|  |  |  |  |
| --- | --- | --- | --- |
| – Appendix 2 –  **Conclusions from forecast analyses for the energy sector** | | | |
|  | C:\Users\Marta\Downloads\solar-panel.png | C:\Users\Marta\Downloads\science.png |  |
| C:\Users\Marta\Downloads\energy.png | C:\Users\Marta\Downloads\wind.png |  |  |
| C:\Users\Marta\Downloads\gas-pipeline.png |  | Ministry of  Climate and Environment | |



|  |  |  |  |
| --- | --- | --- | --- |
|  |  |  |  |

**ENERGY POLICY  
OF POLAND**

**UNTIL 2040**

**Table of Contents**

[Introduction 3](#_Toc67409956)

[1. Conclusions from forecast analyses for the fuel and energy sector taking into account balanced increases of CO2 emission allowance prices 4](#_Toc67409957)

[1.1. Assumptions 4](#_Toc67409958)

[1.2. Forecast of fuel prices in imports to the European Union 5](#_Toc67409959)

[1.3. Forecast of CO2 emission allowance prices in the EU ETS 6](#_Toc67409960)

[1.4. Forecast of technical and economic parameters of technologies used in the energy sector 7](#_Toc67409961)

[1.5. Forecast of primary energy consumption and final energy consumption 8](#_Toc67409962)

[1.5.1. Final energy savings 11](#_Toc67409963)

[1.6. Forecast of domestic energy production by fuel type 13](#_Toc67409964)

[1.7. Forecast of gross inland consumption of fuels and energy 14](#_Toc67409965)

[1.8. Forecast of net imports by fuel 15](#_Toc67409966)

[1.9. Forecast of gross final energy consumption from renewable sources 16](#_Toc67409967)

[1.10. Forecasts of thermal energy generation and combined heat and power generation 19](#_Toc67409968)

[1.11. Electricity forecasts 20](#_Toc67409969)

[1.11.1. Forecast of electricity generation unit decommissioning 20](#_Toc67409970)

[1.11.2. Forecast of electricity generation capacity 21](#_Toc67409971)

[1.11.3. Electricity generation forecast by fuel 24](#_Toc67409972)

[1.11.4. Electricity price forecast 26](#_Toc67409973)

[1.12. Transmission interconnection capacity forecasts 27](#_Toc67409974)

[1.12.1. Electricity transmission interconnection capacity forecasts 27](#_Toc67409975)

[1.12.2. Forecasts of gas transmission interconnection capacity 27](#_Toc67409976)

[1.13. Forecasts of pollutant emissions 29](#_Toc67409977)

[1.14. Forecast of capital expenditure related to changes in the energy sector 32](#_Toc67409978)

[2. Conclusions from the forecast analysis for the power sector taking into account high prices of CO2 emission allowances and environmental and system costs 35](#_Toc67409979)

[2.1. Main assumptions 35](#_Toc67409980)

[2.2. Forecast electricity demand and net maximum capacity 39](#_Toc67409981)

[2.3. Forecast structure of net installed capacity 40](#_Toc67409982)

[2.4. Forecast of net electricity generation structure 42](#_Toc67409983)

[2.5. Forecast of net specific emissions in the sector of power plants and CHP plants 44](#_Toc67409984)

[2.6. Forecast of hard coal consumption in power plants and CHP plants 45](#_Toc67409985)

[2.7. Forecast of natural gas consumption in power plants and CHP plants 46](#_Toc67409986)

[2.8. Capital expenditure 47](#_Toc67409987)

[2.9. Conclusions of the analyses 49](#_Toc67409988)

[2.10. Conclusions – confirmation of PEP2040 specific objectives 51](#_Toc67409989)

[2.11. Extended technical and economic assumptions 51](#_Toc67409990)

[List of abbreviations 54](#_Toc67409991)

# Introduction

This document forms Appendix 2 to ***Energy Policy of Poland until 2040***(PEP2040). The document consists of two chapters presenting the conclusions of two analyses.

The results presented in Chapter 1 constitute forecasts of the development of the fuel and energy sector in the 20‑year horizon in the scenario of balanced increase of CO2 emission allowance prices, converging with the forecasts of the International Energy Agency. *The National Energy and Climate Plan 2021–2030* (KPEiK), submitted to the European Commission on 30 December 2019, indicates the same forecasts presented in this chapter.

Chapter 2 draws conclusions from the results of the analysis for the electricity sector, which assumes a high CO2 allowance price scenario and considers environmental and system costs. The need to prepare an additional analysis resulted from the dynamically changing regulatory and economic environment in Poland and the EU, as well as from comments made during PEP2040 consultation process.

A particularly important determinant of the attached forecasts is the adoption by the European Union (EU) in December 2019 of an EU-wide target to achieve complete climate neutrality in 2050, an upward revision of the ambition of the Paris Agreement, which obliges a balance between emissions and removals of greenhouse gases in the second half of the 21st century. Poland supported the EU headline target, but pointed out the need to take our country's unique starting position into account, which requires a separate path to achieve the Paris Agreement target. Subsequently, the European Commission (EC) undertook work to raise the target for reducing greenhouse gas (GHG) emissions in 2030 from 40% to at least 55% with respect to 1990. The importance of these intentions is underlined by the plan to establish the so-called European Green Deal, which replaces the *Europe 2020 Strategy* as the main strategic initiative for the EU. The political commitment contained in the Communication on the European Green Deal and the Conclusions of the European Council of 11 December 2020 is to be transformed into a legal commitment after the adoption by the European Parliament and the Council of the legislative proposal on the European Climate Law, presented by the EC on 4 March 2020. Based on the aforementioned changes, an analysis was made of the change in the electricity balance in the situation of tightened mechanisms for the implementation of the climate and energy policy, which is reflected in the increase in forecasts of CO2 emission allowance prices, which are of key importance for the shaping of the mix. The forecasts presented in Chapter 2 are consistent with those presented in the strategic option in the *Polish Nuclear Power Programme*, adopted by the Council of Ministers on 2 October 2020.

# Conclusions from forecast analyses for the fuel and energy sector taking into account balanced increases of CO2 emission allowance prices

## Assumptions

The analyses were based on forecasts of Poland's economic development prepared by the Ministry of Finance. For the long-term CO2 emission allowance price forecasts, the International Energy Agency studies and the European Commission forecasts accompanying the 2016 Reference Scenario for Energy Sector Development were used. (i.e. the EC Guidelines for Forecasting Assumptions for Integrated National Energy and Climate Plans). The development potential of each technology and its future costs have been determined taking into account a wide range of bibliographic references.

The forecasts take into account political decisions which, as analytical assumptions, are boundary values – e.g. the necessity of meeting the EU obligations regarding the share of RES in the energy balance has been enforced. The model selects generation sources according to cost-effectiveness, but also takes into account the safety conditions of grid operation. This means that even if one of the RES (weather-dependent) technologies were significantly cheaper than other available technologies, the model would not choose these sources as the only ones due to the uncertainty of their use. In such a situation, a source must be selected that will act as a reserve for the RES units. Moreover, due to technical conditions, the pace of connecting sources of particular technologies to the power grid is limited.

Main assumptions made in the analyses:

* The GDP growth paths published by the Ministry of Finance have been adopted – in five-year periods an annual average growth of 2.1–3.6% has been assumed, with services and industry being mainly responsible for the creation of value added;
* The demographic forecast of the Central Statistical Office (GUS) has been adopted, which assumes that the population will fall from around 38 million today to 36.5 million in 2040;
* The disposable income forecast was based on GUS data on household budgets and GDP growth paths – the forecast shows that 2015 household disposable income will almost double by 2040, reflecting improvements in the material situation of the population and determining the national growth in energy demand;
* Due to the need for consistency with the scenarios (REF and ECP) developed for the *National Energy and Climate Plan 2021–2030,* it was decided to use the 2017 forecasts of the Ministry of Finance and International Energy Agency i.e. older than the latest available. Nevertheless, the differences between the 2017 and 2018 long-term forecasts of MF and the IEA do not significantly alter the results of the forecasting analysis for the fuel and energy sector.

In addition, it was assumed that Poland will perform:

* obligations resulting from EU regulations and international agreements in the field of reduction of pollutant emissions, increasing the share of renewable energy sources (RES), improvement of energy efficiency, security of energy supply and building a single energy market;
* activities defined for the *energy* area in the *Strategy for Responsible Development until 2020 (with an outlook to 2030)* in order to improve energy security, increase energy efficiency, develop technology and restructure the hard coal mining sector.

The following assumptions were used for energy resources:

* ***hard coal***: proven balance resources of hard coal deposits as at 31.12.2018 amount to 61,436 million tonnes. Nearly 70% of the total resources are thermal coal and about 30% are coking coal, and other types of coal account for about 1.28% of the total coal resources. The resources of developed deposits currently constitute 37.9% of the balance resources and amount to 22,308 million tonnes. The industrial resources of mines, as determined by the deposit development projects (PZZ), amounted to 3,605.45 million t at the end of 2018. The study assumes that future demand will be covered by domestic coal as far as possible and supplemented by imports;
* ***lignite****:* geological balance resources of lignite as of 31.12.2018 amount to 23,316.5 million t, of which the majority, i.e. 23,315 million t, are thermal coal. Lignite industrial resources as at the end of 2016 amounted to 1,064.6 million t. *Due to its characteristics, lignite is used in close proximity to the mining site, so import/export is not considered in the analyses;*
* ***natural gas:*** the recoverable balance resources of natural gas as at 31.12.2018 amounted to 139.9 billion m3. In the analysed year, the total recoverable resources of the developed gas fields amounted to 89.9 billion m3, which represents 64% of total recoverable resources. Industrial reserves of natural gas fields in 2018 were at 66.64 billion m3. Domestic gas reserves are only a supplement to gas imports – approx. 4 billion m3 was extracted in 2018, and natural gas imports to Poland in 2018 amounted to 14.95 billion m3. It has been assumed that actions will be maintained with a view to enabling future acquisition of the raw material from various directions, including an increase in own extraction;
* ***crude oil***: the state of recoverable oil resources as of 31.12.2018 amounted to 22.56 billion m3. Total recoverable reserves of the developed oil fields amounted to 221.15 billion m3 in the analysed year. As in the case of natural gas, the demand for this energy carrier is met primarily by supplies from abroad.
* ***nuclear fuel****:* Poland does not have uranium ore deposits in a quantity which would be profitable to extract at present, although future extraction of these deposits, including unconventional sources, is not necessarily ruled out. Nuclear fuel is widely available on the world market – its availability is guaranteed by international agreements and its prices will remain stable;
* ***biomass****,* ***agricultural biogas, other biogas***: it was assumed that the technical potential including solid biomass from forestry, agriculture (energy crops, by-products and waste from agriculture and agri-food processing), food processing and biogas is about 610 PJ/year in 2020 and 910 PJ/year in 2030, although the market potential is lower;
* ***geothermal energy, heat pumps***: theoretical geothermal energy resources in Poland are unlimited, however, there are relatively few places where its application is economically justified. Similarly, the heat energy resources that can be extracted with heat pumps are mainly limited by economic considerations, but they are gaining in popularity for individual use. The potential for deep-rock heat utilisation was estimated at 45 PJ per year in the 2030 perspective and 105 PJ in 2040;
* ***water****:* the potential of hydropower in Poland is small and amounts to approx. 30 PJ/year (8 TWh/year), with approx. 25% currently in use;
* ***wind****:* the market potential of onshore wind farms has been estimated at about 10 GW of installed capacity, and of offshore wind farms – approx. 8–10 GW by 2040;
* ***solar***: the real potential of solar plants has been estimated at approx. 7 GW by 2030 and as much as 16 GW by 2040. Much of the potential of solar technologies is in microgrids.

Below are presented forecasts of fuel import prices, prices of emission allowances, technical and economic parameters of individual technologies used in the energy sector. Then, forecasts of primary and final energy consumption, fuel and energy production and consumption are presented. This is followed by forecasts of energy consumption from renewable sources, district heat generation and electricity – unit decommissioning, the projected structure of installed capacity and electricity generation, and electricity prices. The forecasts of capital expenditure in the energy sector required to implement this scenario are also presented.

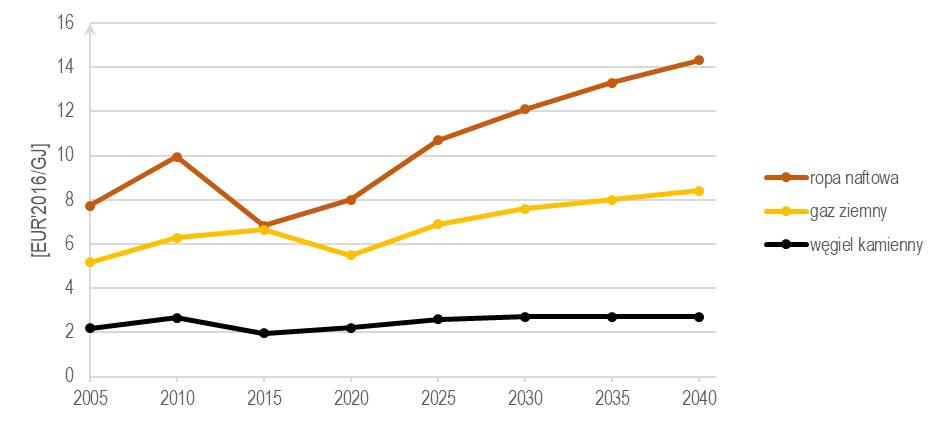
## Forecast of fuel prices in imports to the European Union

International Energy Agency (IEA) forecasts – WEO 2017[[1]](#footnote-1), "New Policies" scenario, were used to calculate model forecasts of fuel prices for EU imports. These forecasts served as the basis for determining the development trends of fuel price forecasts on the domestic market. Forecasts indicate an increase in the prices of all raw materials. The forecasts are summarised in the table and shown in the graph below.

Table 1. Fuel price forecasts for EU imports [EUR'2016/GJ]

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **2005** | **2010** | **2015** | **2020** | **2025** | **2030** | **2035** | **2040** |
| crude oil | 7.73 | 9.94 | 6.83 | 8 | 10.7 | 12.1 | 13.3 | 14.3 |
| natural gas | 5.17 | 6.28 | 6.64 | 5.5 | 6.9 | 7.6 | 8 | 8.4 |
| hard coal | 2.18 | 2.66 | 1.97 | 2.2 | 2.6 | 2.7 | 2.7 | 2.7 |

Source: ARE S.A. based on BŚ, MFW, EC and IEA's 2017 "New Policies" scenario



crude oil

natural gas

hard coal

Figure 1. Fuel price forecasts for EU imports [EUR'2016/GJ]

## Forecast of CO2 emission allowance prices in the EU ETS

Forecasts of CO2 emission allowance prices (EUA, European Union Allowance) in the European Union Emissions Trading System (EU ETS) according to forecasts of the International Energy Agency (WEO2017, "New Policies" scenario) were adopted for further analyses.

**The assumed prices of the emission allowances until 2030 are directionally in line with the EC guidelines on the use of indicators for integrated energy and climate plans[[2]](#footnote-2). Despite the significant increase in CO2 allowance prices in 2018, the EC did not indicate updated (higher) EUA price forecasts in 2019 for use in analytical work for national plans.**

It was assumed that the EUA price in the EU ETS system will gradually increase to 40 EUR'2016/tCO2 in 2040.

Table 2. Forecast price of CO2 emission allowances in the EU ETS [EUR'2016/tCO2]

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **2005** | **2010** | **2015** | **2020** | **2025** | **2030** | **2035** | **2040** |
| price for 1 EUA allowance | 0 | 12 | 8 | 17 | 21 | 30 | 35 | 40 |

Source: Own study by ARE S.A. based on IEA, EC, Thomson Reuters, KfW Bankengruppe

## Forecast of technical and economic parameters of technologies used in the energy sector

The table below summarizes the technical and economic parameters of the new generation and transmission units. These values were adopted in the process of forecasting the structure of production and electrical capacity.

Table 3. Technical and economic parameters of generation and transmission technologies

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **fuel / technology** | **start-up period** | **capital expenditure OVN** | **costs** | | **net electric/ total efficiency** | **service life** | **CO2 emission indicator** |
| **permanent** | **variable** |
| **€K/MWnet** | **€K/MWnet** | **€/MWhnet** | **%** | **years** | **kg/GJ** |
| 1.1. lignite – PL | 2016–2040 | 1,800 | 48 | 3.4 | 44 | 40 | 110 |
| 1.2. lignite – PL+CCS | 2030–2040 | 3,250 | 72 | 8.6\* | 38 | 40 | 14 |
| 1.3. lignite – FBC | 2020–2040 | 2,050 | 50 | 3.4 | 40 | 40 | 106 |
| 2.1. hard coal – PC | 2016–2040 | 1,650 | 44 | 3.2 | 46 | 40 | 94 |
| 2.2. hard coal – IGCC | 2025–2040 | 2,250 | 58 | 5.0 | 48 | 40 | 12 |
| 2.3. hard coal – IGCC+CCS | 2030–2040 | 3,250 | 78 | 7.2\* | 40 | 40 | 12 |
| 2.4. hard coal – CHP | 2016–2040 | 2,250 | 48 | 3.2 | 30/80 | 40 | 94 |
| 2.5. hard coal – CHP+CCS | 2030–2040 | 3,500 | 76 | 10\* | 22/75 | 40 | 12 |
| 3.1. natural gas – GTCC | 2016–2040 | 750 | 18 | 1.8 | 58–62 | 30 | 56 |
| 3.2. natural gas – GTCC+CCS | 2030–2040 | 1,350 | 38 | 4.0\* | 50–52 | 30 | 6 |
| 3.3. natural gas – TG | 2025–2040 | 500 | 16 | 1.4 | 40 | 30 | 56 |
| 3.4. micro CHP gas | 2016–2040 | 2,350 | 97 | – | 20/90 | 25 | 56 |
| 4.1. nuclear – PWR | 2030–2040 | 4,500 | 85 | 0.8 | 36 | 60 | 0 |
| 5.1. onshore wind | 2016–2020 | 1,350 | 50 | – | – | 25 | 0 |
| 5.2. onshore wind | 2021–2040 | 1,350↓1,250 | 50 | – | – | 25 | 0 |
| 5.3. offshore wind | 2020–2030 | 2,450↓2,250 | 90 | – | – | 25 | 0 |
| 5.4. offshore wind | 2031–2040 | 2,250↓2,075 | 90 | – | – | 25 | 0 |
| 5.5. large hydropower | 2020–2040 | 2,500 | 35 | – | – | 60 | 0 |
| 5.5. small hydropower | 2016–2040 | 2,000 | 75 | – | – | 60 | 0 |
| 5.6. geothermal | 2020–2040 | 7,000 | 160 | – | 0.12 | 30 | 0 |
| 5.7. photovoltaic cells | 2016–2020 | 1,100↓800 | 16 | – | – | 25 | 0 |
| 5.8. photovoltaic cells | 2021–2040 | 800↓600 | 16 | – | – | 25 | 0 |
| 5.9. roof photovoltaic cells | 2016–2020 | 1,250↓1,150 | 20 | – | – | 25 | 0 |
| 5.10. roof photovoltaic cells | 2021–2040 | 1,100↓800 | 20 | – | – | 25 | 0 |
| 5.11. agricultural biogas – CHP | 2016–2040 | 3,250↓2,750 | 220 | – | 36/85 | 25 | 0 |
| 5.12. biogas from sewage treatment plants – CHP | 2016–2040 | 3,500 | 135 | – | 34/85 | 25 | 0 |
| 5.13. landfill biogas – CHP | 2016–2040 | 1,800 | 80 | – | 40/85 | 25 | 0 |
| 5.14. solid biomass – CHP | 2021–2040 | 2,950↓2,750 | 120 | – | 30/80 | 30 | 0 |
| 5.15. district heating boiler – coal | 2016–2040 | 350 | 1 | 1.4 | 0.9 | 30 | 94 |
| 5.16. district heating boiler – natural gas | 2016–2040 | 150 | 1 | 0.4 | 0.96 | 30 | 56 |
| 5.18. district heating boiler – fuel oil | 2016–2040 | 200 | 1 | 0.5 | 0.95 | 30 | 74 |
| 5.19. district heating boiler – biomass | 2016–2040 | 500 | 1 | 1.4 | 0.9 | 30 | 0 |
| 5.20. HV electr. transmission grid | 2016–2040 | 190 |  |  |  |  |  |
| 5.21. MV electr. distribution network | 2016–2040 | 250 |  |  |  |  |  |
| 5.22. LV electr. distribution network | 2016–2040 | 500 |  |  |  |  |  |

*\*including transport and storage of CO2*

The following abbreviations are used in the table:

CHP – cogeneration, combined generation of heat and power

PC – condensing power plants with pulverised coal boilers

PL – condensing power plants with pulverised lignite boilers

CCS – carbon capture and storage

GTCC – gas turbine combined cycle power plants

IGCC – integrated gasification combined cycle power plants

FBC – fluidised bed combustion power plants

PWR – pressurised water reactor

MV – medium voltage

EHV – extra–high voltage

HV – high voltage

↓ – means a probable decrease of costs in the direction of the number on the right side of the arrow

Source: ARE S.A. based on:

World Energy Outlook, International Energy Agency, Paris 2016;

WEIO 2014-Power Generation Investment Assumptions, International Energy Agency, Paris 2014;

The Power to Change: Solar and Wind Cost Reduction Potential to 2025", International Renewable Energy Agency, Bonn 2016;

Energy and Environmental Economics – "Recommendations for WECC’s 10- and 20-Year Studies", San Francisco 2014;

World Energy Perspective Cost of Energy Technologies, World Energy Council, Project Partner: Bloomberg New Energy Finance, 2013;

Lazard's Levelized Cost of Energy Analysis – Version 9.0, Lazard, New York 2015;

Scenarios for the Dutch electricity supply system, Frontier Economics, London 2015;

Energy Technology Reference Indicator forecasts for 2010–2050, European Commission JRC Institute for Energy and Transport, Brussels 2014;

Projected Cost of Generating Electricity 2015 Edition, International Energy Agency, Nuclear Energy Agency, Organization for Economic Co-operation and Deployment, Paris, 2015

Cost and Performance Characteristics of New Generating Technologies, Annual Energy Outlook 2016, U.S. Energy Information Administration, Washington 2016.

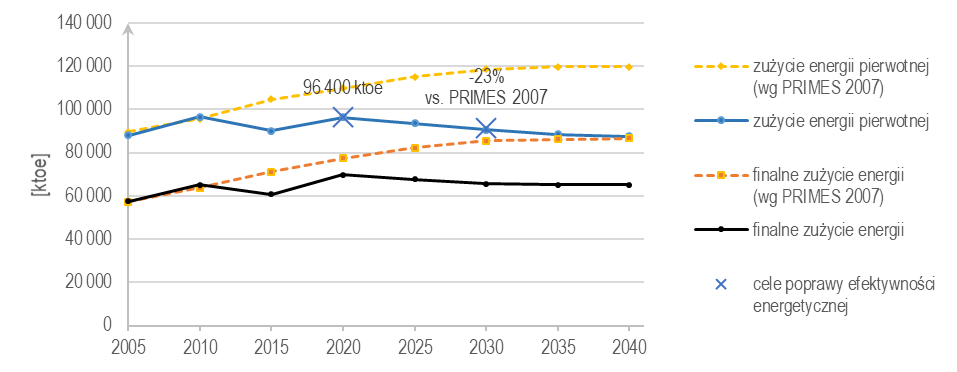
## Forecast of primary energy consumption and final energy consumption

The table and figure below summarize the historical and projected primary and final energy consumption in the country. The forecast indicates the achievement of the 2020 target, i.e. reaching the value of the demand for primary energy in the country at the level of 96.4 Mtoe. It is then projected to fall to 90.7 Mtoe in 2030, which is close to the target indicated in PEP2040 – i.e. a 23% reduction in primary energy consumption compared to forecasts for that year according to PRIMES 2007. Final energy consumption follows a similar pattern as primary energy.

Table 4. Total primary and final energy consumption forecast [ktoe]

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **2005** | **2010** | **2015** | **2020** | **2025** | **2030** | **2035** | **2040** |
| primary energy consumption | 87,952 | 96,589 | 90,104 | 96,423 | 93,509 | 90,682 | 88,613 | 87,647 |
| primary energy consumption (acc. to PRIMES 2007) | 89,581 | 95,611 | 104,804 | 109,829 | 115,057 | 118,583 | 119,774 | 119,826 |
| final energy consumption | 57,472 | 65,230 | 60,775 | 69,720 | 67,682 | 65,509 | 65,229 | 65,112 |
| final energy consumption (acc. to PRIMES 2007) | 57,169 | 63,712 | 71,246 | 77,448 | 82,174 | 85,467 | 86,117 | 86,767 |

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



energy efficiency improvement targets

final energy consumption

final energy consumption

(acc. to PRIMES 2007)

primary energy consumption

(acc. to PRIMES 2007)

primary energy consumption

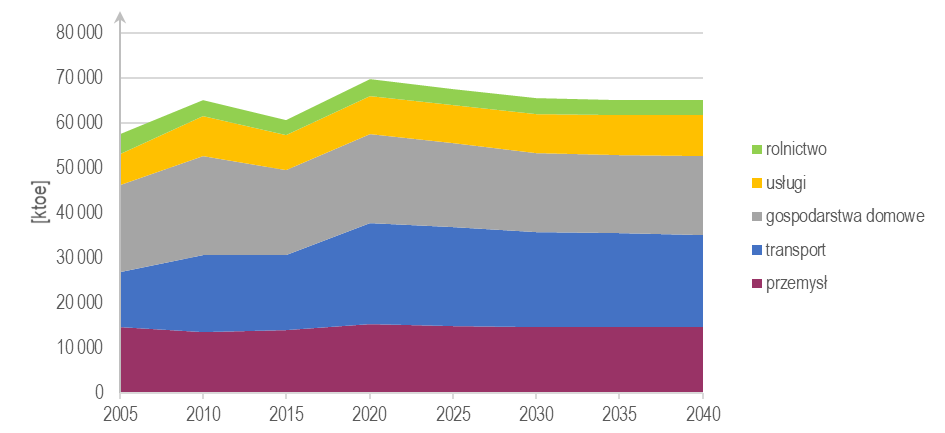
Figure 2. Total primary and final energy consumption forecast [ktoe]

It is worth noting how **final energy consumption** will be distributed **by economic sector**. The biggest differences can be seen in the period 2015–2020 and relate to transport. After 2020, energy use is projected to decrease in all sectors, except in the services sector where there is a slight increase. A key role in reducing final energy consumption in transport is the popularisation of electromobility.

Table 5. Final energy consumption forecast by sector [ktoe]

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **2005** | **2010** | **2015** | **2020** | **2025** | **2030** | **2035** | **2040** |
| industry | 14,616 | 13,498 | 14,096 | 15,316 | 14,902 | 14,763 | 14,664 | 14,596 |
| transportation | 12,221 | 17,187 | 16,559 | 22,546 | 22,075 | 21,049 | 20,827 | 20,492 |
| *including: passenger* | *N/A* | *N/A* | *8,985* | *10,118* | *9,434* | *8,598* | *8,745* | *8,957* |
| *cargo* | *N/A* | *N/A* | *7,494* | *12,346* | *12,557* | *12,364* | *11,995* | *11,449* |
| *special vehicles* | *N/A* | *N/A* | *79* | *82* | *84* | *86* | *87* | *87* |
| households | 19,467 | 21,981 | 18,948 | 19,772 | 18,506 | 17,513 | 17,505 | 17,657 |
| services | 6,730 | 8,833 | 7,842 | 8,343 | 8,586 | 8,700 | 8,853 | 9,079 |
| agriculture | 4,438 | 3,730 | 3,330 | 3,743 | 3,613 | 3,485 | 3,379 | 3,287 |
| **TOTAL** | **57,472** | **65,230** | **60,775** | **69,720** | **67,682** | **65,509** | **65,229** | **65,112** |

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



agriculture

services

households

transportation

industry

Figure 3. Forecast of final energy consumption by sector (without non–energy use)

Decomposition of **final energy consumption[[3]](#footnote-3) by fuel and carriers** also provides important information. Gradual changes are taking place in the fuel structure of final energy consumption. After 2020, there is an increase mainly in electricity consumption, influenced by economic growth and electrification of transport. The share of renewable energy sources is also growing in the balance – an increase in solid biomass, earth and solar energy use (solar collectors, heat pumps, geothermal sources). The decline in biofuels use after 2025 results from the popularisation of electromobility.

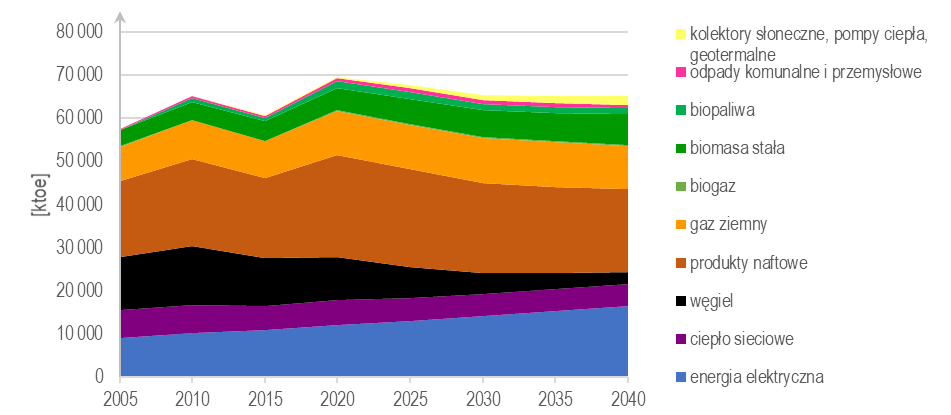
PEP2040 assumes popularisation of district heating. The forecasts do not show an increase in final energy consumption in this area due to improved energy efficiency of energy production, as well as a decrease in specific heat use by entities due to thermal modernisation and stringent efficiency standards in new construction.

In the forecasts of final energy consumption, a decrease in demand for hard coal is mainly related to the gradual process of modernisation of production facilities (in the industrial sector), as well as transition to fuels and carriers such as gas, electricity or RES. Next, the process of replacing old, inefficient batch–charged boilers in households will also translate into the decrease in coal consumption. The forecast assumes that all new boilers meet the requirements of carbon intensity class V.

Table 6. Final energy consumption forecast by fuels and carriers [ktoe]

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

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



solar collectors, heat pumps, geothermal

municipal and industrial waste

biofuels

solid biomass

biogas

natural gas

petroleum products

coal

district heating

electricity

Figure 4. Final energy consumption forecast by fuels and carriers [ktoe]

### Final energy savings

Below you will find detailed information on the methods and measures used in Poland to implement Art. 7 of the Energy Efficiency Directive 2012/27/EU[[4]](#footnote-4) (EED).

#### Calculation of the amount of required energy savings to be achieved over the entire period from 1 January 2021 to 31 December 2030.

Guidance on how to calculate the total amount of new final energy savings to be achieved under the 2021–2030 obligation and the specification of the statistical datasets that can be used is provided in the document titled "Commission Recommendation on transposing the energy saving obligations under the Energy Efficiency Directive"[[5]](#footnote-5).

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

Table 7. Final energy consumption according to Eurostat data 2016–2018 [ktoe]

| **item** | **category (NRG\_BAL\_C)** | **No.** | **2016** | **2017** | **2018**  **(estimated data)** | **average** |
| --- | --- | --- | --- | --- | --- | --- |
| FEC2020–2030 | Final energy consumption [ktoe] | 1 | 66,601 | 70,923 | (71,700) | **69,741** |
| FC\_TRA\_E | Final energy consumption – transport [ktoe] | 2 | 18,557 | 21,431 | (22,444) | **20,811** |
| Final energy consumption (after excluding energy consumed in transport from the calculation) [ktoe] | | 3=1-2 | 48,044 | 49,492 | (49,256) | **48,930** |

Source: Own study based on Eurostat

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

The total final energy consumption savings to be achieved through the energy efficiency obligation scheme or through alternative policy measures shall, in accordance with Art. 7 Sec. 1(b) of Directive 2012/27/EU, be equivalent to at least new savings in each year from 1 January 2021 until 31 December 2030 of **0.8% of annual final energy consumption averaged over the most recent three years before 1 January 2019 (average of 69,741 ktoe)**.

In addition, in accordance with the concept of duration as set out in Appendix V Item 2(i) of Directive 2012/27/EU, each individual measure to increase energy savings is considered to contribute to achieving energy savings not only in the year of its implementation but also in subsequent years until 2030. Therefore, the required amount of savings can be "accumulated" from year to year. The amount of energy savings to be achieved under the obligation covering the period 2021–2030 has been calculated in accordance with Chapter 2.1 of the above recommendations.

The amount of final energy savings to be achieved in 2021 through the implementation of the provisions of Art. 7 is  
558 ktoe (69,741 x 0.8% x 1 year). In 2022, the amount of energy savings is (69,741 x 0.8% x 2 years) cumulative 1,116 ktoe (including 558 ktoe credited from the previous year). Calculations were performed for each subsequent year until 2030, when the total amount of final energy savings required is 5,580 ktoe (69,741 x 0.8% x 10 years). **On the other hand, the total amount of final energy savings, understood as the amount of final energy savings accumulated from year to year, to be achieved in total between 2021 and 2030 is 30,690 ktoe**. The mechanism is shown in the table below.

Table 8. Final energy savings to be achieved in 2021–2030 – annual and cumulative (based on the provisions of the EED) [ktoe]

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

**Data used for the calculation of final energy consumption and sources of that data**

Final energy consumption, the basis from which the energy savings were calculated, was taken from the aforementioned category (FEC2020–2030) in the Eurostat dataset. With respect to the statistical data used for the calculation of the required amount of final energy savings, Chapter 2.2.1 of the Commission Recommendation states that all elements that are required under the first paragraph of Art. 7 Sec. 1(b) of Directive 2012/27/EU are included in the corresponding Eurostat category, i.e. "Final Energy Consumption – Europe 2020–2030" (code FEC2020–2030). This specific category in the Eurostat statistical dataset was established in relation to the Member States' contribution to energy efficiency and energy saving obligation. Eurostat has revised the energy balance on the basis of the international recommendations on energy statistics published by the Statistical Commission.

#### Quantities of required energy savings using the possibilities provided for in Art. 7 Sec. 2 of Directive 2012/27/EU

In accordance with Art. 7 Sec. 2 of Directive 2012/27/EU, Member States may use the option of calculating the required amount of energy savings in one or more of the following ways:

1. using an annual savings rate for energy sales to end–users or for final energy consumption, averaged over the most recent three years before 1 January 2019;
2. **excluding energy consumed in transport from the basis of calculation, in part or in whole,**;
3. using any of the options set out in Art. 7 Sec. 4 of Directive 2012/27/EU.

At the same time (in accordance with Art. 7 Sec. 3 of Directive 2012/27/EU), where Member States make use of the above option, they shall determine:

1. its own annual energy savings rate; and
2. own calculation baseline and the amount of transport energy excluded from the calculation [ktoe].

**Poland will make use of the possibility provided for in Art. 7 Sec. 2(b) of the Directive to exclude** **all final energy consumed in transport from the basis of calculation** carried out in accordance with the first paragraph of Art. 7 Sec. 1(b) of Directive 2012/27/EU.

**Therefore, the average annual final energy consumption in transport was calculated on the basis of the Eurostat statistical dataset**. Calculations were based on statistics from three years (2016, 2017, and 2018) prior to 1 January 2019 [in ktoe], which are indicated in Table 39 at the beginning of this subsection.

Table 9. Energy savings excluding energy consumption in transport

| **category (NRG\_BAL\_C)** | **2016** | **2017** | **2018**  **(estimated data)** | **average** | **annual energy savings** | **indicator** |
| --- | --- | --- | --- | --- | --- | --- |
| Final energy consumption [ktoe] | 66,601 | 70,923 | (71,700) | **69,741** | **558** | **0.8%** |
| Final energy consumption – transport [ktoe] | 18,557 | 21,431 | (22,444) | **20,811** | **N/A** | **N/A** |
| **Final energy consumption (excluding energy consumed in transport) [ktoe]** | **48,044** | **49,492** | **(49,256)** | **48,930** | **563** | **1.15%** |

Table 10. Summary of savings and indicator for determining final energy savings

|  |  |  |
| --- | --- | --- |
| **Final energy savings after deductions** | 21,530 ktoe | These are total final energy savings calculated using an indicator of 0.8% after excluding energy consumption in transport (48,930 ktoe x 0.8%) |
| **Additional savings to be achieved** | 9,160 ktoe | These are the energy savings missing to meet the required minimum level of total energy savings (30,690 ktoe – 21,530 ktoe) |
| **Required own savings indicator with transport exclusion** | 1.15% | Value of the required own indicator that has to be used if energy consumption in transport is excluded from the calculation basis (48,930 x 1.15% = 563) |

The annual savings determined using our own indicator is 563 ktoe, which exceeds the minimum required level i.e. 558 ktoe (see Table 10).

For the second mandatory period under Art. 7 Sec. 1(b) of Directive 2012/27/EU, the options referred to in Art. 7 Sec. 4(b)-(g) of Directive 2012/27/EU are not provided for. Therefore, Sec. 2(d) and (e) of Appendix III to Directive 2012/27/EU are not applicable in this case.

## Forecast of domestic energy production by fuel type

Table 10. shows the volume of domestic supply of fuels and energy carriers. The conclusions of the results are summarised below.

* **Hard coal** mining (excluding coking coal) is moderately reduced between 2015 and 2030, from 32.1 Mtoe to 22.6 Mtoe (in natural units it is respectively: 59.6 million t and 41.6 million t). In the period 2030–2040, the projected level of hard coal extraction is reduced very significantly to 16.2 Mtoe (29.8 million t). The reduction in coal production in this case is associated with a decline in demand across all sectors of the national economy. After 2030, the process of permanent decommissioning of worn-out coal-fired generation units from the national power system is expected to accelerate. The construction of new coal-fired units (in addition to those for which an investment decision has already been taken) will be difficult in conditions of rising CO2 emission allowance prices, continuously tightening environmental requirements and the directions of the EU climate and energy policy, including work on taxonomy. Coal technologies equipped with CCS systems can be competitive, but under conditions of high CO2 emission allowance prices exceeding 50 EUR/t.

The decrease in demand for coal in the industrial sector is mainly due to the process of modernisation of production processes. In households and services – as part of the fight against smog – there will be a gradual replacement of inefficient batch–charged boilers with boilers that meet the highest environmental standards (with high energy conversion efficiency) and replacement of coal technologies with more environmentally friendly ones (district heating, RES, natural gas).

* **Coking coal** extraction will decline slightly from approx. 10 Mtoe to 8.5 Mtoe.
* **Lignite** production will decline after 2030. The forecasts assume launch of the Złoczew open pit, whose resources are utilised by the upgraded units of the Bełchatów Power Plant. For economic reasons, no new lignite-fired power generation units are being built, apart from the Turów unit currently under construction (450 MW).
* **Crude oil** extraction will remain at a stable (relatively small) level (of about 1 Mtoe), as will domestic **natural gas** extraction (about 3.6 Mtoe).
* An increase in domestic production of **biofuels** (mainly HVO/COHVO of the 1st generation) is expected by 2025 due to growing demand in the transport sector and the properties of these substances which enable them to replace conventional fuels without significant technical limitations. However, due to the popularisation of electromobility, the use of biofuels may decline after 2025.
* Between 2015 and 2040, **solid biomass** harvesting is projected to increase by 62% – a fairly significant increase, making significant use of domestic potential. Demand for biomass will grow in all sectors.   
  As the price of CO2 emission allowances rises, the profitability of using biomass in the power and heating sector will increase. In households and services, greater use of biomass will involve replacing old coal-fired stoves with modern pellet-fired ones.

Table 11. Forecast of domestic production by fuel type [ktoe]

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **2005** | **2010** | **2015** | **2020** | **2025** | **2030** | **2035** | **2040** |
| hard coal | 45,736 | 35,302 | 32,136 | 29,367 | 27,433 | 22,615 | 18,831 | 16,210 |
| coking coal | 9,948 | 8,216 | 9,155 | 9,339 | 8,809 | 8,668 | 8,588 | 8,564 |
| coke | 5,721 | 6,701 | 6,666 | 7,160 | 7,174 | 7,192 | 7,241 | 7,323 |
| lignite | 12,736 | 11,559 | 12,299 | 10,637 | 11,110 | 11,095 | 5,971 | 3,761 |
| crude oil | 840 | 681 | 922 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 |
| natural gas | 3,884 | 3,693 | 3,683 | 3,595 | 3,627 | 3,653 | 3,675 | 3,694 |
| nuclear fuel | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| biofuels | 117 | 446 | 936 | 1,100 | 1,133 | 1,042 | 1,006 | 972 |
| solid biomass | 4,166 | 5,866 | 6,268 | 7,356 | 8,385 | 9,753 | 9,986 | 10,193 |

Source: Own study by ARE S.A.

## Forecast of gross inland consumption of fuels and energy

Forecast of gross domestic consumption of individual fuels and energy[[6]](#footnote-6) indicates changes in demand for almost all fuels and energy carriers. The most relevant findings in this regard are presented below:

* National **electricity** consumption will increase by 22% between 2015 and 2030 and 37% between 2015 and 2040. The average annual growth rate of this category is around 1.5% over the entire forecast period under consideration. Electricity consumption is increasing in all sectors. Services, as the fastest growing sector of the economy, will have the highest rate of growth in electricity consumption as the use of equipment, including air conditioning, will increase. Consumption in households will grow moderately – the increasing level of prosperity, the growing number of dwellings, more appliances and the intensity of their use are neutralised by the decreasing electro-intensity of these devices. The increase in electricity consumption in industry will be mainly related to the growing production of industrial products and the upgrading and mechanisation of production plants. The increase in demand by transport will be connected with an improvement in the quality of passenger rail services and the growing popularity of this branch of transport, and in road transport with the development of electromobility.
* Domestic consumption of **hard coal and lignite** is expected to decline as a result of the implementation of the existing energy and climate policy and reduction of coal consumption in households. The decline in coal consumption in the electricity and heating sector accelerates significantly over the period 2030–2040.
* **Crude oil and petroleum product** consumption is projected to decline slightly **between 2020 and 2040**. Economic growth is the driving force for maintaining demand in this sector, but efficiency improvements resulting from technological progress, measures taken to improve the organisation of transport services and the development of transport infrastructure (motorway and expressway networks) are an inhibiting factor.
* The increase in the use of **natural gas** will result from an increase in the use of this fuel in electricity and heat generation, also as regulating and reserve capacity, and to improve air quality, as a fuel with significantly lower carbon intensity than coal.
* Further gradual increase in demand for **renewable energy carriers** such as biomass, biogas, renewable municipal and industrial waste is expected. Only biofuel consumption will see a decline after 2025.

Table 12. Gross domestic fuel and energy consumption forecast [ktoe]

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **2005** | **2010** | **2015** | **2020** | **2025** | **2030** | **2035** | **2040** |
| electricity | 12,532 | 13,440 | 14,154 | 15,258 | 16,156 | 17,297 | 18,289 | 19,412 |
| district heating | 8,032 | 8,021 | 6,721 | 6,721 | 6,626 | 6,204 | 6,153 | 6,204 |
| hard coal | 37,669 | 39,241 | 31,205 | 28,707 | 24,284 | 19,436 | 15,731 | 13,181 |
| coking coal | 7,884 | 8,694 | 9,488 | 9,396 | 8,957 | 8,891 | 8,874 | 8,906 |
| coke | 2,314 | 2,154 | 2,266 | 2,563 | 2,415 | 2,299 | 2,235 | 2,219 |
| lignite | 12,726 | 11,576 | 12,283 | 10,651 | 11,124 | 11,110 | 5,979 | 3,766 |
| crude oil | 18,017 | 22,633 | 25,930 | 27,247 | 27,227 | 26,784 | 26,861 | 26,754 |
| petroleum products | 22,338 | 26,856 | 25,338 | 31,280 | 31,225 | 31,060 | 30,817 | 30,510 |
| natural gas | 12,235 | 12,805 | 13,776 | 16,547 | 17,290 | 18,121 | 19,677 | 20,662 |
| coke-oven gas | 1,480 | 1,744 | 1,704 | 1,676 | 1,651 | 1,641 | 1,642 | 1,651 |
| blast-furnace gas | 885 | 526 | 632 | 576 | 532 | 489 | 454 | 428 |
| other gaseous fuels | 161 | 149 | 162 | 88 | 76 | 76 | 75 | 75 |
| solid biomass | 4,166 | 5,866 | 6,774 | 7,896 | 9,023 | 10,522 | 10,778 | 11,004 |
| biogas | 54 | 115 | 229 | 284 | 318 | 352 | 388 | 425 |
| biofuels | 54 | 868 | 782 | 1,497 | 1,542 | 1,418 | 1,369 | 1,322 |
| nuclear fuel | 0 | 0 | 0 | 0 | 0 | 0 | 4,624 | 6,936 |
| municipal and industrial waste | 157 | 400 | 564 | 1,047 | 1,251 | 1,329 | 1,417 | 1,499 |

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

## Forecast of net imports by fuel

The forecast import–export balance for key fuels and energy carriers is summarised below.

* Although there has been a trend towards an increasing share of imported **electricity** since 2014 (due to increasing import–export capacity and intensive subsidies for non–dispatchable RES in neighbouring countries), this trend is expected to reverse in the 2020s when energy prices in European markets rise. This will result from the completion of the decommissioning of nuclear power plants in Germany (2023) and the withdrawal and replacement of conventional generation capacity in the EU providing a stable and reliable energy supply. Given the high uncertainty of energy prices, Poland's lack of responsibility for the availability of energy from other countries, and the expected increase in the competitiveness of domestically generated electricity, a zero balance of imports and exports of electricity was assumed in the further forecast perspective.
* It was estimated that on a small scale Poland will be an exporter of **hard coal** and importer of **coking coal**. The status of a **coke** exporter will be maintained.
* The modelling shows a steady level of **crude oil** imports and an increase in **natural gas** imports in the future. A negative consequence of increasing the share of gas in the national energy consumption structure is deterioration of the energy self-sufficiency index, nevertheless the use of gas is important for the operation of the power system, for the economy and for reducing CO2 and pollutant emissions.
* As a result of the implementation of nuclear power into the national power system, it will be necessary to import **nuclear fuel**.
* Net imports of **biofuels and solid biomass** are projected to increase as a result of the economic conditions for obtaining the raw materials needed to meet the target for the use of energy from renewable sources.

Table 13. Net import-export balance [ktoe]

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **2005** | **2010** | **2015** | **2020** | **2025** | **2030** | **2035** | **2040** |
| electricity | -962 | -116 | -29 | 65 | 0 | 0 | 0 | 0 |
| hard coal | -8,161 | 489 | -1,588 | -660 | -3,148 | -3,179 | -3,101 | -3,028 |
| coking coal | -1,801 | 944 | 275 | 57 | 148 | 223 | 286 | 342 |
| coke | -3,068 | -4,227 | -4,333 | -4,597 | -4,759 | -4,893 | -5,006 | -5,105 |
| lignite | -2 | -19 | 16 | 14 | 15 | 15 | 8 | 5 |
| crude oil | 17,751 | 22,484 | 26,311 | 26,533 | 26,515 | 26,074 | 26,153 | 26,048 |
| natural gas | 8,531 | 8,874 | 9,947 | 12,952 | 13,663 | 14,468 | 16,002 | 16,968 |
| nuclear fuel | 0 | 0 | 0 | 0 | 0 | 0 | 4,624 | 6,936 |
| biofuels | -65 | 427 | -144 | 397 | 409 | 376 | 363 | 350 |
| solid biomass | 0 | 0 | 506 | 540 | 638 | 769 | 792 | 811 |

"-" means export, "+" means import

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

## Forecast of gross final energy consumption from renewable sources

The national and sectoral trajectories presented in this subsection[[7]](#footnote-7) of RES share assume the implementation of tasks indicated in PEP2040 e.g. implementation of offshore wind energy. In addition, the trends of decreasing technological inputs were implemented, although the safety conditions of the power grid operation were taken into account.

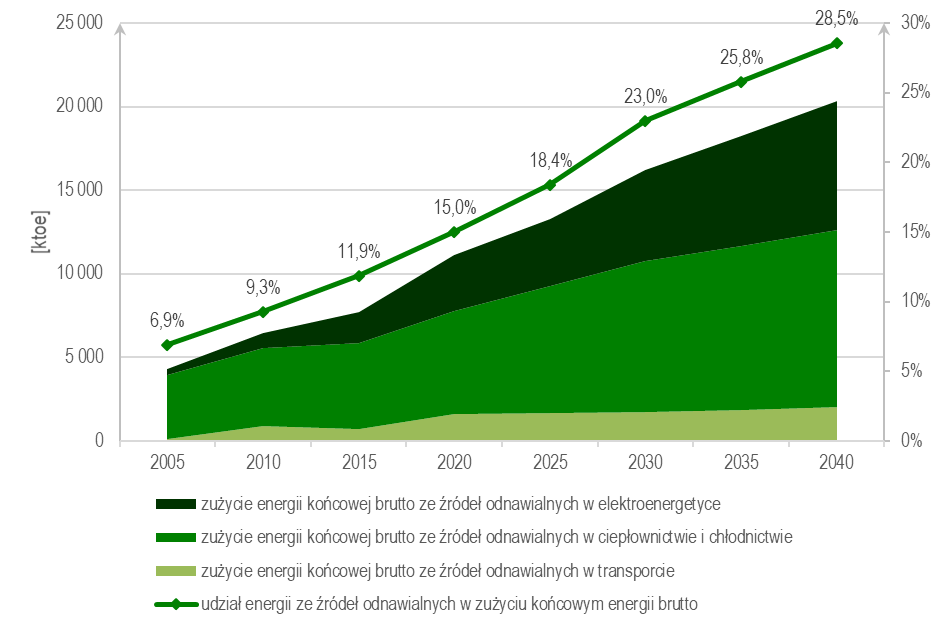
It has been assumed that the basic support mechanisms for electricity generation from renewable energy sources, which will continue to operate in the period under consideration, will be the certificates of origin system (gradually phased out) and the auction system (expected to be in place by the end of 2035 for all RES technologies listed in the Act with the exception of offshore wind farms, for which support is expected to continue beyond the outlook of PEP2040).

It has been assumed that the technologies preferred in the RES energy supply auctions announced in the future will be mainly the sources characterised by stable operation and those which may be a valuable supplement to the currently installed generation units. An assumption of maximum construction rate for each technology was made and the amount of installed capacity achieved for each technology is the result of the cost optimisation process.

Cost optimisation, as well as the analysis of development opportunities based on current trends and in the absence of extraordinary measures going beyond the current legal framework, indicates a **feasible level of RES share in gross final energy consumption in 2020 – 15%, in 2030 –23%, and in 2040 – 28.5%**. It should be noted that RES are becoming competitive under the conditions of rising CO2 emission allowance prices and a significant reduction in technology costs.

The sector in which the share of RES consumption is growing the fastest is the power sector, where the main support stream is directed to. The share of RES increases in this sector from 22.1% in 2020 to 31.8% in 2030 and 39.7% in 2040. There is an increase in the RES share in the heating and cooling sector, in line with the RES Directive, by 1.1 percentage points on average per year, but this is a big challenge for the sector, both due to investments and organisational and technical difficulties. The most relevant information regarding RES utilisation is presented in the figure below, detailed results of the analysis are presented in the following four tables.

The increased use of RES in transport also implies the need for significant changes in the sector. There are also technological and organisational difficulties, in particular, limitations in blending or limits resulting from EU regulations on the use of biofuels from food raw materials.

*Figure 5. Forecast of gross final energy consumption from RES in the three sub-sectors [ktoe] and the share of RES in gross final energy consumption*

gross final energy consumption from RES in electricity generation

gross final energy consumption from RES in heating and cooling

gross final energy consumption from RES in transport

share of energy from RES in gross final energy consumption

Table 14. Forecast of total and sectoral gross final consumption of energy from renewable sources [ktoe] and share of RES consumption – total and by sector [%]

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **[ktoe]** | **2005** | **2010** | **2015** | **2020** | **2025** | **2030** | **2035** | **2040** |
| ***gross final energy consumption (RES–OS denominator)*** | **61,573.8** | **69,156.4** | **64,596.0** | **73,512** | **71,508** | **69,345** | **68,906** | **68,836** |
| gross final energy consumption from RES | 4,245.4 | 6,399.3 | 7,664.4 | 11,027 | 13,143 | 15,937 | 17,761 | 19,637 |
| RES consumption in electricity generation | 331.7 | 890.3 | 1,894.3 | 3,369 | 4,004 | 5,493 | 6,581 | 7,715 |
| RES consumption in heating and cooling | 3,867.6 | 4,641.6 | 5,116.7 | 6,163 | 7,604 | 9,027 | 9,812 | 10,601 |
| RES consumption in transport | 95.2 | 916.2 | 721.2 | 1,613 | 1,677 | 1,708 | 1,856 | 2,024 |
|  |  |  |  |  |  |  |  |  |
| **[%]** | **2005** | **2010** | **2015** | **2020** | **2025** | **2030** | **2035** | **2040** |
| **share of energy from RES in gross final energy consumption** | **6.9%** | **9.3%** | **11.9%** | **15.0%** | **18.4%** | **23.0%** | **25.8%** | **28.5%** |
| share of energy from RES in the power sector | 3.1% | 7.0% | 13.4% | 22.1% | 24.8% | 31.8% | 36.0% | 39.7% |
| share of RES energy in heating and cooling | 10.2% | 11.7% | 14.5% | 17.4% | 22.7% | 28.4% | 31.5% | 34.4% |
| share of RES energy in transport (with multipliers) | 1.6% | 6.6% | 6.4% | 10.0% | 11.2% | 14.0% | 17.7% | 22.0% |

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

Table 15. Forecast of gross final energy generation from renewable sources **in the power sector** by technology [ktoe] and share of electricity consumption from RES by technology [%]

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **electricity production from RES by technology [ktoe]** | **2005** | **2010** | **2015** | **2020** | **2025** | **2030** | **2035** | **2040** |
| ***gross final consumption of electricity (RES–E denominator)*** | **12,396.7** | **13,390.8** | **14,102.1** | **15,258** | **16,156** | **17,297** | **18,289** | **19,412** |
| hydropower plants\* | 184.3 | 202.0 | 202.4 | 206 | 246 | 254 | 262 | 270 |
| wind power plants\* | 17.5 | 146.2 | 833.0 | 2,020 | 2,278 | 3,290 | 3,940 | 4,746 |
| photovoltaic power plants | 0.0 | 0.0 | 4.9 | 173 | 390 | 584 | 929 | 1,274 |
| biomass power plants | 120.4 | 507.8 | 776.2 | 822 | 835 | 1,001 | 984 | 887 |
| biogas power plants | 9.6 | 34.3 | 77.9 | 132 | 230 | 334 | 431 | 498 |
| renewable municipal waste | 0.0 | 0.0 | 0.0 | 17 | 25 | 30 | 35 | 40 |

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **share of technology in the consumption of energy from RES in the power sector [%]** | **2005** | **2010** | **2015** | **2020** | **2025** | **2030** | **2035** | **2040** |
| hydropower plants | 55.6% | 22.7% | 10.7% | 6.1% | 6.1% | 4.6% | 4.0% | 3.5% |
| wind power plants | 5.3% | 16.4% | 44.0% | 59.9% | 56.9% | 59.9% | 59.9% | 61.5% |
| photovoltaic power plants | 0.0% | 0.0% | 0.3% | 5.1% | 9.7% | 10.6% | 14.1% | 16.5% |
| biomass power plants | 36.3% | 57.0% | 41.0% | 24.4% | 20.8% | 18.2% | 15.0% | 11.5% |
| biogas power plants | 2.9% | 3.9% | 4.1% | 3.9% | 5.7% | 6.1% | 6.5% | 6.5% |
| renewable municipal waste | 0.0% | 0.0% | 0.0% | 0.5% | 0.6% | 0.5% | 0.5% | 0.5% |

\*standardised values

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

Table 16. Forecast of gross final energy consumption from renewable sources **in district heating and cooling** by source [ktoe] and share of different types of sources in the consumption of energy from renewable sources in district heating and cooling [%]

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **gross final energy consumption from renewable sources in heating and cooling by source [ktoe]** | **2005** | **2010** | **2015** | **2020** | **2025** | **2030** | **2035** | **2040** |
| ***gross final consumption of energy in heating and cooling (RES–H&C denominator)*** | **38,064.0** | **39,558.3** | **35,202.3** | **35,489** | **33,472** | **31,794** | **31,141** | **30,822** |
| geothermal energy | 11.4 | 13.4 | 21.7 | 31 | 45 | 59 | 75 | 109 |
| solar energy | 0.1 | 10.0 | 45.0 | 108 | 271 | **455** | 570 | 591 |
| solid biomass | 3,814.5 | 4,554.6 | 4,896.0 | 5,597 | 6,473 | 7,288 | 7,555 | 7,950 |
| biogas | 40.9 | 50.8 | 88.4 | 135 | 243 | 341 | 436 | 508 |
| heat pumps | 0.0 | 9.9 | 25.6 | 177 | 431 | 728 | 1,001 | 1,247 |
| renewable municipal waste | 0.7 | 2.9 | 39.9 | 115 | 140 | 157 | 176 | 197 |
|  |  |  |  |  |  |  |  |  |
| **share of technology in energy consumption from RES in district heating and cooling [%]** | **2005** | **2010** | **2015** | **2020** | **2025** | **2030** | **2035** | **2040** |
| geothermal energy | 0.3% | 0.3% | 0.4% | 0.5% | 0.6% | 0.7% | 0.8% | 1.0% |
| solar energy | 0.0% | 0.2% | 0.9% | 1.7% | 3.6% | 5.0% | 5.8% | 5.6% |
| solid biomass | 98.6% | 98.1% | 95.7% | 90.8% | 85.1% | 80.7% | 77.0% | 75.0% |
| biogas | 1.1% | 1.1% | 1.7% | 2.2% | 3.2% | 3.8% | 4.4% | 4.8% |
| heat pumps | 0.0% | 0.2% | 0.5% | 2.9% | 5.7% | 8.1% | 10.2% | 11.8% |
| renewable municipal waste | 0.0% | 0.1% | 0.8% | 1.9% | 1.8% | 1.7% | 1.8% | 1.9% |

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

Table 17. Projection of gross final energy consumption from RES in the transport sector by technology [ktoe] and share of technology in RES consumption in transport [%]

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **gross final energy consumption from RES in the transport sector by technology [ktoe]** | **2005** | **2010** | **2015** | **2020** | **2025** | **2030** | **2035** | **2040** |
| ***gross final consumption of energy in transport (RES–T denominator)*** | **10,178.7** | **14,951.0** | **14,488.0** | **20,295** | **19,804** | **18,884** | **18,673** | **18,356** |
| electricity | 49.1 | 48.8 | 67.8 | 118 | 142 | 291 | 488 | 703 |
| 1st generation biofuels/1st generation HVO/COHVO | 46.1 | 867.4 | 653.4 | 1,274 | 1,198 | 999 | 889 | 832 |
| 2nd generation biofuels or 2nd generation HVO/COHVO | 0.0 | 0.0 | 0.0 | 221 | 338 | 418 | 479 | 489 |
| electricity consumption for road transport qualified as RES | 0.3 | 0.34 | 0.48 | 13 | 53 | 150 | 295 | 473 |
| electricity consumption for rail transport qualified as RES | 43.7 | 43.30 | 61.06 | 96 | 82 | 132 | 182 | 218 |
| electricity consumption in pipeline transport classified as RES | 5.2 | 5.13 | 6.26 | 9 | 7 | 9 | 11 | 12 |
| total electricity consumption in transport | **343.0** | **287.0** | **267.2** | **355** | **627** | **1004** | **1356** | **1769** |
| including: for road transport purposes | 1.8 | 2.0 | 1.9 | 39 | 234 | 517 | 819 | 1190 |
| for rail transport purposes | 305.2 | 254.9 | 240.6 | 290 | 363 | 457 | 507 | 550 |
| in pipeline transport | 36.0 | 30.2 | 24.7 | 26 | 29 | 31 | 31 | 30 |

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **[%]** | **2005** | **2010** | **2015** | **2020** | **2025** | **2030** | **2035** | **2040** |
| share of electricity in the consumption of energy from RES in transport | 51.6% | 5.3% | 9.4% | 7.3% | 8.4% | 17.0% | 26.3% | 34.7% |
| share of biofuels in energy consumption from RES in transport | 48.4% | 94.7% | 90.6% | 92.7% | 91.6% | 83.0% | 73.7% | 65.3% |
| share of electricity for road transport | 0.5% | 0.7% | 0.7% | 11.0% | 37.3% | 51.4% | 60.4% | 67.3% |
| share of electricity for rail transport | 89.0% | 88.8% | 90.1% | 81.6% | 58.0% | 45.5% | 37.4% | 31.1% |
| share of electricity for other modes of transport | 10.5% | 10.5% | 9.2% | 7.4% | 4.7% | 3.1% | 2.3% | 1.7% |

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

## Forecasts of thermal energy generation and combined heat and power generation

The demand for district heat will grow, but due to the priority given to energy generation in cogeneration, the importance of heat plants will decline. The quoted forecast results are based on the assumption of greater intensification of actions for connecting new consumers to heating networks and on assumptions concerning actions for thermal modernisation of buildings.

Table 18. Forecast of heat production at power plants, CHP plants and heating plants [TJ]

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **2005** | **2010** | **2015** | **2020** | **2025** | **2030** | **2035** | **2040** |
| CHP plants | 219,883 | 205,851 | 186,626 | 207,729 | 213,015 | 205,980 | 213,620 | 212,328 |
| *including industrial waste heat* | *214* | *82* | *271* | *295* | *339* | *375* | *388* | *407* |
| heating plants | 116,409 | 129,980 | 94,767 | 82,955 | 62,828 | 53,635 | 43,070 | 46,404 |
| **TOTAL** | 336,292 | 335,831 | 281,393 | 290,684 | 275,842 | 259,615 | 256,690 | 258,732 |

Source: Own study by ARE S.A.

In 2015, 66% of the usable heat came from combined heat and power (CHP), while the rest of the heat is produced in water boilers (heating plants and district heating boilers of the utility power industry). Thus, there is a significant potential in the country that can be exploited by converting non–compliant water boilers to cogeneration units. Waste incineration plants have some potential, but so does the use of waste heat from industrial plants or other plants that generate waste heat.

In the analyses, the rate of cogeneration development in Poland was determined in accordance with the forecasts of demand for usable heat, taking into account economic factors and assuming support for high–efficiency cogeneration. The results of the model calculations (see table below) indicate a constant percentage of CHP generation, but it is important to note that the volume of electricity generated by CHP will increase. The share of heat generated by CHP will increase throughout the period, which is related to the decreasing use of district heating plants without an electric component.

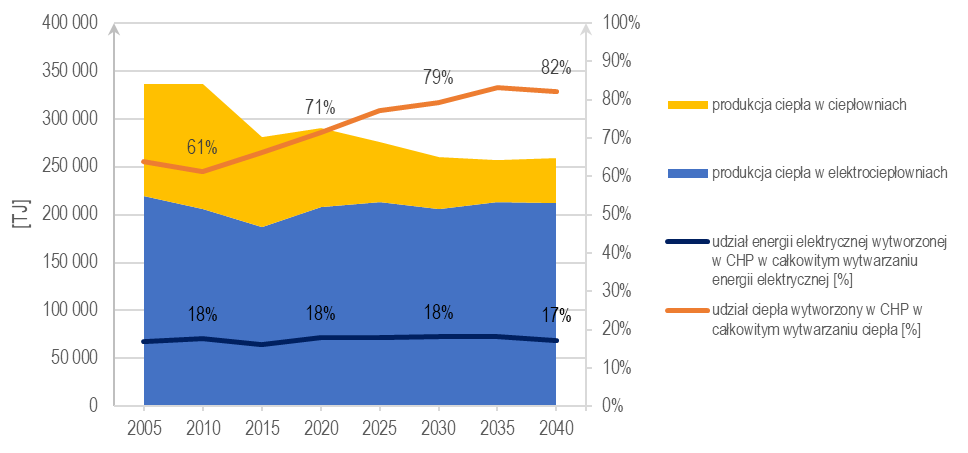
With the assumptions set out in the study, gas-fired combined heat and power plants are the fastest developing technology (the pro-environmental character of these units, availability of fuel and competitiveness in the conditions of growing prices of CO2 emission allowances are the arguments for the choice of such a solution).

Table 19. Forecast share of electricity generation in cogeneration and share of heat generation in cogeneration [%]

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **2005** | **2010** | **2015** | **2020** | **2025** | **2030** | **2035** | **2040** |
| share of electricity generated from CHP in total electricity generation [%] | 17% | 18% | 16% | 18% | 18% | 18% | 18% | 17% |
| share of heat produced from CHP in total heat production [%] | 64% | 61% | 66% | 71% | 77% | 79% | 83% | 82% |

Source: Own study by ARE S.A.

The graph below visualizes the decrease in generation of power in CHP plants, but also the increase in heat generation in CHP, which is a very welcome trend for energy efficiency improvement.



production of heat in heating plants

production of heat in CHP plants

share of electricity generated from CHP in total electricity generation [%]

share of heat produced from CHP in total heat production [%]

Figure 6. Forecast heat production [TJ] and share of electricity and heat produced in cogeneration [%]

## Electricity forecasts

### Forecast of electricity generation unit decommissioning

The schedule of the decommissioning of existing generating units as well as the upgrading plans were based on surveys conducted among power companies and information from the annual reports of power companies. Moreover, the shut-down schedule implemented in the forecast optimisation model is based on expert assessment of the technical condition of the basic equipment (boilers, turbines), the number hours worked as well as the derogations granted and the legitimacy of incurring the capital expenditure in order to meet the EU requirements regarding the emission standards arising from the BAT conclusions. According to analyses, the largest number of generating units will be decommissioned after 2030, with hard coal and lignite power plants being the main sources. At that time we can also observe a large number of shut-downs of wind power plants, which results from the wear of the oldest turbines. Phasing out of energy storage facilities refer to pilot plants.

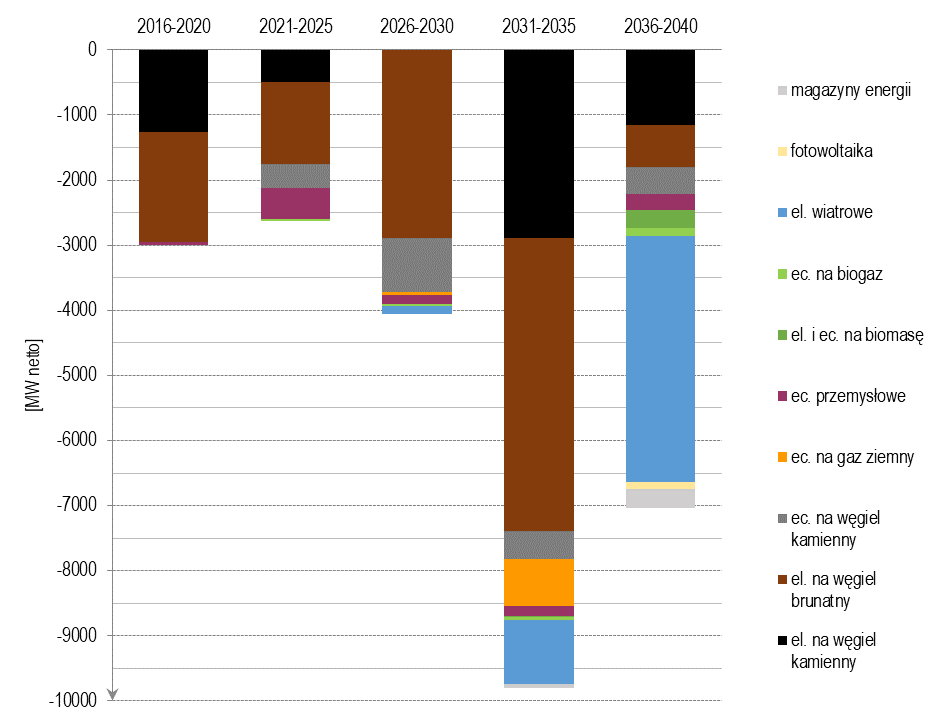
The figure below illustrates the determined and assumed permanent decommissioning of generating units in the utility and industrial power sector in 2016–2040.

According to estimates, in 2016–2040, about 26.5 GW of generation capacity will be permanently decommissioned, including about 15.8 GW in the group of centrally dispatched heat generating units (JWCD) and about 3.2 GW of installed capacity in utility CHP plants from the group of non–centrally dispatched generating units (nJWCD). The cumulative decommissioning values are shown in the table below.

Table 20. Cumulative capacity decommissioning between 2016 and 2040 [MWnet]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **2016–2020** | **2021–2025** | **2026–2030** | **2031–2035** | **2036–2040** | **2016–2040** |
| **Cumulative capacity decommissioning, including:** | 3,004 | 2,626 | 4,050 | 9,806 | 7,042 | 26,528 |
| heat JWCD | 2,041 | 1,756 | 2,884 | 7,398 | 1,804 | 15,883 |
| nJWCD from utility CHP group | 0 | 371 | 1,016 | 1,147 | 697 | 3,231 |

Source: Own study by ARE S.A.



energy storage

photovoltaics

wind pp

biogas CHP

biomass pp and CHP

industrial CHP

natural gas CHP

hard coal CHP

lignite pp

hard coal pp

Figure 7. Forecast of permanent generation unit shut-down from 2016 to 2040

Source: Own study by ARE S.A.

### Forecast of electricity generation capacity

The results of the analyses indicate a relatively large change in the structure of electricity generation in Poland in the 2040 perspective. The generating capacity may increase from approx. 46 GW in 2018 (37.3 GW in 2015) to approx. 59 GW in 2030 (an increase of about 58%) and to 72 GW in 2040, almost doubling the capacity in that period (93%).

The share of renewable sources in the power balance is gradually increasing – from 18% in 2015 to around 40% in 2030 and 50% in 2040. The share of gas-fired units, which are important for the balancing of the power system due to its high flexibility of operation, is increasing. The generating capacity structure between 2030 and 2035 includes the first nuclear unit with a capacity of 1–1.6 GW (the forecast assumes a capacity of 1.3 GW of a single unit, which is not the basis for inferring technology choice). Further units with a total installed capacity of approx. 6–9 GW will be commissioned every 2–3 years. The installed capacity of energy storage facilities will also gradually increase, as will the level of capacity reserved in demand side response (DSR) management tools. This is due to the implementation of smart grids, increased awareness of energy consumers, as well as the expected popularisation of aggregators.

On the other hand, the forecast indicates a decrease in the installed capacity in system units fired with coal, especially after 2030. This applies in particular to worn-out coal-fired units that will not meet the requirements for pollutant emissions. Due to the higher efficiency of the new coal-fired units currently under construction, they can produce more electricity at the same capacity (approx. 38% efficiency vs. 45–46%). The share of coal- and lignite-fired units in the installed capacity will be reduced from about 70% in 2015 to 40% in 2030 and to 19% in 2040.

Table 21. Net generating capacity forecast for electricity generation sources by technology [MW]

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

pp – power plants, CHP – combined heat and power plants

Source: Own study by ARE S.A.

The change in the fuel mix of installed capacity is particularly clear after 2030. This is due to the decommissioning of worn-out coal-fired units which are being replaced by new hard coal-fired units (4.4 GW by 2025) characterised by high efficiency, the development of RES, the implementation of the nuclear programme and a significant increase in the capacity of gas-fired units (almost 2 GW of combined cycle power plants may be built by 2040). The capacity of lignite-fired power plants is decreasing due to the decommissioning of existing units. The only new investment based on lignite is a unit with a net capacity of approx. 450 MW in Turów. The role of coal-fired CHP plants in the system will also be significantly reduced, as the majority of new system cogeneration units are likely to be plants fired with natural gas. Approximately 2.5 GW of new units of this type may be built by 2030 and additionally more than 3.5 GW in the following years until 2040. They will replace old heating plants and CHP plants operating on hard coal and after 2030 also a part of currently operating gas-fired CHP plants. Together with the new combined cycle power plants, they will increase the reliability of the electricity system, which is essential for the high share of uncontrollable renewable energy sources (wind and solar). Among renewable sources, wind energy will continue to dominate, with photovoltaics, biomass, hydroelectric power plants and biogas accounting for a much smaller share. Gas turbines have been singled out as they are present in the system to provide needed additional reserve and flexibility, meaning they will be in operation for a small amount of time and thus produce little energy on an annual basis. Including them under gas-fired power plants would distort the inference about the use of gas-fired power plants and combined heat and power plants.

The forecast indicates that the installed capacity of utility coal-fired power plants in 2040 will be about half of the capacity installed in 2015 (26.3 GW vs. 13.7 GW). Meanwhile, the capacity installed in renewable technologies will increase several times (6.7 GW vs. 37.4 GW), although their utilisation rate is much lower than for conventional units.

DSR/energy storage

gas turbines – reserve

pumped storage pp

hydraulic pp

biogas CHP

biomass pp and CHP

offshore wind pp

onshore wind pp

photovoltaic pp

nuclear pp

natural gas CHP

natural gas pp

industrial CHP

hard coal CHP

hard coal pp – new

hard coal pp – existing

lignite pp

Figure 8. Net generating capacity forecast for electricity generation sources by technology [MW]

### Electricity generation forecast by fuel

The results of the analysis of the development directions of the domestic power sector indicate gradual changes that will take place in the electricity production structure as a result of legal and market conditions, determined mainly by the EU climate and energy policy. Particularly dynamic changes are observed in the period 2030–2040.

The development of renewable energy sources is well noted, although analyses suggest that it would take place at a slower pace under market conditions. In 2030 their share in electricity generation may reach 32%, and in 2040 – 40%. Wind power and photovoltaics, which are characterised by volatile production, will be responsible for a large part of RES energy growth. The volume of net electricity generated from RES in 2040 could be up to four times higher than in 2015.

Increasing production from RES and imposing an obligation to purchase proper amounts of CO2 emission allowances under the ETS on carbon–based generating units will cause a gradual decrease in the share of this type of power plants in the electricity production structure from about 77% in 2018 (about 80% in 2015) to about 56% in 2030 and to about 28% in 2040. The main factor affecting this process is the scope of permanent decommissioning of coal-fired units, determined on the basis of declarations from energy companies, and the decreasing operating time of such units. Nevertheless, despite the significant decline in share, coal-fired power plants will remain a significant producer of electricity in the country. To a large extent, the generating units in Opole, Jaworzno and in Ostrołęka (the fuel used will depend on the investor's decision) put into operation in 2019 and being under construction, as well as the unit in Kozienice put into operation in 2017, will contribute to this. The share of generation in gas-fired units (new units are mainly high-efficiency combined cycle gas and steam units) in the generation structure will increase from 3.9% in 2015 to about 10% in 2030 and to 17% in 2040. The presence of uncontrollable sources in the projected amounts will require investments in flexible sources (e.g. gas-fired), energy storage, etc., which are necessary for RES integration in the power system.

A very important element of the national CO2 emission reduction policy is the development of nuclear power in Poland. It is projected that nuclear capacity could generate even more than 20 TWh in 2035. This is almost twice as much energy as will be obtained in the same period from photovoltaics, with almost 4.5 times less installed nuclear capacity.

The import-export balance is assumed to be zero in the forecasts. Poland is not responsible for the availability of energy from other countries, therefore forecasts cannot base the security of energy supply on potential imports.

Table 22. Gross electricity generation forecast by fuel [TWh]

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **2005** | **2010** | **2015** | **2020** | **2025** | **2030** | **2035** | **2040** |
| lignite | 54.8 | 48.7 | 52.8 | 47.0 | 50.4 | 49.9 | 27.5 | 17.3 |
| hard coal\* | 88.2 | 89.2 | 79.4 | 75.4 | 72.3 | 63.1 | 53.2 | 45.7 |
| gaseous fuels\*\* | 5.2 | 4.8 | 6.4 | 12.0 | 15.3 | 20.7 | 31.3 | 38.4 |
| heating oil | 2.6 | 2.5 | 2.0 | 1.9 | 1.9 | 1.9 | 1.8 | 1.7 |
| nuclear power | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 20.4 | 30.6 |
| solar energy | 0.0 | 0.0 | 0.1 | 2.0 | 4.5 | 6.8 | 10.8 | 14.8 |
| onshore wind energy | 0.1 | 1.7 | 10.9 | 23.5 | 23.7 | 23.8 | 24.2 | 24.6 |
| offshore wind energy | 0.0 | 0.0 | 0.0 | 0.0 | 2.7 | 14.5 | 21.7 | 30.6 |
| biomass | 1.4 | 5.9 | 9.0 | 9.6 | 9.7 | 11.6 | 11.4 | 10.3 |
| biogas | 0.1 | 0.4 | 0.9 | 1.5 | 2.7 | 3.9 | 5.0 | 5.8 |
| hydropower | 2.2 | 2.9 | 1.8 | 2.4 | 2.9 | 3.0 | 3.0 | 3.1 |
| from pumped water | 1.6 | 0.6 | 0.6 | 0.6 | 0.8 | 0.9 | 1.2 | 1.5 |
| other\*\*\* | 0.7 | 1.1 | 1.0 | 0.7 | 0.9 | 1.1 | 1.2 | 1.3 |
| **total** | **156.9** | **157.7** | **164.9** | **176.7** | **187.9** | **201.2** | **212.7** | **225.8** |

\* including coke oven gas and blast furnace gas

\*\* high-methane and nitrogen-rich natural gas, gas from demethylation of mines, gas accompanying crude oil

\*\*\* inorganic industrial and municipal waste

Source: Own study by ARE S.A.

municipal and industrial waste

from pumped water

hydropower

biogas

biomass

offshore wind energy

onshore wind energy

solar energy

nuclear power

heating oil

gaseous fuels\*\*

hard coal\*

lignite

\*\* high-methane and nitrogen-rich natural gas, gas from demethylation of mines, gas accompanying crude oil

\* including coke oven gas and blast furnace gas

Figure 9. Gross electricity generation forecast by fuel [TWh]

### Electricity price forecast

The forecasts of prices for end consumers (energy consumers for own use) were based on forecasts of averaged system costs taking into account estimates of costs related to the operation of individual support schemes in Poland, the level of taxation and the rates of transmission and distribution charges. The presented electricity price forecasts include costs related to the operation of support schemes for energy generated from renewable energy sources, in cogeneration and for projects aimed at improving energy efficiency. The study also assumed the introduction of a capacity payment mechanism.

The following table and figure show the forecast of electricity prices for the three defined end-consumer groups. The prices presented are average prices offered under comprehensive and unbundled contracts, including taxes. According to the results obtained, a gradual increase in electricity prices is expected in all three groups of end consumers under consideration. Price increases are spread evenly across sectors. The main factors determining the projected growth are the rising costs over time of purchasing CO2 emission allowances and the costs of developing emission-free technologies. Industrial enterprises are in principle entitled to reduce the amount of output VAT by the amount of input VAT on the purchase of electricity.

Table 23. Electricity price forecast by sector [PLN'2018/kWh]

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **2005** | **2010** | **2015** | **2020** | **2025** | **2030** | **2035** | **2040** |
| households | 0.516 | 0.657 | 0.680 | 0.718 | 0.839 | 0.851 | 0.867 | 0.869 |
| services | N/A | N/A | 0.609 | 0.634 | 0.755 | 0.767 | 0.783 | 0.784 |
| industry | 0.298 | 0.453 | 0.372 | 0.498 | 0.554 | 0.561 | 0.574 | 0.555 |

Source: Own study by ARE S.A.

services

industry

households

Figure 10. Electricity price forecast by consumer [PLN'2018/kWh]

## Transmission interconnection capacity forecasts

### Electricity transmission interconnection capacity forecasts

The table below summarizes historical and forecast data on cross-border electricity interconnection capacity. The total capacity on all cross-border interconnections in 2015 was about 10 GW.

Table 24. Forecast cross-border electricity interconnection capacity on existing and planned interconnections [MW]

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **interconnection** | **2005** | **2010** | **2015** | **2020** | **2025** | **2030** | **2035** | **2040** |
| **Germany** | Krajnik-Vierraden | 592 | 592 | 592 | 2,078 | 2,078 | 2,078 | 2,078 | 2,078 |
| **Germany** | Mikułowa-Hagenverder | 2,730 | 2,730 | 2,730 | 2,640 | 2,640 | 2,640 | 2,640 | 2,640 |
| **Czech Republic** | Wielopole/ Dobrzeń – Nosovice/ Albrechtice | 2,772/2,480 | 2,772/2,480 | 2,772/2,480 | 2,772/2,480 | 2,772/2,480 | 2,772/2,480 | 2,772/2,480 | 2,772/24,80 |
| **Czech Republic** | Kopanina/Bujaków – Liskovec | 800/794 | 800/794 | 800/794 | 800/794 | 800/794 | 800/794 | 800/794 | 800/794 |
| **Slovakia** | Krosno Iskrzynia – Leměšany | 2,078 | 2,078 | 2,078 | 2,078 | 2,078 | 2,078 | 20,78 | 2,078 |
| **Sweden** | Słupsk – Stärno | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 |
| **Belarus** | Białystok – Roś\* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Ukraine** | Rzeszów – Chmielnicka\* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Ukraine** | Zamość – Dobrotwór | 381/310 | 381/310 | 381/310 | 381/310 | 381/310 | 381/310 | 381/310 | 381/310 |
| **Lithuania** | Ełk – Alytus | 0 | 0 | 488 | 488 | 488 | 0 | 0 | 0 |
| **Lithuania** | Żarnowiec-Darbenai (Harmony Link) | 0 | 0 | 0 | 0 | 0 | 700 | 700 | 700 |
| **TOTAL** | | **9,953 / 9,584** | **9,953 / 9,584** | **10,441 / 10,072** | **11,837 / 11,468** | **12,467  / 12,098** | **12,049 / 11,680** | **12,049 / 11,680** | **12,049  / 11,680** |

\*closed,  
with different availability in winter and summer marked: winter period / summer period

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

Due to limitations in the transmission of power between national electricity systems, the technical capacity for electricity transmission is not always equal to the real commercial capacity. These limitations are of various nature, ranging from maintenance work to limitations introduced by transmission system operators in order to ensure the security of network operation.

According to the EU regulation on the internal electricity market[[8]](#footnote-8), by the end of 2025 at the latest, transmission system operators are obliged to make a minimum of 70% of cross-border transmission capacity available (in compliance with the criteria of secure operation of the electricity grid).

### Forecasts of gas transmission interconnection capacity

In 2015, the maximum capacity of the national transmission system (NTS) to receive natural gas was over 25.8 billion m3 per year. In 2016, the LNG regasification terminal in Świnoujście was put into operation, with an annual capacity of about 5 billion m3.

Key investment projects ensuring diversification of natural gas supply sources and directions are considered to be: construction of the Baltic Pipe – capacity of approx. 10 billion m3 annually towards Poland and 3 billion m3 towards Denmark and Sweden (includes the construction of the Norway–Denmark and Denmark–Poland interconnections and expansion of the Polish and Danish transmission systems to increase transmission capacity); expansion of the LNG terminal in Świnoujście – regasification capacity of approx. 8.3 billion m3, construction of an FSRU–type regasification terminal in the Gulf of Gdańsk, interconnection with Slovakia – capacity of 5.7 billion m3 towards Poland and 4.7 billion m3 towards Slovakia; interconnection with Lithuania – 1.9 billion m3 towards Poland and 2.4 billion m3 towards Lithuania. Moreover, in case of market interest, interconnections with the Czech Republic and Ukraine may also be feasible.

Table 25. Parameters of the cross-border input points to the gas transmission system

| **interconnection** | **terminal point** | **input / output** | **2020** | **2025** | **2030** | **2035** | **2040** |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **LNG Terminal** | LNG Terminal | input | 4,993.2 | 8,300 | 8,300 | 8,300 | 8,300 |
| **Germany** | GCP IN (Lasów, Gubin) | input | 1,594.3 | 1,594.3 | 1,594.3 | 1,594.3 | 1,594.3 |
| **Germany** | GCP OUT (Lasów Rewers, Kamminke) | output | 440.8 | 440.8 | 440.8 | 440.8 | 440.8 |
| **Czech Republic** | Branice | input | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 |
| **Czech Republic** | Cieszyn\* | input | 587.2 | 587.2 | 587.2 | 587.2 | 587.2 |
| **Ukraine** | Drozdowicze | input | 4,380.0 | 4,380.0 | 4,380.0 | 4,380.0 | 4,380.0 |
| **Ukraine** | Hermanowice tow. Ukraina\*\* | output | 02 | 02 | 02 | 02 | 02 |
| **Belarus** | Tietierowka near Białystok | input | 236.5 | 236.5 | 236.5 | 236.5 | 236.5 |
| **Belarus** | Wysokoje near Janów Podlaski | input | 5,475.0 | 5,475.0 | 5,475.0 | 5,475.0 | 5,475.0 |
| **Belarus** | Kondratki near Białystok EUROPOL | input | 33,741.2 | 33,741.2 | 33,741.2 | 33,741.2 | 33,741.2 |
| **Germany** | Mallnow near Słubice EUROPOL | output | 30,602.4 | 30,602.4 | 30,602.4 | 30,602.4 | 30,602.4 |
| **Germany** | Mallnow near Słubice EUROPOL reverse | input | 6,132.0 | 6,132.0 | 6,132.0 | 6,132.0 | 6,132.0 |
| **Yamal** | PWP | input | 9,076.1 | 9,076.1 | 9,076.1 | 9,076.1 | 9,076.1 |
| **Denmark** | Baltic Pipe | input | 0 | 10,000 | 10,000 | 10,000 | 10,000 |
| **Denmark** | Baltic Pipe | output | 0 | 3,000 | 3,000 | 3,000 | 3,000 |
| **Slovakia** | GIPS | input | 0 | 5,700 | 5,700 | 5,700 | 5,700 |
| **Slovakia** | GIPS | output | 0 | 4,700 | 4,700 | 4,700 | 4,700 |
| **Lithuania** | GIPL | input | 0 | 1,900 | 1,900 | 1,900 | 1,900 |
| **Lithuania** | GIPL | output | 0 | 2,400 | 2,400 | 2,400 | 2,400 |
| **FSRU** | FSRU | input | 0 | 4,500 | 4,500 | 4,500 | 4,500 |

\* value calculated taking into account seasonal variation; \*\* no continuous capacity, Intermittent conditionally continuous capacity: 1463– 2190 million m3//year, values above 1,463 million m3/year depending on arrangements between GAZ–SYSTEM and Ukrtransgaz.

Source: Own study.

## Forecasts of pollutant emissions

The forecast emission levels take into account the full implementation of the Industrial Emissions Directive (IED)[[9]](#footnote-9) in Poland, as well as other existing and projected regulations on the reduction of emissions from the combustion of fuels in stationary plants and means of transport (including the Medium Combustion Plant Directive – MCP). It has also been assumed that by 2040 the problem of pollutant emissions from households and local boiler plants will have been comprehensively solved, as a result of which the carbon intensity of this sector will be similar to that of the utility and industrial energy sector.

The integrated emission indicators of SO2, NOx and PM10 for combustion of particular types of fuels were estimated on the basis of, among others, the EMEP/EEA guidelines[[10]](#footnote-10) and national publications concerning individual combustion sources.

The obtained results of the forecasts for 2030 in terms of SO2 and NOx emissions as a result of the implementation of PEP2040 correspond to the target emissions ceilings for 2030, set for Poland in the NEC Directive[[11]](#footnote-11). **In case of failure to implement PEP2040, the national ceilings for SO2 and NOx in 2030 will not be met**. It will be possible to meet them at a later date than set out in the NEC Directive, probably only after 2035. Data for total emissions are shown in the figure on the next page.

Table 26. Forecasts of emissions of major air pollutants and carbon dioxide in 2030 and 2040.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **scenario** | **emissions balance** | **2030** | | | | **2040** | | | |
| **SO2** | **NOx** | **PM10** | **CO2** | **SO2** | **NOx** | **PM10** | **CO2** |
| ***thousand t*** | | | ***million t*** | ***thousand t*** | | | ***million t*** |
| **Implementation of PEP2040** | **total** | **319** | **455** | **147** | **268** | **181** | **377** | **103** | **209** |
| combustion of fuels | 312 | 394 | 109 | 246 | 174 | 316 | 65 | 187 |
| **No implementation of PEP2040** | **total** | **471** | **574** | **197** | **353** | **345** | **485** | **155** | **292** |
| combustion of fuels | 464 | 513 | 159 | 327 | 338 | 424 | 117 | 267 |

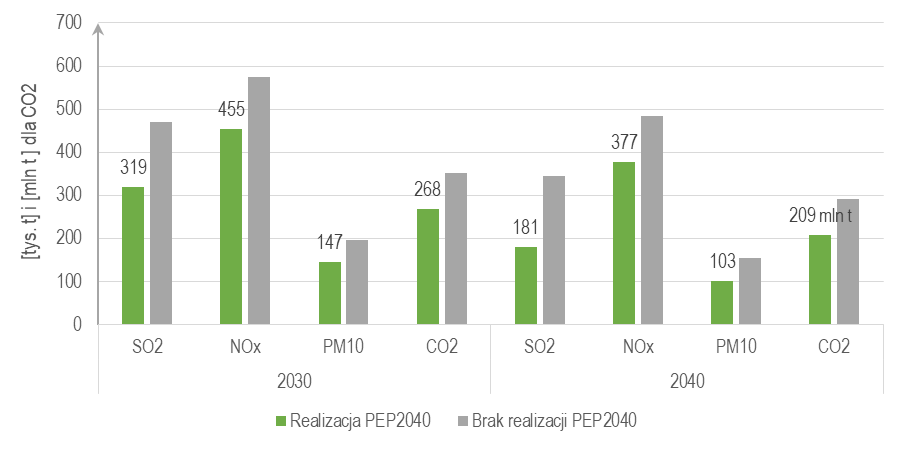
Source: Own study by ATMOTERM S.A.

In terms of reducing carbon dioxide emissions compared to 1990, the forecasts carried out produce the results shown in the table below. In 2040, the implementation of PEP2040 allows for a reduction of as much as 45% of CO2 emissions compared to 1990. This is about 80 million t of CO2 less than if PEP2040 is not implemented.

Table 27. Projected reductions in carbon dioxide emissions (excluding LULUCF) compared to 1990

| scenario | CO2 emissions in 1990 | CO2 emissions in 2030 | | CO2 emissions in 2040 | |
| --- | --- | --- | --- | --- | --- |
| [million t] | [million t] | reduction comp. to 1990 | [million t] | reduction comp. to 1990 |
| **Implementation of PEP2040** | 377 | **268** | **29%** | **209** | **45%** |
| **No implementation of PEP2040** | 377 | 353 | 6.4% | 292 | 23% |

Source: Own study by ATMOTERM S.A.



[kt] and [Mt] for CO2

No implementation of  
PEP2040

Implementation of  
PEP2040

Figure 11. Forecasts of emissions of main air pollutants [thousand t] and carbon dioxide [million t] in 2030 and 2040.

Key emission indicators by ETS and non–ETS were also analysed. The table and graph below indicate the projected steady decline in GHG emissions over the forecast period for both ETS and non–ETS. Only for non–ETS over the period 2015–2020 is an increase projected due to increasing transport activity. The ETS projects a GHG reduction of 25% between 2005 and 2030.

Table 28. Forecast greenhouse gas emissions by ETS and non–ETS sector [kt CO2eq]

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

Source: Own study by ATMOTERM S.A., historical data: KOBIZE

Figure 12. Projected greenhouse gas emissions by ETS and non–ETS sector [kt CO2eq]

Energy Policy of Poland until 2040 is strongly focused on reducing emissions in the electricity and heat generation sub-sector. Actions aimed at this goal result in both significant decreases in CO2 emissions of this sub-sector and in key pollutants. The tables and figures below illustrate the systematic decline in these indicators, which **decrease significantly** over the period 2005–2040. All indicators in 2040 will be 61–91% lower than in 2005, and will be reduced by about half between 2020 and 2040.

The increase in particulate emissions between 2015 and 2020 is due to the increase in energy demand. However, this is offset in subsequent years by the decommissioning of old coal-fired units, which is being replaced by high-efficiency conventional coal- and natural gas-fired generation units with much lower emissions, the growth in the use of renewable energy, and, in the 2030s, the commissioning of nuclear units.[[12]](#footnote-12)

Table 29. Forecast of contaminants emissions from electricity and heat production [kt] and CO2 emission intensity for electricity and heat production [t CO2eq./MWh]

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **2005** | **2010** | **2015** | **2020** | **2025** | **2030** | **2035** | **2040** |
| **NOx (as NO2) [kt]** | 291.2 | 278.9 | 214.5 | 151.7 | 126.3 | 116.8 | 87.9 | 73.9 |
| **SOx (as SO2) [kt]** | 820.2 | 507.0 | 398.7 | 158.7 | 132.2 | 122.2 | 91.9 | 77.4 |
| **PM2.5 [kt]** | 15.3 | 9.4 | 6.9 | 10.0 | 8.3 | 7.7 | 5.8 | 4.9 |
| **PM10 [kt]** | 29.8 | 17.6 | 12.2 | 16.9 | 14.0 | 13.0 | 9.8 | 8.2 |
| **CO2[t CO2eq./MWh]** | 0.685 | 0.664 | 0.669 | 0.541 | 0.509 | 0.461 | 0.334 | 0.268 |

Source: Own study by ATMOTERM S.A., historical data: KOBIZE

|  |  |
| --- | --- |
| NOx (as NO2)  SOx (as SO2) |  |

Figure 13. Forecast of emissions of pollutants from generation of electricity and heat – NOx, SOx and dust – PM2.5 and PM10 [kt]

Figure 14. CO2 emission intensity for electricity and heat production [t CO2eq./MWh]

## Forecast of capital expenditure related to changes in the energy sector

**Poland's energy transition by 2040** leading to the diversification of the energy mix in a socially acceptable manner and, at the same time, ensuring energy security, maintaining competitiveness of the economy and limiting environmental impact, will require huge capital expenditure, the scale of which may reach **around PLN 1,613 billion** in 2021–2040. This scale of costs will pose a huge challenge for the whole economy.

The evolution of the Polish energy sector towards a low–carbon one will be a long and very costly process. This process must be spread over time due to the technical feasibility of building and connecting new sources. Furthermore, it must be done in such a way that the economic and social effects arising from it can be mitigated. In particular, action taken must not lead to increased energy poverty, which can occur when energy costs are too high. Protection and support must also be given to those regions that will suffer most from the reduction of the share of coal in power generation, as part of the so-called *just transition*.

The table below shows capital expenditure in the whole economy, then in particular sub-sectors. The item "capital expenditure in the entire fuel and energy sector" includes in particular expenditures in the electricity, heat, gas and fuel sectors. The totals in the tables are included in the outlook from 2021, while the full scope of the analysis included inputs from 2016.

Table 30. Forecast energy-related capital expenditure in the whole economy in 2016–2040 [PLN'2018 million]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **2016–2020** | **2021–2025** | **2025–2030** | **2031–2035** | **2036–2040** | **2021–2040** |
| **energy-related capital expenditure in the national economy** | 429,436 | 453,301 | 431,948 | 391,402 | 336,272 | **1,612,924** |
| capital expenditure in the entire fuel and energy sector | 242,443 | 204,280 | 207,140 | 238,346 | 217,828 | **867,594** |
| energy-related capital expenditure in non-energy sectors (industry, households, services, transport and agriculture) | 186,993 | 249,021 | 224,808 | 153,057 | 118,444 | **745,330** |

Source: Own study by ARE S.A.

The table below shows how capital expenditure in each of the fuel and energy sub-sectors evolve between 2016 and 2040.

*Table 31. Projected capital expenditure in the energy sector – by sub-sectors [PLN'2018 million]*

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **sector** | **2016–2020** | **2021–2025** | **2025–2030** | **2031–2035** | **2036–2040** | **2021–2040** |
| generation of electricity | 92,272 | 52,932 | 55,298 | 107,972 | 103,457 | **319,659** |
| transmission and distribution of electricity | 38,438 | 45,309 | 47,635 | 44,188 | 42,895 | **180,026** |
| generation of district heat | 9,959 | 12,470 | 14,433 | 10,251 | 5,598 | **42,751** |
| distribution of district heat | 5,719 | 6,721 | 5,238 | 4,341 | 3,637 | **19,937** |
| gas industry | 43,085 | 28,446 | 28,446 | 18,781 | 18,781 | **94,454** |
| liquid fuels | 44,035 | 48,033 | 49,782 | 44,448 | 42,827 | **185,091** |
| hard coal and lignite mining | 8,935 | 10,369 | 6,308 | 8,365 | 634 | **25,676** |
| **total** | 242,443 | 204,280 | 207,140 | 238,346 | 217,828 | **867,594** |

Capital expenditure for electricity generation include modernisation and expansion of the electricity generation sector (power plants and CHP plants, energy storage, DSR, IED/BREF compliance costs).

Expenditure for electricity transmission and distribution include funds for the expansion and upgrading of the transmission and distribution grid, including the reinforcement of the distribution grid for the development of RES, electromobility and the installation of smart meters in 80% of households by 2028, using transmission and distribution network development plans presented by operators.

Capital expenditure for the generation of district heat include upgrading and construction of new heat plants supplying heat to district heating networks (excluding industrial heat plants producing heat for their parent plants). Whereas, the item 'distribution of district heat' indicates the capital expenditure for the development and upgrading of district heating networks.

The item 'gas industry' includes capital expenditure in the sector according to the plans of gas companies. Capital expenditures related to the liquid fuels sector were assumed on the basis of data reported by companies operating on the Polish market and include investments indicated in PEP2040.

The item 'hard coal and lignite mining' includes capital expenditure related to the implementation of the *Programme for the hard coal mining sector in Poland* of January 2018 and the *Programme for the lignite mining sector in Poland* of May 2018. The costs of pit reclamation have been included.

The expenditure in the **electricity sector** is detailed below. Most of the expenditure falls in the 2030–2040 period, when most existing coal-fired units are decommissioned and replaced by nuclear, gas and renewable energy sources. In the same period, a significant proportion of the renewable energy generation units currently in operation will have to be replaced. The required investment in renewable energy sources for the entire 2021–2040 period was estimated to be about 58% of the total investment in the electricity generation sector. The figure on the next page shows the distribution of expenditure in the manufacturing sector by fuel.

The forecast capital expenditure in the transmission and distribution sub-sector are the costs of network expansion or reinforcement associated with introducing new capacity into the system (table below). Estimating this category of costs is subject to a high degree of uncertainty due to the many factors that determine the cost components – from the location of the sources, to the length of the lines and the rated capacity of the grid, to the area in which they are located.

Table 32. Forecast capital expenditure in the power sector in 2016–2040 [PLN'2018 million]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **2016–2020** | **2021–2025** | **2025–2030** | **2031–2035** | **2036–2040** | **2021–2040** |
| **total expenditure on generating units** | 92,272 | 52,932 | 55,298 | 107,972 | 103,457 | **319,659** |
| **by type** |  |  |  |  |  |  |
| power plants | 67,184 | 36,211 | 41,808 | 97,030 | 87,923 | **262,972** |
| CHP plants | 17,290 | 14,623 | 12,591 | 8,957 | 12,996 | **49,167** |
| DSR/energy storage | 112 | 290 | 900 | 1,984 | 2,538 | **5,712** |
| access to IED/BREF | 7,687 | 1,809 | 0 | 0 | 0 | **1,809** |
| **by fuel** |  |  |  |  |  |  |
| carbon | 41,697 | 10,115 | 0 | 1,299 | 2,016 | **13,430** |
| gas | 7,729 | 11,354 | 2,672 | 8,146 | 5,870 | **28,042** |
| nuclear | 0 | 0 | 0 | 52,904 | 26,452 | **79,355** |
| other | 3,138 | 2,438 | 2,019 | 3,115 | 4,799 | **12,370** |
| **renewable** | 39,709 | 29,025 | 50,607 | 42,509 | 64,320 | **186,460** |
| water | 497 | 1,433 | 543 | 543 | 543 | **3,061** |
| wind | 26,978 | 8,328 | 33,762 | 24,887 | 45,331 | **112,308** |
| photovoltaic | 9,061 | 9,746 | 7,503 | 12,745 | 12,830 | **42,825** |
| biomass | 1,840 | 5,962 | 5,014 | 421 | 1,259 | **12,655** |
| biogas | 1,332 | 3,555 | 3,786 | 3,913 | 4,357 | **15,612** |
| **total expenditure on grid inf.** | 38,438 | 45,309 | 47,635 | 44,188 | 42,895 | **180,026** |
| transmission grid | 6,299 | 7,868 | 13,100 | 10,740 | 10,859 | **42,567** |
| distribution grid | 32,139 | 37,441 | 34,535 | 33,447 | 32,036 | **137,459** |
| **total expenditure in the power sector** | **130,710** | **98,241** | **102,933** | **152,159** | **146,351** | **499,685** |

Source: Own study by ARE S.A.

Renewable sources

Other fuels

Nuclear

Coal

Gas

Figure 15. Projected capital expenditure in the manufacturing sector between 2016 and 2040 [EUR'2016 million]

The next table shows the distribution of inputs in the heating sector. The highest level of expenditures will be incurred in 2021–2030, which is related to the priority of increasing the use of district heating.

Table 33. Projected capital expenditure in the district heating sector [PLN'2018 million]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | 2016–2020 | 2021–2025 | 2025–2030 | 2031–2035 | 2036–2040 | 2021–2040 |
| **total investment in generating units (commercial, excluding industrial)** | **9,959** | **12,470** | **14,433** | **10,251** | **5,598** | **42,751** |
| district heating boilers | 1,322 | 5,668 | 10,619 | 1,089 | 3,315 | 20,691 |
| heat storage | 57 | 128 | 0 | 29 | 0 | 157 |
| upgrading of sources | 8,581 | 6,674 | 3,814 | 9,132 | 2,283 | 21,903 |
| **expenditures on the expansion and upgrading of heating networks** | **5,719** | **6,721** | **5,238** | **4,341** | **3,637** | **19,937** |
| **total expenditure in the district heating sector** | **15,677** | **19,190** | **19,671** | **14,592** | **9,235** | **62,688** |

Source: Own study by ARE S.A.

# Conclusions from the forecast analysis for the power sector taking into account high prices of CO2 emission allowances and environmental and system costs

Given the changes in the environment from the end of 2019, a **forecast was made for the electricity sector with more ambitious EU energy and climate policy targets**. It adopted a forecast of significantly higher prices of CO2 emission allowances by the National Centre for Balancing and Emission Management (KOBiZE), which directly reduced the economic effectiveness of the use of generation assets of fossil fuel-based sources. The forecast relates only to the power sector and is coherent with forecasts presented in the strategic option in the *Programme of Polish Nuclear Power Generation* adopted by the Council of Ministers on 2 October 2020.

In addition, the forecast presented in the document is the result of an analytical model (total cost methodology) that minimises the total cost generated by the power system, also taking into account properly allocated external costs, i.e. environmental costs, reflecting the negative impact of the power system on the environment, and system costs generated in particular by unstable renewable energy sources. The inclusion of these costs in the analytical model made it possible to determine an energy mix that not only takes into account the very ambitious climate policy targets adopted at the EU level, but also allows for the efficient use of generation units while ensuring the level of adequate reserve in the system. The results presented in the Appendix below can be interpreted as an approximation of the economically and socially optimal energy mix, the implementation of which in market conditions requires additional regulations allocating external costs to the sources generating those costs.

## Main assumptions

1. **Price paths for CO2 emission allowances**

The growing climate ambitions of the EU increasingly contribute to rising prices of emission allowances in the EU ETS system, significantly worsening the financial condition of the Polish power sector. According to the estimations of KOBiZE[[13]](#footnote-13), raising the EU reduction target in an extreme case may cause even a three-fold increase in the prices of CO2 emission allowances in 2030 as compared to the prices in 2020. The additional forecast scenario presented in this appendix to PEP2040 shows the assumed development directions of the electricity sector assuming a 50% GHG reduction target.

Table 34. Price paths for CO2 emission allowances [EUR2018/tCO2]

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **2020** | **2025** | **2030** | **2035** | **2040** |
| Price path used to draw up KPEiK | 17 | 21 | 30 | 35 | 40 |
| Price path with a 50% GHG reduction target in 2030 | 25 | 35 | 54 | 60 | 60 |

Source: Ministry of Climate and Environment on the basis of forecasts of the KOBiZE Climate and Energy Analysis Centre and assumptions of KPEiK

The forecasts of CO2 emission allowance prices assumed in this scenario at the level of 54 EUR/tCO2 in 2030 are coherent with the forecasts presented by the EC for the impact assessment of the *2030 Climate Target Plan[[14]](#footnote-14)* taking into account the target of 55% reduction of GHG emissions by 2030. The EC projected prices of CO2 emission allowances in 2030 amount to 32–65 EUR/tCO2 depending on the scenario.

1. **Price paths for oil, natural gas, coal and uranium**

Fossil fuel price paths were updated for model calculations using the International Energy Agency (IEA) forecasts – WEO 2019[[15]](#footnote-15), "Stated Policies EU" scenario. The forecasts are summarised in the table and shown in the graph below.

Table 35. Fossil fuel price paths[EUR2018/GJ]

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **2020** | **2025** | **2030** | **2035** | **2040** |
| Crude oil | 10.7 | 12.0 | 13.0 | 14.2 | 15.2 |
| Natural gas | 6.2 | 6.4 | 6.4 | 6.7 | 7.1 |
| Hard coal | 2.9 | 2.5 | 2.6 | 2.6 | 2.6 |
| Uranus | 0.5 | 0.5 | 0.5 | 0.5 | 0.6 |

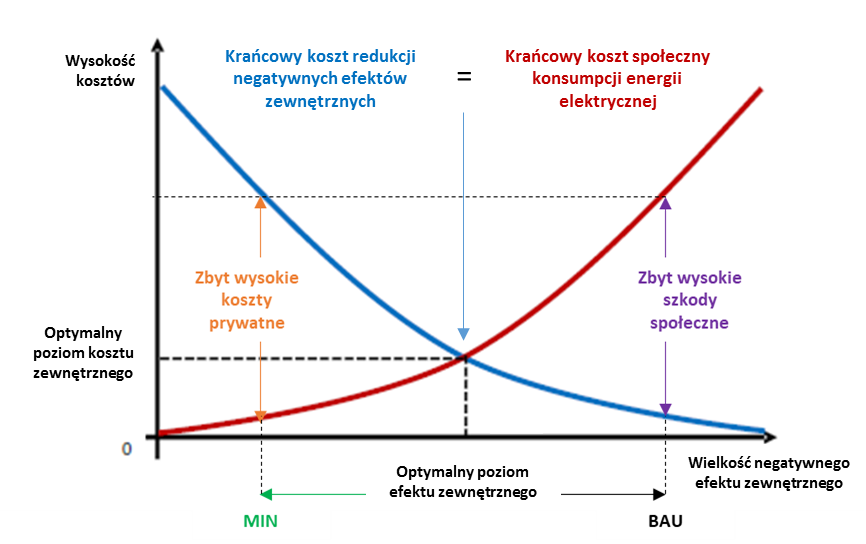
Source: Ministry of Climate and Environment based on IEA World Energy Outlook 2019, Stated Policies EU scenario

1. **Total cost methodology**

The "total cost methodology" (TCM) was used to develop this scenario which differs significantly from the investor's economic calculation. The overarching objective of the TCM is to minimise the total costs to the economy and society of generating energy, taking into account the indirect operating costs of the energy sector, as well as system (technical) and environmental requirements. Side effects from electricity generation, such as emissions and system imbalances, burden third parties with a portion of the plant's operating costs that are not included in the cost of energy at the investment decision stage. These side effects form a group of external costs which include system costs (reserve capacity, grids, balancing), environmental costs (health, ecosystem) and macroeconomic costs (security, import-export balance, employment).

The "total cost methodology" attributes external costs directly to their source, aiming for an equitable distribution of the cost between investors, end consumers and other energy market participants. The energy mix, optimised in terms of total cost, allows for efficient use of available resources, which translates into improved price competitiveness of Polish enterprises on the international and domestic markets and allows for lower electricity prices for households. The commonly used investor's calculation, on the other hand, is aimed at maximising individual investor returns. In this model, the external costs of power generation are not included as an investor's cost and are passed on to other market participants and end consumers. This leads to an energy mix that may not be cost-optimal for society.

The role of the state is to develop a strategy that reconciles the interests of both end consumers and investors in the energy sector. Given the incomplete cost mapping in the current energy market, regulatory action is needed to reduce external costs in a rational manner. The government administration aims to create optimal market mechanisms, which will enable investors to implement investments assumed in the strategy and receive a justified return on invested capital, while respecting the impact on the environment and other market participants (system aspects). The final effect of the application of the TCM is the achievement of the minimum energy price at which the end consumer, when purchasing electricity, pays off the capital expenditure and operating costs of the power sector, without having to incur technically and economically unjustified external costs. The figure below shows the mechanics of the TCM.



**Final cost of the reduction of negative external effects**

**Final social cost of electricity consumption**

**Excessive private costs**

**Excessive social damage**

**Level of negative external effect**

**Optimum level of external effect**

**Optimum level of external cost**

**Level of costs**

Figure 16. Mechanics of external cost optimisation in the "total cost methodology" – reference drawing; MIN – minimum technically possible reduction of the external effect, BAU – Business as Usual, system design without considering external costs

1. **System costs**

The electricity system functions as a system of interconnected vessels in which the generation, transmission, distribution and use of electricity are interdependent. The indicators of particular importance, determining the way of system management, are the parameters of operation of the available and future generation base. The diversity of technologies in terms of flexibility of operation, stability and predictability of generation, average capacity utilisation, failure rate or ability to choose a convenient location has a direct impact on the cost of system operation as a whole. The greater the deviation of the properties of the generating source from the parameters that allow the system to operate safely, the higher the costs generated in its other components.

The lowest system costs are generated by dispatchable sources, which are characterised by the ability to produce energy on demand according to the demand profile of consumers, a high coefficient of capacity utilisation during the year and the possibility of building them in convenient network nodes close to centres of energy demand.

System maintenance costs increase significantly for uncontrollable sources such as wind and solar technologies. Unpredictability of operation and unreliability of supply, locational constraints due to wind and solar conditions, asynchronous operation that reduces the inertia available in the system, and low power concentration are factors that make it difficult to manage the system safely and economically.

This results in significant system costs that are ignored by investors when evaluating the economics of uncontrollable sources. These costs include:

* costs of maintaining the reserve and changing the load profile of the system (profile cost),
* costs of developing transmission and distribution infrastructure,
* balancing costs and system flexibility.

The largest cost component is the profile costs associated with permanent changes in the efficiency of generating units. The growth of uncontrollable generating units, which have priority access to the grid, reduces the number of available operating hours for controllable technologies, responsible for the safe operation of the system. The systematic reduction of working hours makes it more difficult to obtain a return on investment in dispatchable sources, increasing uncertainty about the ability to fully depreciate assets. This results in an increasing risk of stranded costs in the sector as a result of premature shut-down of existing generation units. Growing investment uncertainty, correlated with an increase in the share of non-controllable RES in electricity generation, leads to a systematic increase in the weighted average cost of capital (WACC) of new, dispatchable system power plants. This leads to postponing or not making investment decisions on future controllable generation sources. Ultimately, the increased level of risk, which translates into higher costs of financing dispatchable power plants necessary to secure unstable RES generation, increases the total cost of energy production from the power system. In the total cost methodology, due to the invariability of the WACC of individual technologies throughout the forecast period, profile costs valorising the change in asset utilisation efficiency have been entirely assigned to uncontrollable RES, which are a source of cost-effectiveness distortion for other system participants. These costs have been included in the modelling in a dynamic way – they increase as the penetration of particular uncontrollable sources in electricity generation increases. The optimiser builds unstable RES sources taking into account the decrease in technology costs and increase in system costs, determining the optimal number of these sources by minimising the total cost of power system development.

1. **Environmental costs**

Rationally reducing the negative impact of the energy sector on the environment and the health of citizens requires the identification, valuation and subsequent consideration of all environmental costs when optimising the national energy strategy. The identification of negative environmental effects associated with the production of electricity was carried out for the full production cycle, taking into account the extraction of energy resources, transport, conversion and final energy use. The studies used in the analysis[[16]](#footnote-16) provided a rough economic assessment of the impact of the electricity sector on human health, the ecosystem and the size of agricultural crops.

The model analysis starts with the determination of emissions of toxic substances, such as particulate matter (PM2.5, PM10), sulphur oxides (SOx), nitrogen oxides (NOX) or heavy metals, and energy emitted in the form of harmful noise, heat or radiation. Through mathematical models, the radius of dispersion of harmful factors around the power plant and the intensity of negative environmental effects in the studied area are determined. Based on functions that determine the effect of concentrations of individual effects on the quality of air, drinking water, soil, and agricultural crops, an increase in the probability of disease and degradation of surrounding ecosystems is determined. The obtained coefficients allow for a unit valuation of the impact of emissions on health and the environment. The cost indices calculated in this way are used as components of the sector's economic optimisation criterion.

## Forecast electricity demand and net maximum capacity

The forecast electricity demand and net maximum capacity used in the scenario is consistent with the forecast contained in the *Development Plan for meeting current and future electricity demand for 2021–2030* developed by the Transmission System Operator and approved by the President of the Energy Regulatory Office on 28 May 2020. The forecast was based on the estimation of final energy consumption in Poland in the long-term perspective. The analysis took into account a number of macro-factors affecting the structure of energy consumption in the household, transport, industry and service sectors, changes in energy efficiency, forecasts of Gross Domestic Product growth in individual sectors, technological and consumer changes, and changes resulting from EU regulations in terms of Poland achieving the required RES target in gross final energy consumption. Structural changes have been taken into account, i.e. primarily the development of the electric vehicle market and heat pumps.

Domestic net electricity demand was estimated to be over 181 TWh in 2030 and over 204 TWh in 2040. Demand for maximum capacity will be almost 28 GW in 2030 and over 31 GW in 2040. The total net increase in electricity demand in 2020–2040 is 27.7%. Peak power demand during this period will increase by 27.8%.

Table 36. Forecast net electricity and net capacity demand at annual peak [GW]

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **2020** | **2025** | **2030** | **2035** | **2040** |
| net electricity demand [TWh] | 159.9 | 170.1 | 181.1 | 191.9 | 204.2 |
| net power demand at annual peak [GW] | 24.5 | 25.9 | 27.7 | 29.5 | 31.3 |

Source: Development plan for meeting current and future electricity demand in 2021-2030, PSE S.A.

Figure 17. Forecast of net peak power demand

Figure 18. Electricity demand forecast

## Forecast structure of net installed capacity

The results of the optimisation model indicate that the net generating sources' net generating capacity increases to approximately 56.6 GW in 2030 and to 60 GW in 2040, representing a 38% increase in net generating capacity over the current state.

The share of renewable energy sources in the power balance has grown from about 25% in 2020 to about 39% in 2030 and to about 48% in 2040, driven by increases in photovoltaic and wind capacity. The installed capacity of offshore wind is about 5.9 GW in 2030 and the target is 9.6 GW in 2040. Total photovoltaics (PV) capacity was about 5.1 GW in 2030 and about 10 GW in 2040. A greater PV capacity development is constrained due to the high system cost generated by this technology. The share of gas-fired units, which are important for power system balancing due to its high flexibility of operation, grew from the current level of about 5% to about 11% in 2030 and 24% in 2040, with part of the gas-fired units in 2040 being open cycle gas turbine (OCGT) power plants. The generating capacity mix between 2030 and 2035 includes a first nuclear unit with a capacity of 1.1 GW, followed by others at 2-year intervals, up to 4.4 GW in 2040. A total of 6 nuclear units with a total capacity of 6.6 GW appear in the extended model outlook until 2045.

For technical and economic reasons, the forecast assumes a large reduction in the installed capacity of coal-fired sources. Their share in the power system will decrease from the current level of approx. 52% to approx. 37% in 2030 and approx. 11% in 2040. The decommissioning schedule for system power plants based on coal fuels results from the technical exhaustion of the existing units and the end of their technical life. New coal units are not built due to the lack of economic justification caused by high CO2 emission allowance prices and the environmental costs implemented in the model.

Table 37. Forecast structure of net installed capacity by technology until 2040 [MW]

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **2025** | **2030** | **2035** | **2040** |
| coal CHP | 4,094 | 3,913 | 3,095 | 2,842 |
| gas CHP | 2,205 | 2,107 | 1,667 | 1,530 |
| gas CHP, new | 480 | 1,374 | 2,048 | 2,943 |
| biomass and biogas CHP and pp | 1,115 | 1,302 | 1,442 | 1,423 |
| hard coal power plants, existing | 10,730 | 10,222 | 4,986 | 2,208 |
| hard coal pp, recent and new | 3,480 | 3,480 | 3,480 | 3,480 |
| lignite power plants | 7,448 | 7,448 | 3,812 | 1,126 |
| nuclear pp | 0 | 0 | 2,200 | 4,400 |
| gas (CCGT) pp | 4,701 | 4,701 | 6,701 | 7,701 |
| gas peak (OCGT) pp | 0 | 0 | 250 | 3,600 |
| hydraulic pp | 2,419 | 2,419 | 2,419 | 2,419 |
| onshore wind pp | 9,661 | 8,663 | 4,827 | 6,939 |
| offshore wind pp | 0 | 5,900 | 9,590 | 9,590 |
| photovoltaic (PV) pp | 5,114 | 5,114 | 5,114 | 9,814 |
| **total** | **51,446** | **56,642** | **51,630** | **60,014** |

*Source: The Ministry of Climate and Environment, in collaboration with the Office of the Government Plenipotentiary for Strategic Energy Infrastructure and PSE S.A. Transmission System Operator*

photovoltaic (PV) pp

offshore wind pp

onshore wind pp

hydraulic pp

gas peak (OCGT) pp

gas (CCGT) pp

nuclear pp

lignite pp

hard coal pp, recent and new

hard coal pp, existing

biomass and biogas CHP and pp

gas CHP, new

coal, gas and other CHP

Figure 19. Forecast structure of the installed capacity of the NPS for 2021–2040

## Forecast of net electricity generation structure

In the optimisation model, the import–export balance was assumed to be zero, due to the need to ensure self-sufficiency of domestic generation in the absence of the availability of foreign energy imports. Poland is not responsible for the availability of energy from other countries, therefore analyses cannot base the security of energy supply on potential imports. Consequently, net electricity generation matches demand and grows from current demand of about 160 TWh to a level of 181.1 TWh in 2030 and to a level of 204.2 TWh in 2040.

The largest increase in the volume of net electricity produced was in RES, which will produce almost four times more electricity in 2040 than they do today. The share of wind power in net electricity generation was about 26% in 2030 (including 13% offshore) and 30% in 2040 (19% offshore). Photovoltaic power plants produce 2.5% of electricity in 2030 and 5% in 2040.

Growth similar to RES can be observed for gas sources which, due to their technical characteristics, play a key role in balancing the power system. The current share of less than 10% in electricity production of gas-fired power plants is observed to increase to 24% in 2030 and almost 30% in 2040.

An important share of electricity generation is provided by nuclear power, which from 2030–2035 will allow to replace the decommissioned coal-fired units operating in the base of the power system. The results of the model showed that nuclear power plants will produce about 9% of electricity in 2035 and about 16% in 2040. An important point is that nuclear power has a very low environmental cost as well as a systemic cost, which makes it a very attractive technology for a socially optimal energy mix.

The high price of CO2 emission allowances and the environmental cost results in a marked decline in the amount of electricity produced by coal-fired sources between 2020 and 2040. From the current around 90 TWh, coal-fired power plants will produce only 11 TWh in 2040. The reported amounts of electricity produced from coal do not include energy production from coal-fired combined heat and power plants. This figure is included in the aggregate corresponding to CHP plants, which also includes gas-fired CHP plants.

Table 38. Net electricity generation forecast [TWh]

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **2025** | **2030** | **2035** | **2040** |
| biomass and biogas | 6.6 | 7.4 | 8.0 | 7.5 |
| hard coal | 35.9 | 26.9 | 21.8 | 18.2 |
| lignite | 50.6 | 41.0 | 18.1 | 4.6 |
| nuclear power | 0.0 | 0.0 | 16.7 | 33.4 |
| natural gas | 45.1 | 52.6 | 67.5 | 67.6 |
| hydropower | 1.8 | 1.8 | 1.9 | 1.8 |
| wind energy, onshore | 25.4 | 23.1 | 14.5 | 22.1 |
| wind energy, offshore | 0.0 | 24.0 | 39.2 | 39.4 |
| solar energy | 4.6 | 4.4 | 4.3 | 9.6 |
| **total** | **170.1** | **181.1** | **191.9** | **204.2** |

*Source: The Ministry of Climate and Environment, in collaboration with the Office of the Government Plenipotentiary for Strategic Energy Infrastructure and PSE S.A. Transmission System Operator*

Figure 20. Structure of electricity generation [TWh]

Solar energy

Wind energy, offshore

Wind energy, onshore

Water

Natural gas

Nuclear

Lignite

Hard coal

Biomass and biogas

CHP plants

Figure 20. Electricity production structure [TWh]

Solar energy

Wind energy, offshore

Wind energy, onshore

Water

Natural gas

Nuclear

Lignite

Hard coal

Biomass and biogas

CHP plants

Figure 21. Share of sources in the structure of electricity generation [%]

## Forecast of net specific emissions in the sector of power plants and CHP plants

Electricity generation according to the model results presented above results in a significant reduction of the averaged level of emissions, which is affected by decommissioning of lignite- and hard coal-fired units as well as commissioning of nuclear and combined cycle gas and steam units and investments in RES. Forecast total emissions decrease by 34 million tCO2 (by 25%) by 2030, and 78 million tCO2 (by 58%) by 2040.

A very important factor that causes a deep reduction of CO2 emissions in the energy sector is the implementation of nuclear power. The average CO2 emission indicator of power and CHP plants decreases from 830 kgCO2/MWh to 533 kgCO2/MWh in 2030 (by 35.8%) and to 278 kgCO2/MWh in 2040 (by 66.5%).

Figure 22. Total annual CO2 emissions from power plants and CHP plants [million tCO2]

Figure 23. Average CO2 emission indicator in power plants and CHP plants [kgCO2/MWh]

## Forecast of hard coal consumption in power plants and CHP plants

When evaluating the results of the model in terms of ensuring energy security and the plan for utilisation of domestic resources, it is crucial to analyse the demand for hard coal by the commercial power industry.

According to the results of the model, which reduced the share of coal-fired power plants in the production of electricity, the consumption of hard coal in power plants and CHPs decreases from over 30 million tonnes per year in 2020 to about 11 million tonnes in 2040. This is a direct result of the increased price path of CO2 emission allowances, as well as environmental costs implemented into the model, which reduce the profitability of using coal technologies. Consequently, this results in a significant decrease in demand for thermal coal. Due to significantly lower carbon intensity, the results of the optimisation model indicated a higher capacity factor of gas sources at the expense of coal-fired power generation, which is reflected in an increase in demand for this fuel.

Figure 24. Hard coal consumption in power plants and combined heat and power plants [million t]

## Forecast of natural gas consumption in power plants and CHP plants

The significant increase in the share of electricity from renewable sources, as well as the aforementioned process of coal unit decommissioning, has resulted in a significant increase in the share of electricity produced in gas-fired power plants in the optimal energy mix, which directly translates into an increase in demand for natural gas in this sector.

According to the model, consumption at the level of 4.2 billion m3 of gas in power plants and CHP plants in 2020 will rise to the level of 12.3 billion m3 of gas in 2040, reaching the peak demand of 13.4 billion m3a few years earlier.

Figure 25. Consumption of natural gas in power plants and CHP plants [billion m3]

## Capital expenditure

The following charts show the capital expenditure necessary to be incurred for the development of the National Power System in order to achieve the energy mix resulting from the optimisation model. According to the results of the model, the highest annual capital expenditure fall in the period 2026–2030 and is associated with investments in offshore wind energy. Between 2031 and 2040, most of the needed expenditure is required to implement nuclear power. Cumulative capital expenditure in 2021–2040, including the costs of financing during construction (capital interest included in the initial value of fixed assets) exceed PLN 340 billion. This scale of costs poses a huge challenge to the whole economy and requires private and public capital to work together.

Table 39. Capital expenditure for the development of generation capacity [PLN billion]

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **2021–2025** | **2026–2030** | **2031–2035** | **2036–2040** | **total** |
| coal, gas and other CHP | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| gas CHP, new | 3.9 | 4.6 | 3.9 | 3.1 | 15.5 |
| biomass and biogas CHP and pp | 0.7 | 3.4 | 3.0 | 1.3 | 8.3 |
| hard coal power plants, existing | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| hard coal pp, recent and new | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| lignite power plants | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| nuclear pp | 0.0 | 16.0 | 63.0 | 25.9 | 104.8 |
| gas (CCGT) pp | 7.2 | 0.0 | 10.1 | 0.3 | 17.7 |
| gas peak (OCGT) pp | 0.0 | 0.0 | 3.1 | 5.0 | 8.1 |
| hydraulic pp | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| onshore wind power plants | 18.5 | 0.0 | 0.0 | 16.0 | 34.4 |
| offshore wind power plants | 20.0 | 74.3 | 31.4 | 0.0 | 125.8 |
| photovoltaic pp (PV) | 14.2 | 0.0 | 0.0 | 13.4 | 27.6 |
| **total** | **64.5** | **98.3** | **114.5** | **64.9** | **342.3** |

pp – power plants, CHP – combined heat and power plants

Source: The Ministry of Climate and Environment, in collaboration with the Office of the Government Plenipotentiary for Strategic Energy Infrastructure and PSE S.A. Transmission System Operator

photovoltaic (PV) pp

offshore wind pp

onshore wind pp

hydraulic pp

gas peak (OCGT) pp

gas (CCGT) pp

nuclear pp

lignite pp

hard coal pp, recent and new

hard coal pp, existing

biomass and biogas CHP and pp

gas CHP, new

coal, gas and other CHP

photovoltaic (PV) pp

offshore wind pp

onshore wind pp

hydraulic pp

gas peak (OCGT) pp

gas (CCGT) pp

nuclear pp

lignite pp

hard coal pp, recent and new

hard coal pp, existing

biomass and biogas CHP and pp

gas CHP, new

coal, gas and other CHP

Figure 26. Capital expenditure for the expansion of generating capacity [PLN billion], including the costs of financing during the construction period (capital interest included in the initial value of fixed assets)

Figure 27. Cumulative capital expenditure for the expansion of generating capacity, including the costs of financing during construction (capital interest included in the initial value of fixed assets)

## Conclusions of the analyses

1. **Renewable energy sources**

In order to achieve the target set in PEP2040 for the share of RES in electricity generation in 2030, there is a significant development of offshore wind farms and the development of photovoltaics. In the further period, the installed capacity in PV technology is dynamically increasing, which results from its growing profitability. The results of the optimisation model show that by 2040 the installed PV capacity will be nearly 10 GW, similar to the installed offshore wind capacity.

For onshore wind, we see a relatively small increase in installed capacity between 2020 and 2025. In the following years, until the mid-2030s, due to the depletion of some of the existing onshore wind capacity and at the same time the high system cost generated by this technology, there is a gradual reduction in the amount of installed capacity. After 2035, new onshore wind capacity increases again to 6.9 GW in 2040.

The capacity of other RES (biomass, biogas) is growing only slightly. Installed capacity between 2035 and 2040 will amount to 1.4 GW and will account for about 4% in electricity generation over the entire period analysed.

The presented values of installed capacity in solar sources (photovoltaics) and onshore wind farms in the years 2025–2035 are the result of strategic decisions concerning the development of the offshore wind farm sector and minimisation of the total cost of electricity generation in the national power system. The early development of offshore wind farms, provided through the Act on promoting offshore wind farm generation, results in a significant increase in electricity generation from uncontrollable sources over the period 2025–2035. Due to the need to ensure power balance and energy production in the NPS as well as to minimise the total costs of the transition, controllable sources are developed in addition to the uncontrollable sources in order to secure the operation of the system. An additional increase in unstable energy production in the 2025–2035 period, in which there is an accumulation of the commissioning of old, economically inefficient coal sources, would at the same time increase investment needs in dispatchable sources needed to maintain the necessary reserve capacity. By minimising the total cost of the energy transition, the model avoids the accumulation of capital expenditure and decides to rebuild the available capacity first, as a result of which the development of photovoltaics and onshore wind farms is stagnant. Greater development of these technologies in the period under discussion is possible, however, given the projected balance situation in the NPS, it will result in higher costs of ensuring energy supply security.

1. **Natural gas**

Due to economic and technical conditions, natural gas will be used in cogeneration and gas-fired power plants as reserve, regulating and peaking capacity. Installed capacity in natural gas-fired units reaches over 11 GW in 2040. Demand for natural gas in the power sector rises from 4.2 billion m3 in 2020 to a peak of 13.4 billion m3 in 2036, and then declines slightly. Technical import capacity after 2023 will make it possible to cover such demand while maintaining energy security (without supplies from the East).

1. **Nuclear power**

Nuclear power, not only because of its zero emissions, but also because of its low environmental and system cost, is a highly desirable part of the energy mix. This technology will not only achieve deep decarbonisation of the power system to the extent required by the EU, but will also minimise the social cost of operation of the NPS. According to the model results, the first nuclear unit with a capacity of 1.1 GW will be completed in 2030–2035, with subsequent units to be built every 2 years, according to the technical capabilities of the NPS.

1. **Hard coal**

The high CO2 price scenario and the environmental costs implemented result in that the installed capacity in hard coal-fired power plants will be rapidly reduced between 2020 and 2040. In 2040, only 2.2 GW of capacity will remain in the system from the 11.5 GW of hard coal capacity existing today and 3.5 GW of units under construction or built in recent years. Due to high operating costs, these units will constitute a back-up, which means only a 3% share of this technology in electricity generation in 2040.

As a result, the use of hard coal in power plants and combined heat and power plants will fall to 11.2 million tonnes per year in 2040 (from over 30 million tonnes per year in 2020).

1. **Lignite**

The schedule of the decommissioning of lignite-fired units and the lack of profitability of investing in new generating capacity will result in a dynamic reduction of the capacity installed in this technology in the NPS after 2030, which will simultaneously result in a significant decrease in electricity generation from sources based on this raw material. In 2040, only 1.1 GW of lignite-fired generation units will remain in the system, which will translate into a 2% share in electricity production.

## Conclusions – confirmation of PEP2040 specific objectives

The presented results of the forecast from the optimisation model, which assumes prices of CO2 emission allowances much higher than in the scenario presented in Chapter 1, as well as takes into account the share of environmental and system costs, confirm the proper definition of specific objectives in PEP2040, namely:

* optimal use of own energy resources,
* expansion of electricity generation and grid infrastructure,
* diversification of natural gas sources and suppliers and expansion of network infrastructure,
* implementation of nuclear power,
* development of renewable energy sources (including offshore wind farms),
* development of district heating and cogeneration,
* improvement of energy efficiency

Their implementation will not only allow for a significant reduction in the carbon intensity of the NPS, but will also lead to the achievement of an energy mix that is optimal in terms of social costs while maintaining the fundamental role of the state, which is to ensure energy security.

## Extended technical and economic assumptions

This chapter complements Chapter 2.1 and indicates details of the technical and economic assumptions made for the model. All economic indicators used in the analysis were assumed to be based on forecast paths referred to as realistic or average. The use of average values was considered to be the most rational assumption and one bearing the lowest risk of overestimation or underestimation of technology costs.

Table 40. Unit capital expenditure, contractual – Overnight Cost (OVN) [million PLN/GW net]

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **2020** | **2025** | **2030** | **2035** | **2040** |
| nuclear power – PWR GEN III+ | 22,346 | 21,657 | 21,147 | 20,576 | 19,996 |
| offshore wind farms (OffWF) | 15,010 | 13,396 | 11,953 | 10,692 | 9,590 |
| onshore wind farms (OnWF) | 6,462 | 5,880 | 5,298 | 5,032 | 4,761 |
| photovoltaics (PV) | 3,903 | 3,518 | 3,129 | 2,956 | 2,782 |
| biomass | 13,802 | 13,733 | 13,502 | 13,233 | 12,957 |
| natural gas – OCGT | 2,326 | 2,203 | 2,148 | 2,108 | 2,078 |
| natural gas – CCGT | 3,266 | 3,133 | 3,069 | 3,017 | 2,975 |
| natural gas – CCGT + CCS | 8,002 | 7,478 | 7,155 | 6,894 | 6,669 |
| hard coal – ASC PC | 7,363 | 7,363 | 7,363 | 7,363 | 7,363 |
| hard coal – ASC PC + CCS | 20,684 | 20,113 | 19,708 | 19,247 | 18,776 |
| hard coal – IGCC | 14,536 | 13,816 | 13,434 | 13,125 | 12,863 |

Source: Ministry of Climate and Environment in cooperation with the Office of the Government Plenipotentiary for Strategic Energy Infrastructure on the basis of forecasts of the National Renewable Energy Laboratory (NREL) – ATB'19[[17]](#footnote-17), International Energy Agency (IEA) – WEO'19[[18]](#footnote-18) and Polskie Sieci Elektroenergetyczne (PSE) - PRSP'20[[19]](#footnote-19)

Table 41. Unit fixed O&M costs (FOM) [million PLN/GW net]

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **2020** | **2025** | **2030** | **2035** | **2040** |
| nuclear power – PWR GEN III+ | 371 | 371 | 371 | 371 | 371 |
| offshore wind farms (OffWF) | 405 | 344 | 292 | 247 | 210 |
| onshore wind farms (OnWF) | 156 | 150 | 143 | 138 | 133 |
| photovoltaics (PV) | 47 | 42 | 38 | 35 | 33 |
| biomass | 411 | 411 | 411 | 411 | 411 |
| natural gas – OCGT | 45 | 45 | 45 | 45 | 45 |
| natural gas – CCGT | 39 | 39 | 39 | 39 | 39 |
| natural gas – CCGT + CCS | 124 | 124 | 124 | 124 | 124 |
| hard coal – ASC PC | 121 | 121 | 121 | 121 | 121 |
| hard coal – ASC PC + CCS | 295 | 295 | 295 | 295 | 295 |
| hard coal – IGCC | 199 | 199 | 199 | 199 | 199 |

Source: Ministry of Climate and Environment in collaboration with the Office of the Government Plenipotentiary for Strategic Energy Infrastructure based on the forecasts of the National Renewable Energy Laboratory (NREL) – ATB'19

Table 42. Unit variable O&M costs (VOM) [PLN/MWh]

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **2020** | **2025** | **2030** | **2035** | **2040** |
| nuclear power – PWR GEN III+ | 26 | 26 | 26 | 26 | 26 |
| offshore wind farms (OffWF) | 0 | 0 | 0 | 0 | 0 |
| onshore wind farms (OnWF) | 0 | 0 | 0 | 0 | 0 |
| photovoltaics (PV) | 0 | 0 | 0 | 0 | 0 |
| biomass | 20 | 20 | 20 | 20 | 20 |
| natural gas – OCGT | 26 | 26 | 26 | 26 | 26 |
| natural gas – CCGT | 10 | 10 | 10 | 10 | 10 |
| natural gas – CCGT + CCS | 26 | 26 | 26 | 26 | 26 |
| hard coal – ASC PC | 18 | 18 | 18 | 18 | 18 |
| hard coal – ASC PC + CCS | 37 | 37 | 37 | 37 | 37 |
| hard coal – IGCC | 29 | 29 | 29 | 29 | 29 |

Source: Ministry of Climate and Environment in cooperation with the Office of the Government Plenipotentiary for Strategic Energy Infrastructure based on the forecasts of the National Renewable Energy Laboratory (NREL) – ATB'19; VOM of nuclear power plants includes a fee for the decommissioning fund in accordance with the RM Regulation of 10 October 2012.[[20]](#footnote-20)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **2020** | **2025** | **2030** | **2035** | **2040** |
| offshore wind farms (OffWF) | 44.5% | 45.7% | 46.9% | 48.2% | 49.5% |
| onshore wind farms (OnWF) | 35.4% | 36.2% | 36.9% | 37.6% | 38.4% |
| photovoltaics (PV) | 10.6% | 11.5% | 12.4% | 13.2% | 14.1% |

Table 43. Annual average capacity factor (CF) [%]

Source: Ministry of Climate and Environment in cooperation with the Office of the Government Plenipotentiary for Strategic Energy Infrastructure on the basis of the results of the strategic scenario for optimisation of the total cost of electricity generation in the National Power System carried out in cooperation with PSE S.A.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **2020** | **2025** | **2030** | **2035** | **2040** |
| nuclear power – PWR GEN III+ | 32.6% | 32.6% | 32.6% | 32.6% | 32.6% |
| offshore wind farms (OffWF) | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| onshore wind farms (OnWF) | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| photovoltaics (PV) | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| biomass | 25.3% | 25.3% | 25.3% | 25.3% | 25.3% |
| natural gas – OCGT | 35.4% | 36.6% | 37.9% | 37.6% | 37.6% |
| natural gas – CCGT | 51.2% | 51.8% | 52.4% | 52.3% | 52.3% |
| natural gas – CCGT + CCS | 45.4% | 45.5% | 45.6% | 45.5% | 45.5% |
| hard coal – ASC PC | 38.8% | 39.0% | 39.1% | 39.0% | 39.0% |
| hard coal – ASC PC + CCS | 30.9% | 33.9% | 37.7% | 36.9% | 36.9% |
| hard coal – IGCC | 40.7% | 43.4% | 46.5% | 45.8% | 45.8% |

Table 44. Annual average electricity generation efficiency [%]

Source: Ministry of Climate and Environment in collaboration with the Office of the Government Plenipotentiary for Strategic Energy Infrastructure based on the forecasts of the National Renewable Energy Laboratory (NREL) – ATB'19 and aggregated data of Polskie Sieci Elektroenergetyczne (PSE)

# List of abbreviations

|  |  |  |
| --- | --- | --- |
| **CHP** | – | combined heat and power |
| **DSR** | – | demand side response |
| **EC** | – | European Commission |
| **EU** | – | European Union |
| **EU ETS** | – | European Union Emissions Trading System |
| **EUA** | – | European Union Allowance |
| **GHG** | – | greenhouse gases |
| **GUS** | – | Central Statistical Office |
| **IEA** | – | International Energy Agency |
| **JWCD** | – | centrally dispatched generating units |
| **KOBiZE** | – | National Centre for Balancing and Emission Management |
| **KPEiK** | – | *National Energy and Climate Plan 2021–2030* |
| **LULUCF** | – | Land Use, Land-Use Change and Forestry |
| **nJWCD** | – | generation units which are not centrally dispatched |
| **NPS** | – | national power system |
| **RES** | – | renewable energy sources |
| **TCM** | – | total cost methodology |
| **WACC** | – | weighted average cost of capital |

1. *World Energy Outlook 2017 (WEO 2017)*, International Energy Agency, 2017. [↑](#footnote-ref-1)
2. *The National Energy and Climate Plan 2021-2030,* submitted to the European Commission on 30 December 2019, indicates the same forecasts presented in this document. [↑](#footnote-ref-2)
3. Final energy consumption is understood as the consumption of the final consumer for their own use. This means that, for example, a household may use final energy in the form of electricity and natural gas for space heating. Thus, e.g. the "coal" item does not include the use of coal to generate electricity. [↑](#footnote-ref-3)
4. Art. 7(6) of Directive 2012/27/EU *on energy efficiency* (Directive (EU) 2018/2002 of the European Parliament and of the Council of 11 December 2018 amending Directive 2012/27/EU on energy efficiency) provides that Member States shall describe in their integrated national energy and climate plans, in accordance with Appendix III to Regulation (EU) 2018/1999, the calculation of the energy savings to be achieved between 1 January 2021 and 31 December 2030, as referred to the first paragraph of Art. 7 Sec. 1(b) of Directive 2012/27/EU and, where applicable, explain how the annual savings rate and the basis for calculation have been determined and which of the options referred to in Art. 7 Sec. 4 have been used and to what extent.

   In addition, in accordance with the provisions of Item 5) of Appendix V to Directive 2012/27/EU, Member States shall also notify to the European Commission the detailed method of operation of the energy efficiency obligation schemes and the alternative policy measures referred to in Art. 7a and 7b and Art. 20 Sec. 6 of Directive 2012/27/EU that they propose. [↑](#footnote-ref-4)
5. Commission Recommendation of 25 September 2019 on transposing the energy saving obligations under the Energy Efficiency Directive, C(2019) 6621 FINAL. [↑](#footnote-ref-5)
6. Calculated according to the algorithm: (+) final consumption (+) energy sector consumption (+) energy transition sector consumption (–) transmission and distribution losses (+/–) statistical differences (=) gross domestic energy consumption. [↑](#footnote-ref-6)
7. The gross final energy consumption from RES consists of consumption in three sectors: (1) electricity; (2) heating and cooling; (3) transport. [↑](#footnote-ref-7)
8. Directive (EU) 2019/944 of the European Parliament and of the Council of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU [↑](#footnote-ref-8)
9. Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 *on industrial emissions* (Integrated Pollution Prevention and Control). [↑](#footnote-ref-9)
10. *The EMEP/EEA air pollutant emission inventory guidebook 2016*. [↑](#footnote-ref-10)
11. Directive 2016/2284 of the European Parliament and of the Council of 14 December 2016 on the *reduction of national emissions of certain atmospheric pollutants, amending Directive 2003/35/EC and repealing Directive 2001/81/EC*  [↑](#footnote-ref-11)
12. A wider range of economy-wide forecasts can be found in Appendix 2 (Chapter 5.1.2) of the *National Energy and Climate Plan 2021–2030*. [↑](#footnote-ref-12)
13. Change in reduction targets and prices of emission allowances resulting from the Communication on the European Green Deal, Centre for Climate and Energy Analysis (CAKE) KOBIZE, Warsaw, March 2020. [↑](#footnote-ref-13)
14. SWD(2020) 176 final, 17 September 2020. (Table 28: Overview of key modelling results, p. 130), accessed at: https://eur-lex.europa.eu/resource.html?uri=cellar:749e04bb-f8c5-11ea-991b-01aa75ed71a1.0001.02/DOC\_1&format=PDF [↑](#footnote-ref-14)
15. *World Energy Outlook 2019 (WEO 2019)*, International Energy Agency, 2019. [↑](#footnote-ref-15)
16. NEEDS (2004-2008) – New Energy Externalities Developments for Sustainability http://www.needs-project.org/; European Commission (1990-2005), External Costs of Energy – http://www.externe.info [↑](#footnote-ref-16)
17. *2019 Annual Technology Baseline,* NREL (2019), Mid Scenarios. [↑](#footnote-ref-17)
18. *World Energy Outlook 2019,* IEA 2019, EU Stated Policies scenarios [↑](#footnote-ref-18)
19. *Development Plan for Meeting Current and Future Electricity Demand for 2021–2030 – main document, Generation Sufficiency Analysis for 2020–2030,* PSE 2020. [↑](#footnote-ref-19)
20. Regulation of the Council of Ministers of 10 October 2012 on the level of contributions to cover the costs of final disposal of spent nuclear fuel and radioactive waste, and to cover the costs of the decommissioning of a nuclear power plant carried out by an organisational unit which has been granted authorisation to operate the nuclear power plant [↑](#footnote-ref-20)