heat output of less than or equal to 150 kW.

Electrical power

the maximum permanent power at which the power plant (heat-power plant) can operate continuously for at least 15 hours, in good condition and under normal conditions.

Electrical power plant/combination capacity

— the maximum permanent power at which the power plant/heat plant can operate continuously for at least 15 hours in good condition and under normal conditions. Two concepts of attainable power are used: Gross and net achievable power.

IAS

CED *Market Stability Reserve* — a long-term mechanism to stabilise the CO2 emissionsmarket.

Energy mix

— energy production and consumption structure by energy carrier or generation mode.

PPP

purchasing power*parity*, exchange*rate* calculated on the basis of a comparison of the prices of a fixed basket of goods and services in different countries at the same time, expressed in their currencies. PPPs are an indicator of the level of differences between countries.

Gross production

— the amount of electricity produced by all power plants and combined heat and power plants over the period considered, including the consumption of own needs and losses in the transformers of the power plant.

Net production

— the amount of electricity produced by all power plants and combined heat and power plants over the period considered, excluding self-consumption, energy losses in grid-linked transformers (excluding pumping energy).

Prosumer

— final customer producing electricity exclusively from renewable energy sources in a micro-installation for its own use, which is not connected with an economic activity governed by the Freedom of Economic Activity Act of 2 July 2004.

Capacity market

— a mechanism that rewards the maintenance in the system of a certain level of available capacity for a fee specified in the auction system.

Certificate of origin

— a producer of electricity from renewable energy sources whose installation started working before 1 July 2016. The document confirms the origin of this energy from renewable energy sources and is convertible into a so-called certificate, which, as a property law, is traded on the Commodity Exchange.

Guarantees of origin

— a document certifying to the final customer that the amount of energy specified in that document has been produced from renewable energy sources. Applies to electricity, biomethane, heating or cooling, renewable hydrogen, biogas and agricultural biogas.

Cross-border exchanges — transmission of power and energy via an interconnection line connecting two or more countries, usually measured on the exporter's side and accounted for in accordance with agreed international agreements and contracts.

High-efficiency cogeneration — generation of electricity or mechanical energy and useful heat from cogeneration that provides primary energy savings in:

a) a cogeneration unit of not less than 10 % compared to separate electricity and heat production with reference efficiency values for separate production, or

b) cogeneration units with an installed electricity capacity of less than 1 MW compared to separate generation of electricity and heat with reference efficiency values for separate generation.

Final electricity demand **total** electricity system demand, not taking into account the own needs of power plants and combined heat and power plants and transmission and distribution losses.

Gross electricity demand — total electricity system demand, including the consumption of the own needs of power plants and combined heat and power plants and transmission and distribution losses.

Demand for electricity — the amount of electricity that the customer (customers) should receive in order to meet his or her needs.

Power demand — total system load during the period considered, e.g. during a day, week or year.

Non-energy use — energy used as a technological raw material in the production of certain products.

Abbreviations and terminology

aKPEiK — — update of the National Energy and Climate Plan 2021-2030

BAT — — *Best Available Technology* – Best available technology

BREF — — *Best Available Techniques Reference* – BAT reference documents

BM — The World Bank

CCS — *Carbon Capture and Storage*

WHAT — central heating

COP — — *Coefficient of Performance*

CWU — domestic hot water

DSR — *Demand* **Side** *Response*

EED — **Energy** *Efficiency* Directive

ENPEP — *Energy and Power Evaluation Program*

EUA — — 1 tonne of CO_2 emission allowance

EU ETS — *European Union Emissions Trading System*

EUROSTAT — European Statistical Office

FBC — *fluidised bed combustion* **units** – fluidised boiler units

GCV *gross calorific value*

GHG *greenhouse* gases

GTCC — — *gas turbine* combined cycle

GUS — Central Statistical Office

HVO — *Hydrated* vegetable oils

IED – Industrial Emissions Directive

IGCC — *Integrated Gasification Combined Cycle*

JRM – Capacity market units

JWCD — —Centrally-dispatched manufacturing unit

EC — European Commission

NECPs — National Energy and Climate Plan 2021-2030

NAP — — National Renewable Energy Action Plan

KPDEE — — National Energy Efficiency Action Plan for Poland

KSE — National electricity system

LCP — *Large Combustion Plants* – Directive 2001/80/EC on the limitation of emissions of certain pollutants into the air from large combustion plants

MAE — International Energy Agency

MAED — Model for Analysis of Energy Demand

ME — Minister responsible for Energy

MESSAGE — — CED *Model for Energy Supply Strategy Alternatives and their General Environmental Impacts* – model of alternative energy supply strategies and their overall environmental impact

MEW — small hydropower plants up to 5 MW

MF — Minister responsible for Public Finances

IAS — — *Market* Stability Reserve

ME — — Minister responsible for the Environment

nJWCD – non-manufacturing units Centrally Digested

NBP — The National Bank of Poland

NCV — — *net calorific* value of fuel

NEC — — *National Emission Ceilings* – Directive 2016/2284 on the reduction of national emissions of certain atmospheric pollutants, amending Directive 2003/35/EC and repealing Directive 2001/81/EC

TSO — Transmission system operator

RES — — renewables

EP — European Parliament

PEP — Poland's energy policy

PIG **State Mining** Institute

GDP — —Brutto cockrain product

GDP/Ma – GDP per capita indicator

Pkm **passenger-kilometres**

PPEJ — Polish nuclear programme

PPP — *Purchasing* Power *Parities*

RE — European Council

RES — — *Renewable Energy Sources* – RES energy

RES-OS — share of energy from renewable sources in gross final consumption of energy (National Descriptor – Overall Share)

RES-E — share of renewable energy in gross final consumption of energy in the electricity area (sector indicator deominator)

RES-H&C — share of energy from renewable sources in gross final consumption of energy in the heating and cooling area (sector indicator deominator)

RES-T — share of energy from renewable sources in gross final consumption of energy in the transport area (sector indicator deominator)

SOR **Strategy** for Responsible Development

STEAM-PL — *Set of Tools for* Energy Demand Analysis and Modelling

TG — —gas turbines

Tkm — tonne-kilometres

WAM — scenario with additional policies and measures

WEM — scenario of implemented policies and measures(*with existing measures*)