POLSKIE TOWARZYSTWO
ELEKTROCIEPŁOWNI
ZAWODOWYCH

Decarbonization of the district heating sector in Poland in light of the "Fit for 55" package

An analysis by the Polish Association of Professional Combined Heat and Power Plants

POLSKIE TOWARZYSTWO ELEKTROCIEPŁOWNI ZAWODOWYCH (POLISH ASSOCIATION OF PROFESSIONAL COMBINED HEAT AND POWER PLANTS)
April 2022

Table of contents

Introduction **4**

1 Description of the conditions for operation of the district heating sector in Poland **4**

1.1 The district heating sector in statistical terms 4

1.1.1 Potential of large-scale district heating 4

1.1.2 Basic figures characterizing the district heating sector in Poland 5

1.1.3 Heat generation 6

1.1.4 Fuel consumption in the large-scale district heating sector 6

1.1.5 Sales, generation costs and selling prices of heat 7

1.1.6 Meeting the requirements of an efficient district heating system 8

1.2 Polish district heating sector in comparison with other European countries 9

1.3 Climatic conditions in Poland 12

1.4 Conditions arising from the location of district heating systems in cities 15

1.5 Available technologies for medium- and large-sized district heating systems 17

1.5.1 Coal technologies 17

1.5.2 Gas technologies 18

1.5.3 Other technologies 19

2 Key legislative proposals for district heating in "Fit for 55" package **21**

2.1 Issues arising from the draft EED 21

2.2 Issues arising from the draft RED III directive 23

2.3 Issues arising from the draft EPBD 24

3 Key assumptions used to determine optimal technology options **25**

3.1 Macroeconomic and market assumptions 26

3.2 Technical and economic assumptions 29

3.3 Benchmark heat markets 30

3.4 Technology options 33

3.5 Data on large-scale heat markets in Poland 36

4 Analysis results **37**

4.1 Fuel demand considerations 41

4.2 Conditions of the district heating networks 44

4.3 Conditions for consumer systems 46

5 Summary and recommendations **47**

5.1 Summary 47

5.2 Recommendations 49

Appendix 1: Case study of the transformation of the district heating system in the Kraków metropolitan area 52

1. Heat market – Overview: 52
2. Macroeconomic and market assumptions 54
3. Technical and economic assumptions 54
4. Technology options 54
5. Analysis results 55

Introduction

This analysis was conducted to verify the feasibility of transforming the district heating sector in Poland as assumed in the "Fit for 55" package. The district heating sector in Poland has unique characteristics and importance compared to other European Union member states. The current situation of the district heating sector in Poland, along with climatic conditions, is detailed below. At the same time, available technologies and fuels for transforming the district heating sector were identified. The above facts were taken into account in the conducted study of the possibility of complying with the most relevant requirements under the proposed EU legislation, in particular the draft EED, RED III and EPBD directives. The answer to the question of the possibility of transforming the district heating sector in Poland comes from the results of economic model calculations. The use of market-based, economic data and technological characteristics of the study provided a key answer about the feasibility of adaptation to the requirements of the "Fit for 55" package and an estimate of the cost of transformation. Based on a detailed analysis on systems of different sizes, key conclusions and recommendations for further legislative action were drawn.

The purpose of the analysis is to identify the reasonable conditions for the transformation towards emission reductions. The identified conditions should be the basis for proper adaptation of the introduced regulatory solutions appropriate to the unique challenges facing the district heating sector in Poland. Based on these, recommendations were presented, which can be found at the end of this analysis.

1 Description of the conditions for operation of the district heating sector in Poland

1.1 The district heating sector in statistical terms

1.1.1 Potential of large-scale district heating

Broadly defined, district heating is divided into large-scale district heating, i.e. district heating systems consisting of district heating networks with generating units, and small-scale district heating, i.e. any individual heat source in buildings or households. The large-scale heat is used for heating purposes in 40.4% of households in Poland[1], or approx. 6 million.

As of the end of 2020, 387 companies held licenses issued by the President of the Energy Regulatory Office (ERO) for the generation, transmission, distribution and trading of heat (a total of 797 individual licenses for a given type of heat supply business). Detailed data on the characteristics of the licensed heating industry from 2002 to 2020 are shown in Table 1.

[1] Statistics Poland, "*Energy consumption in households in 2018.*"

Table 1: Potential of the licensed district heating in 2002-2020[2]

Specification	2002	2019	2020	Dynamics 2020/2002 [%]	Dynamics 2020/2019 [%]
Number of licensed district heating companies	894.00	396.00	387.00	43.29	97.73
Number of companies participating in the study	849.00	404.00	399.00	47.00	98.76
Installed capacity in MW	70,952.80	53,560.90	53,271.10	75.08	99.46
Contracted capacity* in MW	38,937.00	34,408.00	34,665.54	89.03	100.75
Length of networks** in km	17,312.50	21,701.20	22,123.11	127.79	101.94
Employment in jobs	60,239.00	29,037.00	28,737.00	47.70	98.97
Total heat sales *** in TJ	469,355.50	344,712.64	343,690.65	73.23	99.70
Heat returned to the network *** in TJ	336,043.00	258,909.40	257,377.29	76.59	99.41
Heat delivered to network-connected consumers*** in TJ	298,938.10	226,671.83	224,500.80	75.10	99.04

* Contracted capacity in 2003, no data on contracted capacity was collected in 2002

** Since 2004, the length of the network also includes low-parameter networks (so-called external consumer systems)

*** Definitions of these categories are provided in the *Methodological Notes* section of the report "Heat power engineering in numbers – 2020"

1.1.2 Basic figures characterizing the district heating sector in Poland

Licensed district heating companies have a diverse and fragmented technical infrastructure, which is defined by two basic values: installed thermal capacity and the length of the district heating network. In 2020, the installed thermal capacity was 53,271.1 MW, and the achievable capacity was 52,593 MW. In 2020, licensed district heating companies had district heating networks with a length of 22,123.1 km (vs. 21,701.2 km in 2019).

Table 2 summarizes the length of the district heating networks in Poland and their development since 2002. It is worth noting that the largest share is made up of district heating networks with a length of more than 50 km. At the same time, the data shows the highest growth rate for this category.

Table 2: Length of district heating networks in Poland[3]

Length of networks [km]	2002	2018	2019	2020
Poland	**17,312.5**	**21,367.6**	**21,701.2**	**22,123.1**
3 and below	326.5	39.8	42.2	36.3
3–5	402.4	114.7	94.9	90.8
5–7	431.2	125.3	96.2	90.9
7–10	580.7	381.0	368.7	335.2
10–20	1,597.1	1,256.9	1,197.2	1,269.5
20–50	2,545.1	3,116.3	3,159.8	3,075.5
More than 50	11,429.5	16,333.6	16,742.2	17,224.9

* The length of the district heating network from 2018 includes low-parameter networks (so-called external consumer systems)

Energy companies generate heat in sources of varying sizes, with a quantitative predominance of small sources, i.e. with an installed thermal capacity of up to 50 MW, which 44.6% of the companies had, as shown in Figure 1.

[2] Own study based on the ERO report, "*Heat power engineering in numbers – 2020*"

[3] Ibidem

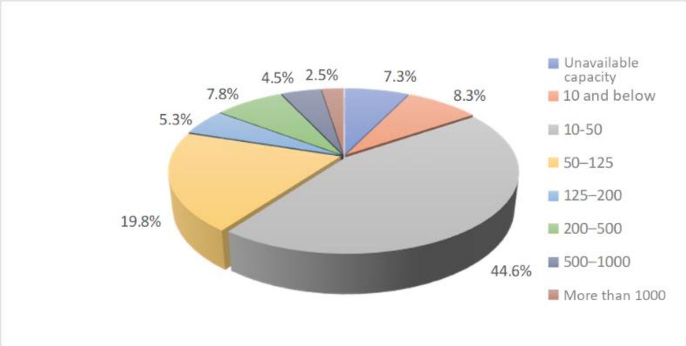


Chart 1: Structure of district heating companies by installed capacity [MW] in heat sources in 2020.[4]

Significantly, the ten licensed entities had an installed capacity of sources exceeding 1,000 MW each, and their combined generating capacity accounted for more than 1/3 of the generating capacity of all licensed sources. These companies were also active in the area of electricity generation.

1.1.3 Heat generation

Energy companies operating in the field of heat generation produced 393.8 thousand in 2020, including heat recovered in technological processes. TJ of heat. Detailed information on the generation of licensed heat, as well as the volumes of heat delivered to the network and customers, is shown in Figure 1.

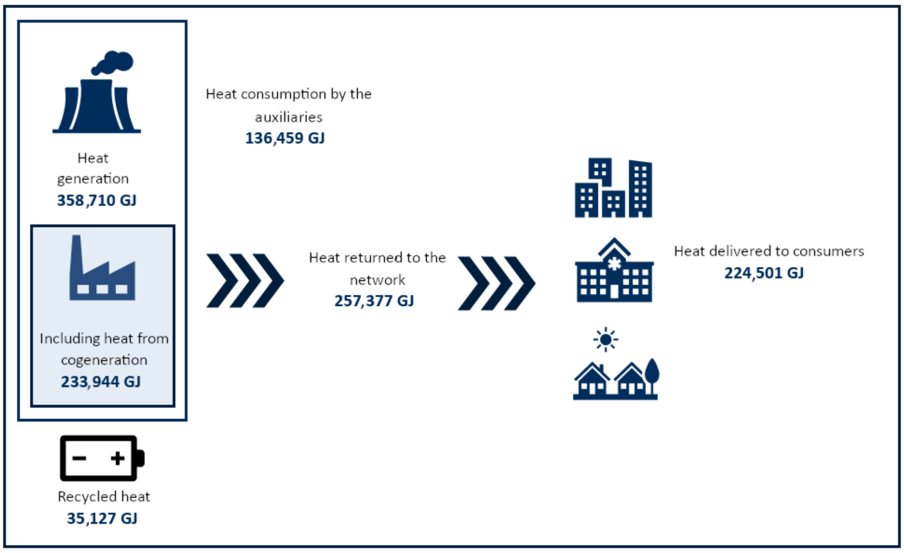


Fig. 1: Heat generation in Poland in 2020[5]

Of the total heat generation in licensed energy companies in 2020, the share of heat generated in cogeneration was 65.2%. Of the 370 companies generating heat in 2020, 34.6% of them also generated heat in cogeneration.

1.1.4 Fuel consumption in the large-scale district heating sector

Currently, the licensed district heating sector continues to be dominated by coal fuels, which accounted for 68.9% of fuels consumed in heat sources in 2020 (2019 – 71%, 2018 – 72.5%, 2017 –

---

[4] *Ibidem*
[5] *Ibidem*

74%). Since 2002, the share of coal fuels decreased by 12.8 pp, while an increase in the share of gaseous fuels – by 6.9 pp and renewable energy sources (RES) – by 7.2 pp – was observed. The structure of fuels in 2002 and 2020 is shown in Figure 2.

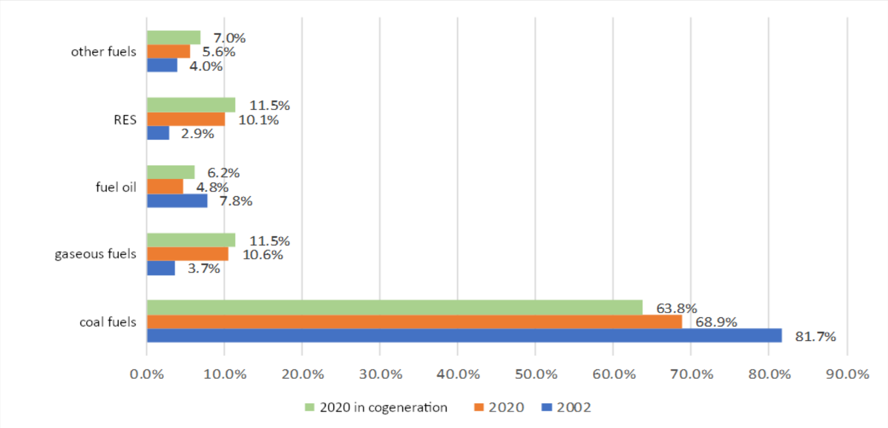


Chart 2: Structure of fuels consumed for heat generation in 2002 and in 2020, and for cogeneration in 2020.[6]

It should be noted that the diversity of fuels used to generate heat is somewhat greater among companies generating heat in cogeneration (heat and power plants). This group of companies is also dominated by coal fuels, but a third are other fuels, including 10.1% of renewable sources, 10.6% of natural gas and 4.8% of fuel oil.

1.1.5 Sales, generation costs and selling prices of heat

In 2020, the volume of total heat sales by licensed district heating companies (including resale to other companies) amounted to 343,690.7 TJ.

The average single-component price of heat sold from all licensed heat-generating sources was PLN 44.33/GJ, up by 8.2% from the 2019 price (PLN 40.97/GJ). At the same time, the average price of heat sold from licensed heat-generating sources without cogeneration was PLN 51.87/GJ, while the average single-component price of heat sold from licensed heat-generating sources with cogeneration was PLN 41.32/GJ.

It is also worth pointing out that the cost of heat generation – and thus the level of its price – is closely correlated with the type of fuel used for this generation as illustrated in Table 3.

Table 3: Prices for heat generated in 2020[7]

Specification	2018 [PLN/GJ]	2019 [PLN/GJ]	2020 [PLN/GJ]	Dynamics 2019/2018 [%]	Dynamics 2020/2019 [%]
Average price of heat generation	**38.72**	**40.97**	**44.33**	**105.81**	**108.2**
Hard coal	37.93	40.34	43.88	106.35	108.77
Brown coal	24.74	25.09	28.03	101.41	111.72
Light fuel oil	68.49	73.75	58.4	107.68	79.19
Heavy fuel oil	34.66	34.95	37.16	100.84	106.33
High methane natural gas	50.72	52.17	53.64	102.86	102.82
Natural gas	42.13	43.34	46.06	102.87	106.28
Biomass	41.42	42.65	45.77	102.97	107.31
Other renewable energy sources	36.44	36.53	37.71	100.25	103.23
Other fuels	36.87	37.84	44.08	102.63	116.49

The level of revenue earned by district heating companies is fundamentally influenced by the volume of heat sales, which depends on the thermal needs of customers and the type of fuel consumed

[6] *Ibidem*
[7] *Ibidem*

at the source. These in turn shape average heat prices and the range of services provided to customers. Consumers' thermal modernization efforts, higher average temperatures of the winter months and increasing levels of consumer savings are reasons for reduced heat supply and, consequently, lower revenues for companies.

The year 2020 was a special period for the entire economy, including the district heating industry. During the COVID-19 pandemic, there was stabilization in the fuel market, although this did not reduce the average price of heat generation, which was influenced by the level of the cost of purchasing CO_2 emission allowances. These data are illustrated in Table 4.

Table 4: Total result on energy activities (electricity and heat) at power plants and combined heat and power plants[8]

Specification	[PLN thousand]
Revenues from sales of electricity and heat	50,327,257.40
Costs of own operations	27,709,782.80
Costs of purchasing energy for resale, costs of remitted property rights, compensatory payment	10,504,497.60
Selling costs	970,872.90
Management costs	1,013,280.20
Total cost of revenue from the sale of electricity and heat	40,198,433.50
Result on sales of electricity and heat	10,128,823.90
Other revenues	1,896,153.90
including revenue from the sale of CO_2 emission allowances	*736,250.30*
Other costs	16,522,353.00
including costs of purchasing CO_2 emission allowances	*11,127,243.70*
Result including other revenues and costs	-4,497,375.20
Financial revenues	79,821.00
Financial costs	797,233.90
Result including financial revenues and costs	-5,214,788.10

1.1.6 Meeting the requirements of an efficient district heating system

According to the current definition, an efficient heating and cooling system is one that uses the following to generate heat or cooling:

- at least 50% of energy from renewable sources, or
- at least 50% waste heat, or
- at least 75% of heat coming from cogeneration, or
- at least 50% combination of such energy and heat[9].

In Poland, the vast majority of district heating systems still remain inefficient, with 2019 data showing the share of efficient systems at only approx. 10% of the total number of district heating systems, mainly in large metropolitan areas. The primary factor causing this starting point is the nature of Poland's district heating networks. In Poland, metropolitan areas are heated and supplied with heat for domestic hot water by large district heating systems with high generating capacities. It is practically impossible to divide large district heating systems into smaller ones, especially in large cities, due to dense housing developments, high density of building infrastructure, land ownership structure. At the same time, there is a shortage of RES technologies that could on a wider scale ensure that the temperature of the medium fed into the network is sufficiently high (this is further described in subsection 1.4). Reducing the temperature on the receiving side of the district heating system is not feasible in a reasonable and responsible manner within a few years.

Achieving the status of an efficient district heating system upon completion of the investment project is a prerequisite for accessing public funding for the retrofit of district heating systems. Restricting state aid to inefficient district heating systems hinders their retrofit and transition to low-carbon technologies.

[8] *Compiled on the basis of ERO data and G.10.2 reports (ARE)*
[9] Article 7b of the Act of April 10, 1997 – Energy Law (Journal of Laws of 2021, item 716, as amended)

1.2 Polish district heating sector in comparison with other European countries

The large-scale district heating sector currently supplies approx. 12-13% of heat demand in the European Union's (EU). The share of district heating as a heating source varies considerably from region to region, for example, in Northern and Eastern European countries it is a common solution, while in Southern Europe and most Western European countries it plays a minor role. The largest district heating sector in Europe is found in Germany, followed by Poland and Sweden.[10] The situation in this regard is illustrated in Figure 2.

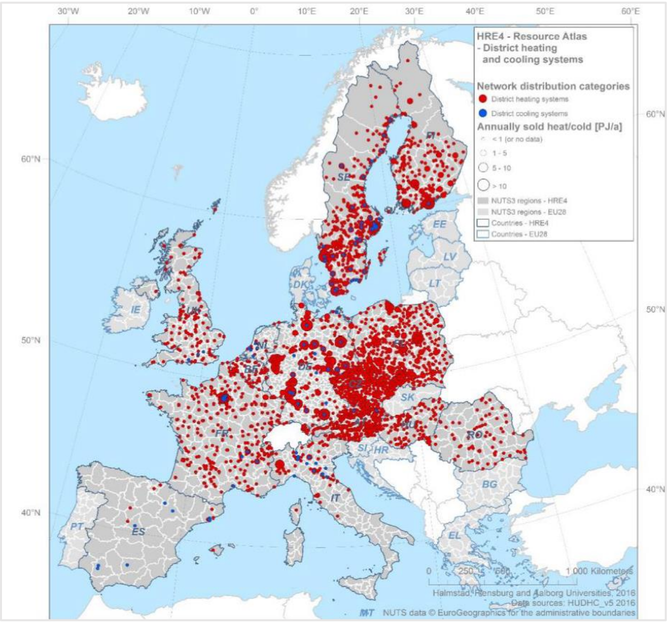


Fig. 2: Map of 3207 district heating (3106) and cooling (101) systems in 2737 cities among 14 member countries of the Heat Roadmap Europe4, by network distribution category and annual volumes of heating and cooling sales[11]

Currently, approx. 60 million EU citizens are supplied with heat through district heating networks, and an additional 140 million live in cities with at least one district heating system[12]**..** According to Heat Roadmap Europe, if the urbanization trend continues and appropriate investments are made, almost half of Europe's heat demand could be met by district heating by 2050.[13]

The district heating sector accounts for more than 50% of gross final energy consumption in the European Union, making it the largest consumer of the energy sector. Three-quarters of Europe's heat is still generated from fossil fuel-based sources, almost half of which is natural gas. Buildings, including the residential and tertiary sectors, currently account for 40% of the EU's total final energy consumption – having the largest share[14]. Housing is responsible for using 54% of final energy for heating and cooling, followed by services at 21% and industry at 24% (2015 data)[15].

District heat sales, or the actual amount of heat delivered to final consumers, is one of the key business indicators that indicates a benchmark as to the size of the sector. Poland's district heating market is the second largest in Europe after Germany, as shown in Figure 3.

---

[10] *EHP, Country by Country Report (2019)*

[11] *U. Persson, Methodologies and assumptions used in the mapping, Heat Roadmap Europe Deliverable 2.3, 2017.*

[12] EHP, *Country by Country Report* (2019)

[13] Heat Roadmap Europe, Heat Roadmap Europe

[14] COM(2020) 662 final, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: A Renovation Wave for Europe – greening our buildings, creating jobs, improving lives, Brussels, October 14, 2020.

[15] European Commission Joint Research Centre (JRC), *Decarbonising the EU heating sector* (2019)

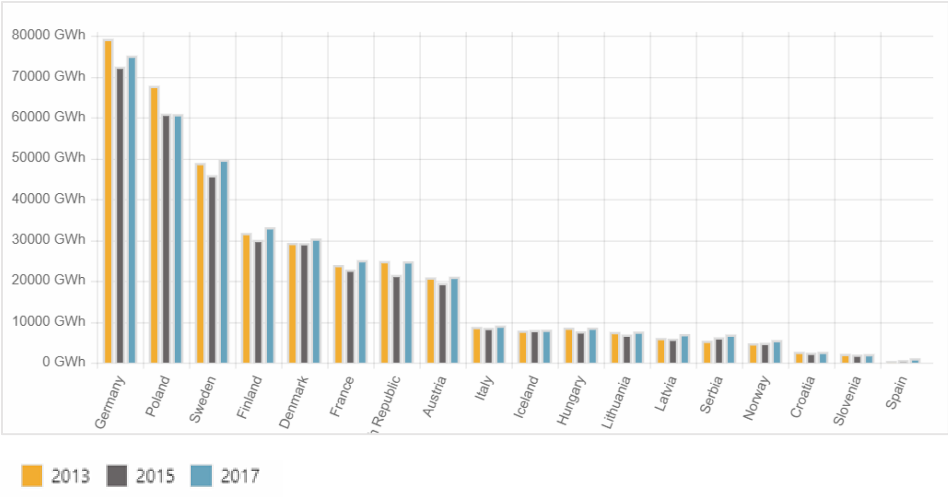


Chart 3: Total district heat sales to customers (2013 – 2017, in GWh)[16]

The size of the heating sector is also determined by the number of its customers. In this respect, ranked first, Poland, together with Germany, is significantly ahead of the rest of European countries. In 2017, the number of heat consumers in Poland exceeded 16 million, meaning that one in four large-scale heat customers in Europe was a resident of this country. The number of large-scale heat consumers in 2017 is shown in Figure 4.

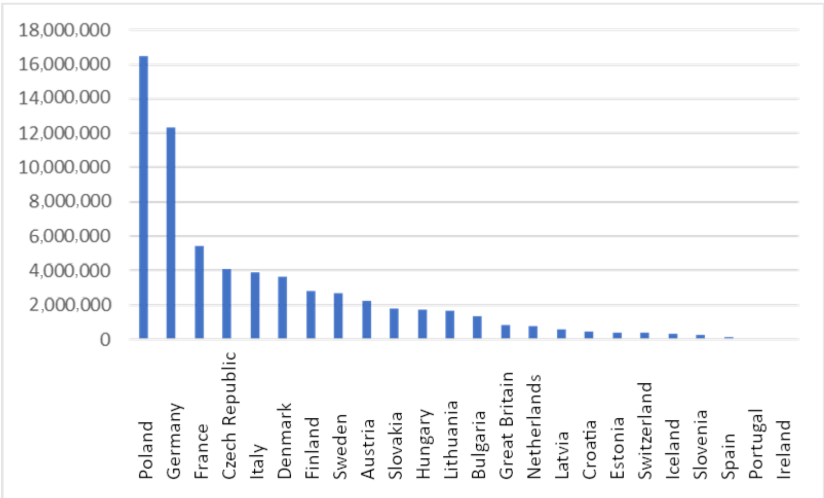


Chart 4: Number of large-scale heat consumers, 2017[17]

In terms of the length of the district heating network, Poland is surpassed in the entire European Union only by Denmark and Germany, as shown in Figure 5. The total length of district heating networks is an additional indicator showing the sector's growth and potential to date. Network investments are a barometer of investor interest and expectations for the sector, as investments in the district heating industry are usually made with a long-term rate of return in mind.

[16] EHP, *op. cit.*

[17] *Ibidem*

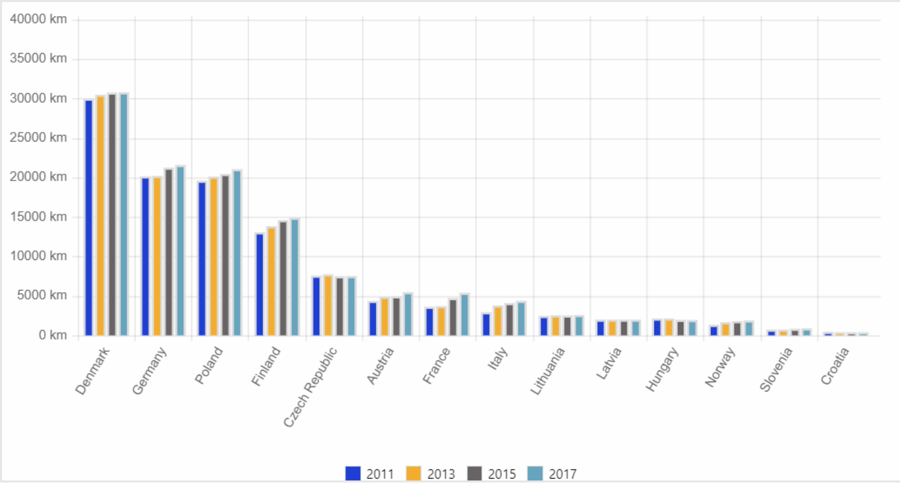


Chart 5: Total length of district heating network in km (2011 – 2017).[18]

One of the most important indicators for assessing the strength of the district heating sector is to compare its market share with other district heating solutions, such as individual natural gas boilers, electric heating, biomass central heating, heat pumps and others in a given area. The data in Figure 6 illustrates the very uneven share of district heating networks in Europe, with Iceland, Denmark, Lithuania, Sweden, Poland and Finland standing out. The most noticeable decline over the last five years analyzed was in Sweden, where increasingly more customers are choosing electric heating due to low electricity prices.

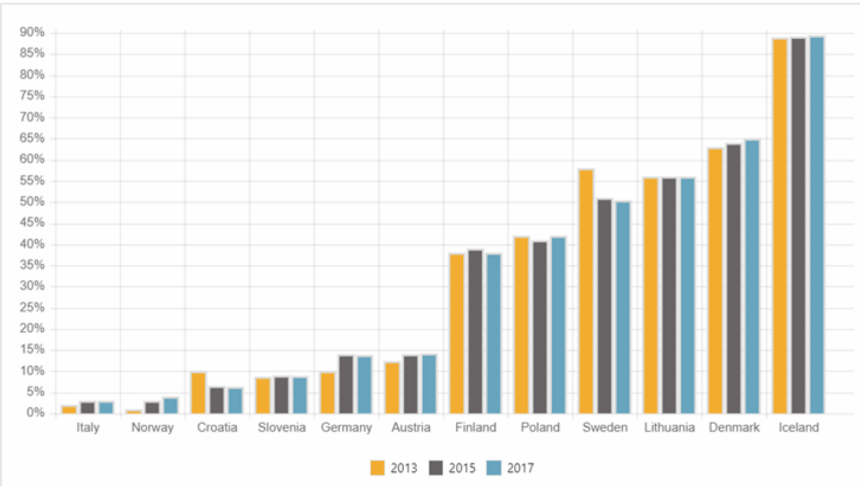


Chart 6: Share of district heating in energy sources used to meet heat demand in district heating network coverage areas (2013-2017) [19]

Poland remains in the group of countries with a low share of renewable energy both in final energy consumption for heating and cooling and in the generation of district heat. The share of renewable energy in district heating in selected EU member states is shown in Figure 7. It should be pointed out that countries such as Denmark, Finland, France and Latvia, which made significant progress over the five years analyzed to increase the share of renewable energy in their district heating systems, made so primarily based on biomass.

[18] *Ibidem*

[19] *Ibidem*

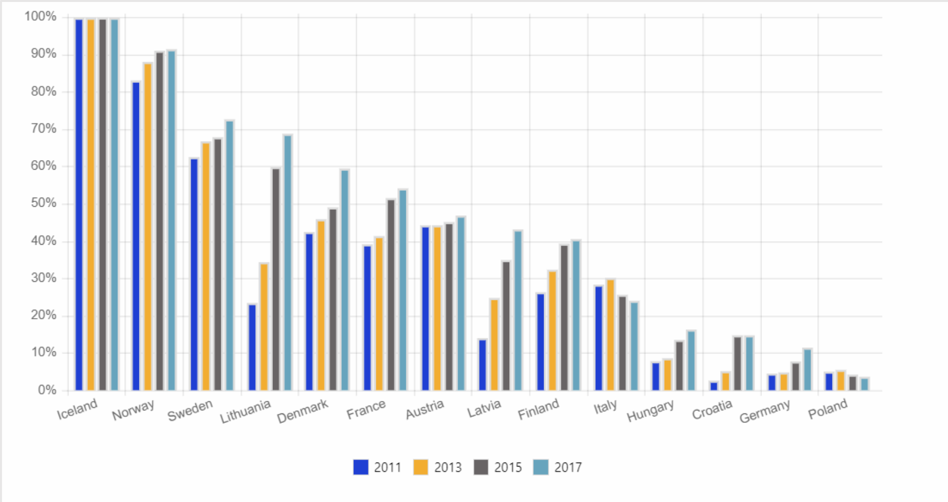


Chart 7: Share of renewable energy in large-scale district heating[20]

1.3 Climatic conditions in Poland

According to the Köppen system, the most common climate classification system, Poland has climatic conditions characteristic of three main climate zones. For the most part, Poland lies in a moderately warm and continental climate zone, while the upper parts of the Sudeten and Carpathian Mountains have a high mountain climate. Poland's climate is characterized by high variability throughout the year, which is due to Poland's location in between zones of influence of various climate-forming factors. The following factors are of greatest importance:

- location in the middle latitudes (54°50'-49°00') – a temperate zone with a certain amount of heat;
- relatively short distance from the Atlantic Ocean, which moderates the climate, meaning it warms in winter and cools in summer;
- relative proximity to the dense land of Eurasia, which makes the climate harsher, i.e., it is cold in winter and hot in summer;
- the latitudinal arrangement of geographic lands that facilitates the movement of air masses along the west-east direction (no terrain obstacles in the form of mountains).

Average annual temperatures in Poland are shown in Figure 3.

[20] *EHP, Country by Country 2019 Report*

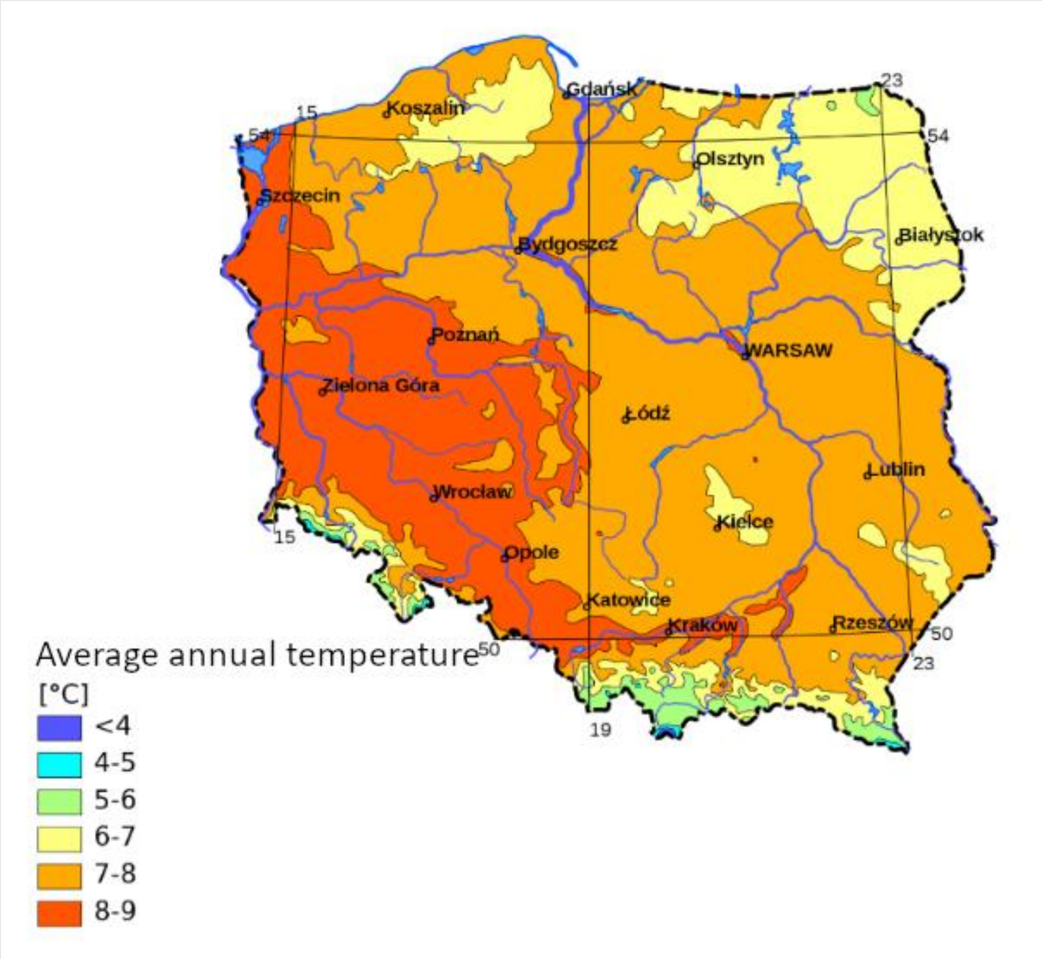


Fig. 3: Average annual temperatures in Poland

Air masses clash over Poland, and their inflow is determined primarily by two large, permanent barycenters – the Azores High and the Icelandic Low. Their location and size change throughout the year, which has a significant impact on the movements of air masses. The climate is most influenced by polar-maritime and polar-continental air masses (dry, hot summers and dry and cold winters), determining its transient nature. In addition, tropical-maritime air masses from the Mediterranean bring storms in summer and frequent thaws in winter. Poland lies in a zone of variable winds with a predominance of westerly winds, which account for approx. 60%. In winter, the winds are mainly easterly.

For the requirements of district heating and for the calculation of heat demand for buildings, according to PN-EN 12831:2006, Poland is divided into as many as five climate zones, which allow to determine the main design parameters of outdoor air. Taking into account the geographical diversity of Poland, the country's region was divided, depending on the season (winter/summer), into areas with a largely constant maximum design temperature.[21] Figure 4 and Table 5 show the division of Poland into climate zones and the design temperatures for each zone.

[21] Source https://strefaklimatyzacji.pl/, February 11, 2022

Fig. 4: Climate zones of Poland according to PN-EN 12831:20061[22]

Table 5: Design temperatures for climate zones in Poland

Climate zone	Design outdoor temperature °C	Average annual outdoor temperature °C
I	-16	7.7
II	-18	7.9
III	-20	7.6
IV	-22	6.9
V	-24	5.5

Poland's climate discussed hereinabove and its temperature conditions have a significant impact on energy consumption for heating the buildings, which in turn significantly affects the operation of district heating systems. To present the scale of demand for district heating in Poland, the concept of degree-days is used. Degree-days is a tool that can be used to assess and analyze energy consumption in buildings in relation to weather variability. In general, degree-days are the sum of the differences between the outdoor temperature and a certain reference (or baseline) temperature over a certain period of time. A key issue in the use of degree-days is the determination of the baseline temperature, which in buildings refers to the energy demand of the building and of the system: both heating and cooling demand[23]. According to the Eurostat data, heating degree-days for Poland in 2020 were as follows: the minimum value was 2,797, and the maximum value was 3,660. Warsaw had 3,050.1 degree-days[24].

Average heating-degree days for Poland compared to other European countries over the past decade are shown in Table 6. It shows that in 2020 the number of heating degree-days in Poland was approx. 9% higher than the EU average.

[22] *Climate in Poland 2020*, Institute of Meteorology and Water Management, source: www.imgw.pl, February 11, 2022
[23] www.ogrzewnictwo.pl, February 11, 2012
[24] For the calculations, a baseline indoor temperature of 15°C was assumed for 5 climate zones according to EN 12831

Table 6: Heating degree-days in European Union countries[25]

YEAR	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
European Union – 27 countries	2,968.15	3,237.86	3,160.09	2,815.53	2,901.23	3,033.05	3,044.85	2,940.90	2,909.29	2,758.95
Belgium	2,404.68	2,766.54	3,021.71	2,323.21	2,632.63	2,695.22	2,584.09	2,511.15	2,532.36	2,339.71
Bulgaria	2,798.59	2,614.00	2,387.56	2,365.02	2,371.11	2,420.17	2,527.59	2,352.10	2,152.56	2,247.42
Czech Republic	3,234.60	3,399.61	3,514.82	2,919.87	3,090.62	3,247.67	3,311.50	2,995.64	2,998.07	3,078.64
Denmark	3,148.45	3,424.15	3,396.28	2,834.98	3,114.15	3,141.46	3,112.11	3,048.54	3,026.80	2,920.71
Germany	2,873.02	3,130.93	3,289.06	2,659.00	2,908.42	3,009.02	2,965.83	2,774.95	2,800.81	2,741.03
Estonia	4,084.00	4,579.62	4,154.32	4,143.17	3,795.56	4,208.45	4,209.57	4,064.64	3,883.05	3,553.49
Ireland	2,766.10	2,861.13	2,835.61	2,629.47	2,912.09	2,744.05	2,668.92	2,754.34	2,706.58	2,744.36
Greece	1,796.64	1,654.99	1,439.27	1,397.47	1,572.95	1,458.36	1,612.13	1,371.74	1,448.99	1,489.06
Spain	1,572.46	1,873.15	1,921.25	1,554.36	1,610.60	1,724.77	1,606.48	1,796.63	1,670.72	1,553.94
France	2,057.49	2,439.28	2,637.51	2,080.89	2,255.70	2,397.90	2,336.00	2,181.92	2,246.95	2,037.95
Croatia	2,359.44	2,355.07	2,290.00	1,885.28	2,246.21	2,264.65	2,323.22	2,139.52	2,076.47	2,137.64
Italy	1,856.24	1,952.79	1,932.55	1,631.87	1,808.06	1,766.12	1,879.86	1,746.84	1,813.91	1,750.40
Cyprus	794.38	817.04	707.11	523.15	749.52	677.81	720.83	470.75	693.06	630.45
Latvia	3,937.92	4,322.02	4,036.79	3,939.85	3,657.39	4,002.81	3,997.38	3,862.19	3,622.92	3,403.51
Lithuania	3,767.86	4,081.27	3,873.17	3,729.28	3,523.32	3,829.94	3,761.50	3,687.57	3,391.36	3,305.64
Luxembourg	2,633.71	2,921.04	3,204.69	2,515.66	2,850.70	2,962.58	2,871.62	2,666.78	2,753.60	2,567.27
Hungary	2,815.26	2,768.77	2,688.69	2,277.68	2,598.04	2,707.02	2,742.93	2,468.70	2,381.22	2,546.56
Malta	549.19	662.36	460.65	374.61	543.90	322.36	534.15	365.57	515.23	401.93
Netherlands	2,516.57	2,817.13	3,012.96	2,282.08	2,625.49	2,679.86	2,538.98	2,528.64	2,514.41	2,386.31
Austria	3,409.28	3,552.85	3,635.43	3,126.98	3,316.42	3,419.30	3,498.07	3,193.65	3,279.50	3,322.79
Poland	**3,315.94**	**3,551.16**	**3,502.91**	**3,094.64**	**3,112.56**	**3,286.01**	**3,288.37**	**3,123.43**	**2,951.82**	**3,006.10**
Portugal	1,089.29	1,347.73	1,336.17	1,138.56	1,080.28	1,233.04	1,054.83	1,307.33	1,109.07	1,007.58
Romania	3,174.10	3,089.55	2,865.71	2,730.97	2,787.05	2,920.43	2,918.88	2,748.49	2,568.23	2,665.91
Slovenia	2,826.88	2,836.51	2,870.67	2,345.72	2,703.06	2,759.75	2,834.88	2,579.61	2,600.72	2,690.84
Slovakia	3,244.11	3,296.36	3,237.52	2,713.17	3,058.95	3,176.37	3,289.94	2,923.83	2,899.05	3,046.66
Finland	5,239.13	5,839.92	5,238.58	5,237.14	5,014.74	5,325.90	5,508.23	5,349.59	5,482.97	4,871.03
Sweden	4,895.71	5,471.41	5,155.24	4,850.03	4,875.48	5,092.48	5,181.13	5,122.22	5,119.61	4,592.94

1.4 Conditions arising from the location of district heating systems in cities

The characteristics of district heating systems and their size in terms of installed capacity in the sources significantly determine the possibility and rate of use of renewable sources. RES plants are not an alternative in the vast district heating systems that supply Poland's large cities. Heat distribution is hampered because the infrastructure is not compatible with RES-based low-temperature sources – efficient use of RES and waste energy requires lowering the water temperature in the district heating network from the current level of 135/70°C to 65/40°C. In contrast, a key element in the implementation of the low-temperature system is the thermal upgrading of buildings and the retrofit of building service systems, which, given the rate and scope of legislative changes related to this area, would generate great costs, including so-called sunk costs. In addition, the energy sector has no influence on the rate of thermal upgrading processes, which, as a rule, is the responsibility of building owners and managers.

Nearly half of Poland's energy companies have an installed capacity of heat sources exceeding 50 MW. These are mainly district heating companies in larger cities with populations over 100,000. In contrast, 20% of the companies have an installed capacity in heat sources of more than 125 MW. In Poland, many localities have district heating systems with capacities ranging from a few MW to more than 1,000 MW, supplied by one or more generation sources. The vast majority of them were built between 1950 and 1970, and were successively expanded in the period afterwards. The systems (both building service systems, transmission and distribution networks and generation sources) were designed keeping in mind the city's development, weather and technological conditions, as high-temperature systems, operating at supply parameters of approx. 140 – 150°C. In larger cities, cogeneration systems were installed in the sources as the most efficient generation systems, while in smaller cities, district heating systems were installed. Centralized systems made it possible to eliminate

[25] Source: EUROSTAT data, February 11, 2022

individual heat sources with low efficiency and greater negative environmental impact, significantly reducing smog and improving air quality. The progressive replacement of old district heating networks with networks in the pre-insulated pipe system over the past 20 years has made it possible to reduce the network's operating parameters to approx. 125°C.

As indicated in subsection 1.1.4, the vast majority of large district heating systems use coal-fired cogeneration units. These assets have been substantially upgraded to meet the environmental emission standards described in the BAT conclusions. Although there has not been a return on investment in all cases, investment processes are already being planned to convert them to gas-fired cogeneration units. The solution bridges the gap to achieving the zero-emission goal. District heating systems based on gas-fired cogeneration units will be able to be supplemented by units using renewable energy sources, such as in places where local biomass resources are available, and the natural choice will be to construct cogeneration sources supplied with this renewable fuel.

In large district heating systems, due to the need to install generating units of very large capacity, the transformation of sources to RES poses significant technical and logistical challenges (e.g., delivery of very large quantities of biomass, required network water temperature, etc.). However, this does not preclude the need for efforts to construct hybrid systems where central generating units will be supplemented by renewable sources of heat generation. Solutions that can be considered in the context referred to hereinabove include:

- Waste-to-Energy Plants (WTE plants) converting municipal waste and sewage sludge from wastewater treatment plants;
- sources fueled by RDF (Refuse Derived Fuel) – an alternative fuel as a method of managing high-heating value waste fraction and using it as fuel;
- ground source heating – in selected locations where suitable geological conditions exist;
- large-scale solar collectors;
- heat pumps, which, due to their relatively small installed capacity, can be operated as a supplement to another heat source, and the solution to increase the share of RES in the system is RES electricity dedicated to drive such a pump;
- use of renewable gases (green hydrogen, biomethane, biogas).

Heat generation using solar collectors, heat pumps or ground source heating results in lower temperatures of the heating medium. In contrast, the reduced temperature of the medium in the district heating network requires adaptation of both the network infrastructure and the building service systems used for space heating. These solutions are therefore easier to implement in newly constructed buildings, especially with individual heat sources, where the entire heating system can be designed and constructed from scratch. In addition, it is necessary to maintain a controllable cogeneration unit at the base of the district heating system, given the low stability of RES plants in the context of meeting the variable daily thermal power and operating parameters of the district heating network.

Heat demand should be met primarily by district heat. Modern district heating systems ensure high fuel efficiency, user comfort, attractive prices and clean air. Newly constructed cogeneration units will enable the growth of RES in the electric power industry by stabilizing the national power system – especially when combined with heat storage allowing for flexible operation. Increasing urbanization and suburbanization requires that the number of buildings connected to the network increase steadily.

Given the size of district heating systems in Poland, the technologies available for use are significantly limited at present. If biomass is used, generating facilities would have to be adapted to consume this fuel or replaced. A very big issue, however, would be obtaining the required amount of suitable biomass, the high probability of technical problems, i.e. chlorine corrosion, and the provision of infrastructure for its storage and transport, which is a particularly big issue in large metropolitan areas.

Attempting to divide existing district heating networks into smaller systems would present a number of technical, logistical and formal and legal challenges, which include:

- acquisition of land for the development of distributed RES plants – given the high degree of urbanization, this may be impossible or may encounter social issues;
- adaptation of the isolated network and adaptation of building service systems to operate on low-temperature parameters. Such works should be performed in parallel. Works on the district heating network may involve reworking areas recently revitalized by municipal authorities. Isolated supply areas could potentially be created in areas with potential problems with pressure or temperature management – the so-called "network ends". A few percent of the entire network may be affected, which, with systems above 50 MW, is a small share;
- in order to use waste heat, ground source heating and the use of heat pumps, the development of an additional power grid in a heavily urbanized area must be considered. This is due to the need to reduce the temperature of feed water in the district heating network to 90°C and below, which requires a significant increase in the flow rate of water as a heating medium. Changing the parameters of this water entails replacing all district heating units and building service systems. In an urbanized municipal area, upgrading a district heating network is a very large organizational challenge and, more importantly, a long-term process;
- retrofitting district heating networks in urbanized areas poses a major logistical challenge due to the need to close communication routes for long periods of time and the lengthy process of obtaining administrative permissions. In addition, in certain city areas it is not technically possible to route new district heating networks or increase the diameters of existing ones.

The process of adapting the district heating network also faces problems related to the ownership arrangement of the network infrastructure, which is most often divided between generation companies and distribution companies. This will cause the retrofit period to be extended, and this also applies to building service systems.

1.5 Available technologies for medium- and large-sized district heating systems

1.5.1 Coal technologies

Due to high unit CO_2 emission levels and the need to use environmental protection systems, coal technologies will be gradually replaced by low-carbon units: in the first place, gas units, and subsequently, renewable sources.

1.5.1.1 Coal-fired boilers

Coal-fired boilers are nowadays commonly used for district heating applications. In principle, there are three main coal combustion technologies: pulverized coal boilers, fluidized-bed boilers and grate boilers. Depending on the operating parameters and characteristics, these units can be divided into two boiler types: steam boilers and water boilers. The primary fuel used for coal-fired boilers is hard coal (or lignite). Given the current requirements laid down by environmental protection regulations, in order to operate coal-fired boilers, additional systems are required to reduce or eliminate individual substances.

1.5.1.2 Coal-fired steam boilers

Coal-fired steam boilers are mainly drum boilers with natural circulation which cooperate with steam turbines in a unit or header configuration (the live steam capacity for typical boilers used in Polish combined heat and power plants ranges between 70 and 480 t/h).

1.5.1.3 Coal-fired fluidized-bed boilers

Coal-fired fluidized-bed boilers are units (with a steam capacity ranging between 75 and 450 t/h) in which combustion takes place in a circulating (or stationary) fluidized bed comprised of a mixture of inert material forming the bed and fuel (coal) burnt in that bed. The specificity of coal combustion in a fluidized bed is characterized by a lower combustion temperature (approx. 800°C), which allows for lower NO_x emissions, unlike pulverized coal-fired boilers. In addition, the characteristics of the furnace allow for reduction of acidic compounds (SO_2, HCl, HF) directly in the furnace chamber by feeding limestone.

1.5.1.4 Coal-fired grate boilers

Grate steam boilers are characterized by lower output than pulverized coal-fired and fluidized bed boilers. Typically, these boilers are OR, OS (OR16 to OR50 with a capacity of 16 to 50 t/h of steam) grate, drum, natural circulation boilers with sheet piling or heavy furnace brickwork technology. They differ in the way the fuel is fed and the design of the furnace. Unlike pulverized coal-fired boilers, where pulverized coal is burned in the furnace chamber using pulverized coal burners, grate boilers are equipped with a grate (step, movable grate) on which a layer of fuel is burned at the bottom of the furnace chamber.

1.5.1.5 Coal-fired water boilers

Water boilers used in Poland are typically water-tube boilers (WP type – from WP70 to WP200) with a thermal capacity of 80 to 230 MW_t. The heat-collecting medium in water boilers (as opposed to steam boilers) is heating water directly routed to and from the municipal district heating network. In these boilers, heating water is pre-heated. These boilers are usually operated as peak-load boilers (as a second stage of water heating) in combined heat and power plants or as primary boilers used only for pre-heating of heating water. The second type of water boilers are grate boilers (combustion technology is similar to steam boilers) of the WR type (with a capacity from approx. 5 MW_t for WR5 to approx. 40 MW_t for WR40). These boilers are also used only to pre-heat heating water in the municipal district heating network.

1.5.2 Gas technologies

1.5.2.1 Gas-fired boilers

Gas-fired boilers used in Poland, due to their short start-up time and fuel cost, are mainly used as peak-load boilers started up during periods of low temperatures and high heat demand. These are water boilers used to pre-heat water from the municipal district heating network. However, it happens that these boilers are the primary facilities in a district heating or combined heat and power plant – usually of low capacity. Gas-fired boilers used in the district heating industry in Poland can be divided into once-through boilers – water-tube boilers with a higher capacity (15 to 140 MW_t) and fire-tube boilers (with a lower capacity from a few to approx. 50 MW_t).

1.5.2.2 Gas turbines in a simple cycle

Simple gas turbine systems are used in systems of combined heat and power plants of lower capacities. The simple system is characterized by low efficiency of power generation, which is related to the high temperature of exhaust gas.

1.5.2.3 Combined cycle gas turbine units

Combined cycle gas turbine units are a development of simple gas turbine systems with heat recovery. Combined cycle gas turbine units are characterized by a very high level of fuel utilization. There are combined cycle gas turbine units with capacities ranging from 42 MW_e to 608 MW_e. In addition to the high efficiency of electricity generation, a major advantage of combined cycle gas turbine systems is their ability to adapt to the forced time-varying volume and structure of generation.

1.5.2.4 Piston engines

Piston engines are also used in small systems of combined heat and power plants. Piston engines are engines in which the thermal energy of fuel is converted into mechanical work using reciprocating motion of the piston, which in turn moves the shaft. The rotary motion of the shaft, which is connected to the generator, is converted into electrical energy. Heat, in turn, can be obtained from the cooling of exhaust gas and engine oil. The most common solutions in Poland include capacities of up to 5 MW_e, but solutions up to 100 MW_e are known. Piston engines have relatively high efficiency compared to simple gas turbine or coal-fired power unit systems.

1.5.3 Other technologies

1.5.3.1 Oil-fired boilers

Oil-fired boilers used in Poland, due to their nature and the cost of the fuel, are mainly used as peak-load boilers started up during periods of low temperatures and high heat demand. These are water boilers used to pre-heat water from the municipal district heating network. However, it happens that these boilers are the primary facilities in a district heating plant or combined heat and power plant – usually of low capacity. Oil-fired boilers used in the district heating industry in Poland are once-through boilers – water-tube boilers with larger capacities – from 15 to 130 MW_t, and fire-tube boilers with smaller capacities from a few to approx. 40 MW_t. Less commonly used in combined heat and power plants are steam boilers fueled with light oil – such boilers are found more often in production plants, where there is a need for process steam of certain parameters, or/and electricity is produced – mainly for auxiliaries.

Oil-based units, due to high fuel prices, planned short annual operating period and not very strict standards, can still serve as peak-load units in power systems.

1.5.3.2 Biomass

Biomass can be burned as supplementary fuel in either coal-fired boilers (biomass co-firing) or in dedicated biomass boilers, usually of circulating fluidized bed design. The very process of converting the chemical energy of fuel in the combustion process, and then producing electricity and heat is similar to the process performed when using coal fuel.

Biomass-fired units with zero CO_2 emissions will fill the district heating base, effectively meeting greenhouse gas reduction targets.

1.5.3.3 Heat pumps

These are facilities that use lower heat sources and supply heat to upper heat sources using electricity. Lower heat sources can be atmospheric air, ground and surface water, ground-source heat, waste heat (wastewater treatment plants, industrial plants, data centers), and ambient energy. The higher the temperature of the lower heat source, the more efficient the heat pump system. Heat is transferred via a coolant (working medium) that changes its physical state, resulting in the transfer or extraction of energy. Under the influence of thermodynamic processes, the liquid evaporates at a low temperature and draws heat from the environment (lower heat source), and is then directed to the compressor. The increase in pressure compresses the gas. The working medium heats up and gradually transfers heat to the air or water in the central heating system or water in the domestic hot water system. Once condensed, it flows through an expansion valve that proportions the amount of medium returning to the evaporator. The medium cools and lowers its pressure, and the cycle begins again.

Heat pumps, especially when combined with RES sources, can be a complement or alternative to biomass-fired units. A certain difficulty in this regard may be the lack of experience in administrative procedures related to, among other things, the rating of heat from heat pumps, the verification of the RES heat stream from the heat pump.

1.5.3.4 Ground-source energy

Poland lies outside the zones of modern tectonic and volcanic activity, hence it is not economically viable at today's technological stage to extract steam beds from great depths for electricity generation. There are sedimentary-structural basins filled with hot groundwater of varying temperatures. The temperatures of these waters range from tens to more than 90°C, and in extreme cases reach one hundred and several tens of degrees, which makes them mainly used in district heating industry. The main method to obtain geothermal energy is to create boreholes to geothermal hot water reservoirs. The second borehole is drilled at certain distance from the abstraction borehole, with which geothermal water, after receiving heat from it, is injected back into the bed. As a rule, geothermal waters are highly saline, this is the reason for particularly harsh operating conditions for heat exchangers and other fittings of ground-source systems. Geothermal energy is used in central heating systems as a primary source of thermal energy. The possibility of using geothermal energy is related to the location, as well as the parameters of the source (in Poland, temperatures range from 42°C to 86°C), which affect the installed power and the volume of heat extracted.

Geothermal sources are highly dependent on geological conditions. Due to their limited availability, they will only play a role in certain locations and individual district heating systems.

1.5.3.5 Municipal waste

Waste-to-Energy Plants (WTE), commonly referred to as waste incineration plants, are facilities that operate a plant designed to recover energy (heat as well as electricity) from municipal waste by thermal treatment. The most commonly used process to thermally transform municipal waste is burning it in boilers with a moving grate. This technology allows for a significant reduction in the weight and volume of waste, and offers the possibility of transforming many different types of waste. Due to the large differences in the moisture content of waste, and thus the large fluctuations in the calorific value of fuel, a booster fuel, usually gas or oil, is used when municipal waste is used for energy purposes to ensure the quality of the combustion process.

WTE plants allow the use of municipal waste for energy purposes, solving the problem of landfilling. Properly sized for the municipal waste market, the plant can operate year-round.

1.5.3.6 Alternative/waste fuel (RDF)

RDF (short for *Refuse Derived Fuel*) is a term used to refer to the calorific fraction of waste with a high calorific value (usually approx. 18 MJ/kg) that is not recyclable. RDF for energy purposes in district heating and combined heat and power plants is used by burning the fuel in grate or fluidized bed boilers. Particularly effective is the use of fluidized bed boilers, which are suitable for the combustion of fuels with varying properties (including calorific value), and allow a wide range of capacity control.

Similar to WTE plants, RDF plants using waste are designed to operate in a district heating base.

1.5.3.7 Electrode boilers

The operation of an electrode boiler is based on the release of heat by the flow of current through a liquid medium connected to a source of electricity through electrodes. The main advantages of electrode boilers include relatively low capital expenditures, low overhaul costs, simplicity of operation, high efficiency, no CO_2 emissions, no need for fuel storage, high power flexibility and the ability to start up quickly. The only disadvantage of electrode boilers is their dependence on electricity prices, which have so far been higher than the price of heat generated by other technologies.

2 Key legislative proposals for district heating in "Fit for 55" package

Given the circumstances surrounding the structure of the district heating sector and the current state of the art, meeting the requirements of the European Union's climate and energy policy will be extremely challenging. In order to achieve climate neutrality goals, it will be necessary to retrofit existing and construct new generation sources using renewable energy sources, as well as to divide existing district heating networks into smaller systems, which, given the conditions described above, will not be possible in every case, and if – the process will be very cost- and time-consuming.

In the context of future challenges for the district heating industry, the key will be the resolutions in the European Commission's proposed "Fit for 55" legislative package[26]. The package consists of more than a dozen legislative proposals for all areas of the economy related to greenhouse gas emissions, which together are expected to enable the Union to achieve a higher net greenhouse gas reduction target of at least 55% in 2030. District heating will be primarily affected by the future shape of legislative proposals in the draft EED[27], RED III[28] and EPBD[29]. This section discusses the most important changes resulting from these legislative proposals in the context of decarbonizing the district heating sector.

2.1 Issues arising from the draft EED

- Revision of criteria for high-efficiency cogeneration (Annex III)

According to the proposed wording of Annex III of the draft EED, in terms of meeting the criterion of high-efficiency cogeneration, a new criterion appears among the existing criteria, which is the introduction of a limit on direct CO_2 emissions (for units using fossil fuels) of less than 270 g of CO_2 per 1 kWh of energy generated in cogeneration (heat, electricity and mechanical energy combined). The direct emissions limit will apply from the date of entry into force of the recast directive, while its role will be particularly important from January 1, 2026, when the criteria in the definition of an efficient heating and cooling system will apply directly to high-efficiency cogeneration.

[26] Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions "Fit for 55": achieving the EU's 2030 climate target on the road to climate neutrality COM/2021/550 final Brussels, July 14, 2021.

[27] COM(2021) 558 final, European Commission Legislative Proposal for a Draft Directive of the European Parliament and of the Council on Energy Efficiency, Brussels, July 14, 2021.

[28] COM(2021) 557 final, European Commission legislative proposal for a draft Directive of the European Parliament and of the Council amending directive (EU) 2018/2001 of the European Parliament and of the Council, Regulation (EU) 2018/1999 of the European Parliament and of the Council, and Directive 98/70/EC of the European Parliament and of the Council with regard to the promotion of the use of energy from renewable sources and repealing Council Directive (EU) 2015/652, Brussels, July 14, 2021.

[29] COM(2021) 802 final, European Commission legislative proposal for a draft Directive of the European Parliament and of the Council on the energy performance of buildings, Brussels, December 15, 2021.

The provisions prevent coal-fired cogeneration from retaining its high-efficiency status while imposing an emissions cap on gas units. The entry of the new criterion will cause coal-fired cogeneration units that are not retrofitted by the end of 2025 to lose their high-efficiency cogeneration status, which in the vast majority of systems will also translate into the loss of efficient district heating and cooling status. The draft EED does not explicitly specify the methodology for calculating the new emissions criterion. This is important in the context of the operating conditions of cogeneration units, including the seasonal variation of the heat curve and the system services provided to the power system – factors that affect the level of direct CO_2 emissions.

The projected horizon for the entry into force of the new criterion therefore creates a risk that the Polish district heating sector will have difficulty in implementing its planned decarbonization strategy, which includes retrofit of coal-fired heat and power plants to high-efficiency cogeneration plants fueled with natural gas. Particularly important will be the risks associated with securing financing for the transformation of Poland's district heating sector. The loss of efficient district heating status associated with the failure to obtain the required volume of heat from high-efficiency cogeneration due to failure to meet the direct emissions criterion may limit available financing, especially from EU funds.

- Amending the definition of an efficient district heating system (Article 24)

According to the proposed wording of Article 24 of the draft EED, it is proposed to amend the definition of an efficient heating and cooling system so that it meets the following criteria in subsequent years:

- **by December 31, 2025**, a system using at least 50% of renewable energy, 50% of waste heat, 75% of combined heat and power, or 50% of a combination of such energy and heat; (existing definition)
- **as of January 1, 2026**, a system using at least 50% of renewable energy, 50% of waste heat, 80% of heat from high-efficiency cogeneration, or at least a combination of such heat supplied to the network in which the share of renewable energy is at least 5% and the total share of renewable energy, waste heat or heat from high-efficiency cogeneration is at least 50%;
- **as of January 1, 2035**, a system using at least 50% of renewable energy and waste heat, with at least 20% of renewable energy;
- **as of January 1, 2045**, a system using at least 75 % of renewable energy and waste heat, with at least 40 % of renewable energy;
- **from January 1, 2050**, a system using only renewable energy and waste heat, with at least 60% of renewable energy.

The designed rate of increase in the mandatory share of RES means that from 2035 district heating systems will not be considered efficient based on the share of high-efficiency cogeneration, but only on the share of RES and waste heat. At the same time, a number of systems may lose this status as early as 2026 due to failure to meet the emissions criteria for high-efficiency cogeneration. This significantly undermines the concept of using the potential and development of high-efficiency gas cogeneration (in the future with hydrogen mix and all-hydrogen or renewable gases) as the most preferred technology in Polish district heating conditions. Given the size of Poland's largest district heating systems, technical difficulties can be expected in obtaining the required shares of RES energy and waste heat. In the context of Polish district heating conditions, the direction of decentralization of generation advocated by the European Commission creates the risk of having to split systems into smaller ones. Implementing such an approach can be a huge challenge, often technically unfeasible due to the nature of the systems, especially in large cities, due to dense developments, high density of building infrastructure and land ownership structure. At the same time, the proposed criteria interfere with investment decisions, jeopardizing the return on investment in modern units of high-efficiency cogeneration fueled with natural gas, which significantly affects the maintenance of financial liquidity of energy companies and their ability to make further investments.

2.2 Issues arising from the draft RED III directive

- Binding overall EU target for 2030 (Article 3)

The draft RED III directive plans to set a higher RES share target of no less than 40% in 2030. The target is binding at the EU-wide level, with no targets set at the level of member states, but it will affect the trajectory of the incremental RES share adopted by Poland in the National Energy and Climate Plan for 2021-2030.

- Lack of mechanism to qualify heat from electricity as RES heat and inability to meet sector targets for heat in this way (Article 7)

Article 7 of the draft RED III directive does not propose a mechanism to account for RES electricity in the sector where it is consumed and to include heat generated from RES electricity as RES heat. Recognition as RES heat of heat generated from RES electricity will enable the sectoral targets to be more fully met, particularly in large-scale district heating. The absence of such regulation will make it virtually impossible to achieve these goals, especially for large district heating systems, for which the number of available RES technologies is significantly limited.

- Introducing a target for RES participation in buildings (Article 15a)

Article 15a of the draft RED III directive plans to introduce an indicative EU target of 49% RES share in buildings by 2030. In conjunction with the plans to introduce new milestones in the definition of efficient heating and cooling systems in the draft EED, the goal is to fulfill minimum shares in new and renovated buildings, as well as promote the transition from fossil fuel systems to RES. The establishment of Article 15a is intended to be complementary to the EPBD, which, as it currently stands, imposes requirements on buildings as regards the EP factor (an indicator of annual demand for non-renewable primary energy), while it is not mandatory to demonstrate a certain share of heat from RES in order to achieve an adequate level of this factor. The proposed Article 15a should be regarded as repeating issues related to buildings, introducing regulatory ambiguity and uncertainty – as it seems that issues related to buildings should not be regulated in more than one piece of legislation.

- The establishment of a binding target for the annual growth of RES in the heating and cooling sector (Article 23(1) and Annex 1a)

It is planned to set a binding annual target for RES growth in the heating and cooling sector (individual and large-scale combined) of 1.1. pp. per year average for the periods 2021-2025 and 2026-2030 with respect to the 2020 level expressed as a national share of gross final energy consumption, and there is a risk that very little time will be left to achieve higher RES gains after the directive's entry into force date and the time for its transposition into national legislation.

In addition, Annex 1a was established, setting out the shares of renewable energy used in the domestic heating and cooling sector in gross final energy consumption from 2020 to 2030 for each member state. In the context of Poland, the value of the RES share in the sector was set at 1.5 pp, which is understood as a non-binding share, taking into account additional commitments. However, the wording of the draft RED III directive does not indicate a methodology for calculating the shares included in Annex 1a, and its correlation with the binding target in Article 23(1) remains unclear.

- Increasing the indicative target for the annual growth of RES in the large-scale heating and cooling sector (Article 24(4)) and rules for third-party access to district heating systems (Article 24(4a))

In the district heating and cooling sector, an indicative annual RES growth target of 2.1 pp per year was proposed, also calculated as an annual average for the periods 2021-2025 and 2026-2030 with respect to the 2020 level. As with Article 23, there is a risk that very little time will be left to achieve higher RES growth after the directive's entry into force date and after the time for its transposition into national legislation has passed.

The draft RED III directive significantly expands the rules for access to heating and cooling networks by adding a new section 4a in Article 24, concerning the obligation to connect RES sources to these systems. In light of the European Commission's new proposals, the rule would be mandatory for large district heating and cooling systems with a capacity of more than 25 MW_t, rather than one of the options for achieving the goal of increasing the share of RES in large-scale district heating and cooling sector, as has been the case so far.

- Tightening conditions for the use of biomass in district heating (Article 29(1))

The draft RED III directive plans to introduce a number of tools that will significantly impede the development of the use of biomass plants in the transformation of district heating. Within this issue, it is planned to strengthen sustainability criteria for biomass fuels. The proposed amendments involve lowering the threshold for the obligation to meet the sustainability criterion for biomass from the current 20 MW_t to 5 MW_t (for solid biomass fuels) and 2 MW (for gaseous biomass/biogas fuels). In addition, member states will be obliged to implement systems that restrict the use of roundwood and expand the provisions for restrictions on biomass sites, including in the forest biomass fraction.

The use of biomass in RES support schemes will also be restricted. It is planned to make the participation of biomass installations in support schemes conditional on compliance with the principle of the hierarchy of biomass use, in which the use for energy purposes ranks among the last. The same is currently true of waste. This will lead to a significant impediment to accessing support schemes for biomass plants after 2026.

In the context of the use of biomass as an energy medium leading to an increase in the share of RES in district heating systems, it should be noted that such plants will have to meet significantly stricter requirements. In addition, the proposed regulations will be reflected in the availability of biomass.

2.3 Issues arising from the draft EPBD

- Phasing out the use of gaseous fuels in districting heating by 2040 (Annex II)

The new Annex II of the draft EPBD sets out a template for a national building renovation plan to replace long-term renovation strategies. One of the elements of the plan is to identify policies and measures leading to the decarbonization of the heating and cooling sector, including through district heating and cooling networks, and the phasing out of fossil fuels in these sectors with a view to phasing them out completely by 2040 at the latest.

The goal of completely eliminating gas by 2040 as a fuel used in cogeneration units feeding district heating systems seems inconsistent with the European Union's overall climate policy. This would mean actually achieving practical zero-carbon district heating 10 years earlier than the climate neutrality target. There are no grounds for this, given the specificity of the energy sector in each member state and the diversity of its transformation paths.

- Lack of the possibility to connect new buildings after 2030 to efficient district heating systems that are not fully decarbonized (Annex III)

Annex III of the draft EPBD sets out requirements for new and renovated zero-carbon buildings, which also includes a table of values for non-renewable primary energy input factors for zero-carbon buildings. In the context of Polish district heating, however, another requirement of Annex III seems particularly relevant, which stipulates that from 2030, new and retrofitted zero-carbon buildings (in the case of public buildings, from 2027) must be supplied, as a rule, exclusively with RES energy or waste heat. From the perspective of the characteristics of Polish district heating systems, this is particularly risky, since in practice it means unjustified degradation of existing district heating systems, where heat is generated from fossil fuels, including natural gas. This poses a threat to the cost-effective and heat supply-secure transformation of district heating systems. This requirement, in conjunction with the other documents in the package, especially the draft RED III and EED directives, leads to overlapping – in a far inconsistent manner – regulations in the buildings area. In the context of the issue of using district heating as one of the possible means of supplying buildings with heat, it is particularly notable that while on the grounds of the draft EED the use of an appropriate volume of, for example, heat from high-efficiency cogeneration generated in a natural gas-fired cogeneration unit by 2035 could provide the grounds for meeting the criterion of an efficient heating and cooling system, but already the revision of the EPBD, through the criteria introduced and, among other things, the definition of a zero-carbon building, would significantly limit, or even prevent, the connection of new customers to such systems after 2030, and thus would block the use and development of efficient heating and cooling systems. Inconsistent solutions in the draft EED and the draft EPBD significantly reduce incentives to take action to meet the criteria for an efficient district heating system.

The proposed wording of the requirements for heat supplied to new buildings set forth in Annex III of the draft EPBD is inconsistent with both the new definition of an efficient heating and cooling system proposed in the EED revision and the changes proposed in Article 15a of the draft RED III directive allowing, in this regard, the use of heat from efficient district heating systems in buildings, and not just heat from RES and waste heat in those efficient district heating systems.

3 Key assumptions used to determine optimal technology options

This section presents the macroeconomic and market assumptions and technical assumptions adopted for the multi-option economic model, which determines the most cost-optimal options for implementing the Fit for 55 Package in individual heat markets that differ in size and demand structure.

Heat markets were divided according to contracted thermal capacity into the following ranges:

- up to 20 MWt (located outside the EU ETS),
- 20 to 50 MWt,
- 50 to 100 MWt,
- 100 to 300 MWt,
- 300 to 500 MWt,
- above 500 MWt.

For each heat market, 4 technology mix options were proposed that meet the requirements indicated in the proposed regulations in the Fit for 55 package for a district heating system to be considered efficient, which are presented later in the document.

The analysis was performed for the period 2022 – 2050. In each year, the model recalculates the most cost-effective source taking into account the variable costs of production and for each year stacks the units and inserts them into the demand derived from the heat profile for a given heat market (see subsection 3.3 for a description). The production of each unit is therefore based on the demand of a given market and the margin situation in a given year. The units with the lowest variable cost operate at the base of the district heating system. The boundary condition is also the final fulfillment by the district heating system in question of the criterion of an efficient district heating system based on the requirements proposed in Article 24 (1) of the revision of the EED, taking into account the volumes of heat generation in each option.

3.1 Macroeconomic and market assumptions

The key factors influencing the selection of the most optimum technologies for heat generation are macroeconomic and market assumptions. This analysis adopts the most current set of assumptions, which were prepared by PTEZ members in February 2022.

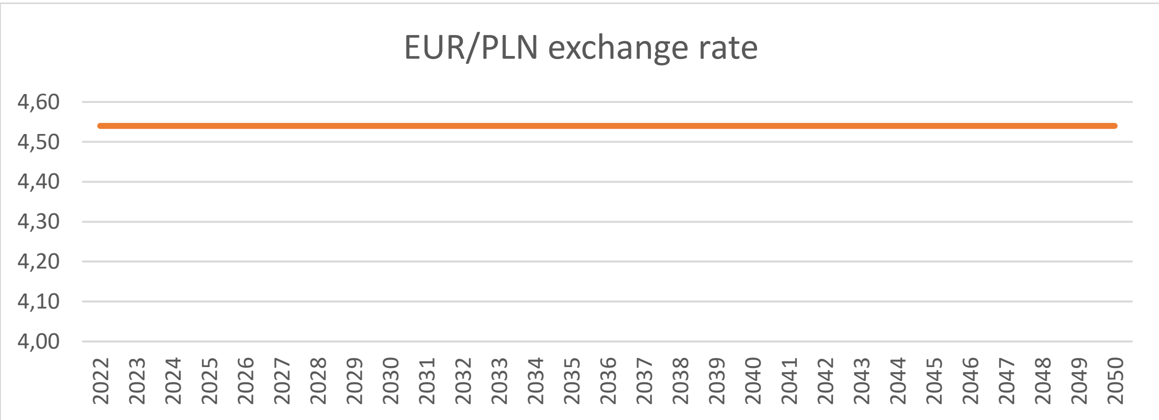


Chart 8: EUR/PLN exchange rate[30]

[30] PTEZ's own study based on the August 2021 guidelines for the use of uniform macroeconomic indicators of the Ministry of Finance.

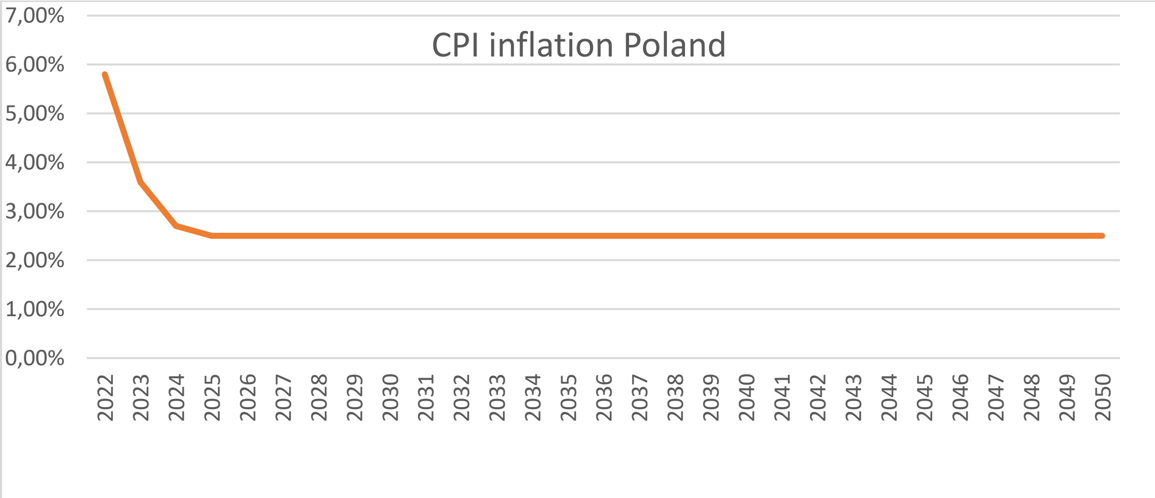


Chart 9: Projection of CPI inflation Poland[31]

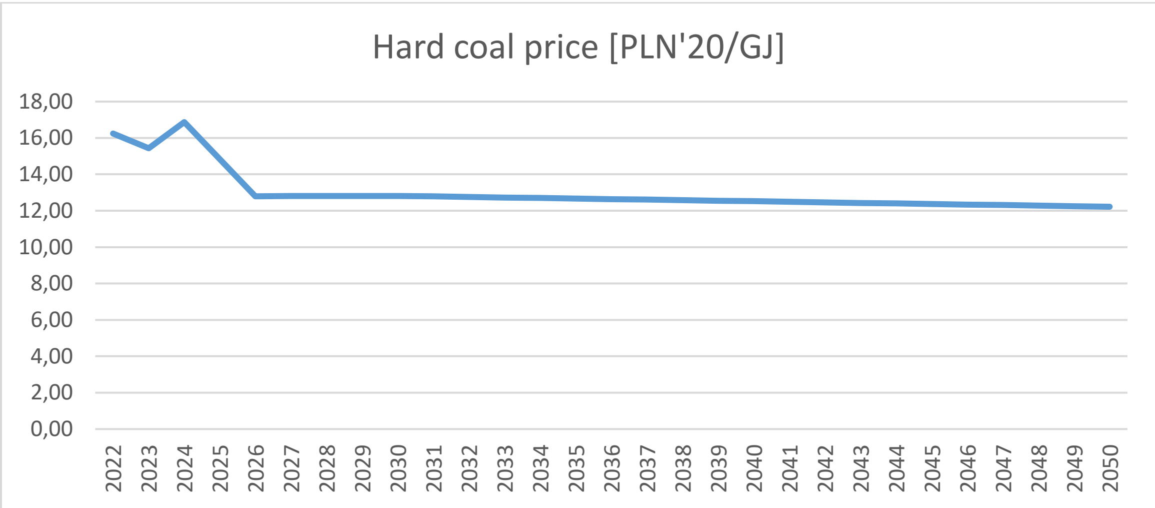


Chart 10: Projection of hard coal prices[32]

[31] PTEZ's own study based on the National Bank of Poland's current inflation and GDP projection (published November 8, 2021) and the Ministry of Finance's August 2021 Guidelines for the use of uniform macroeconomic indicators.

[32] PTEZ's own study based on current ratings and WEO October 2021 report – European Union; scenario Stated Policies.

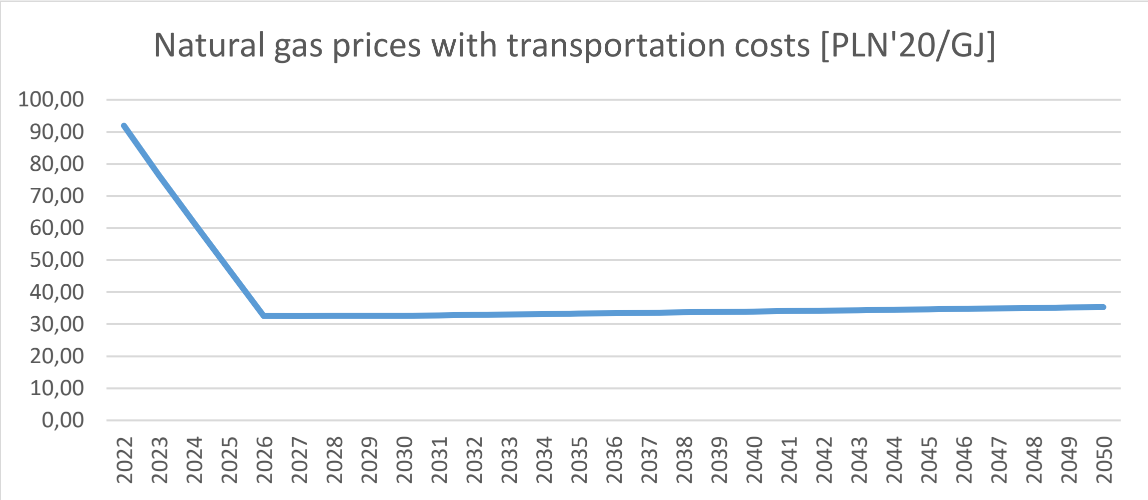


Chart 11: Projection of natural gas prices[33]

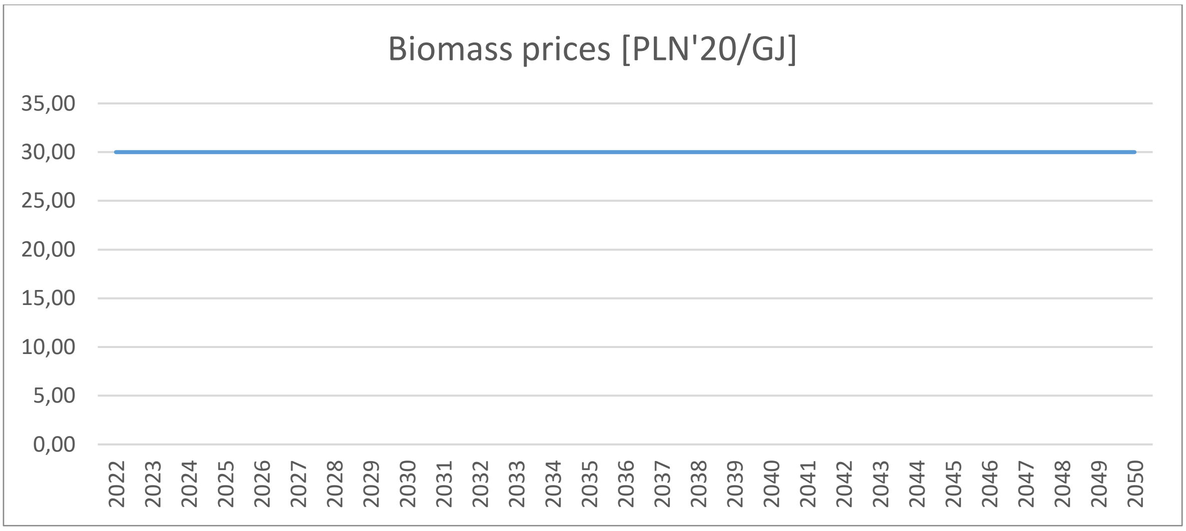


Chart 12: Projection of biomass prices[34]

[33] PTEZ's own study based on current ratings and WEO October 2021 report – European Union; scenario Stated Policies.

[34] PTEZ's own study based on concluded contracts and projection of biomass prices by PTEZ members

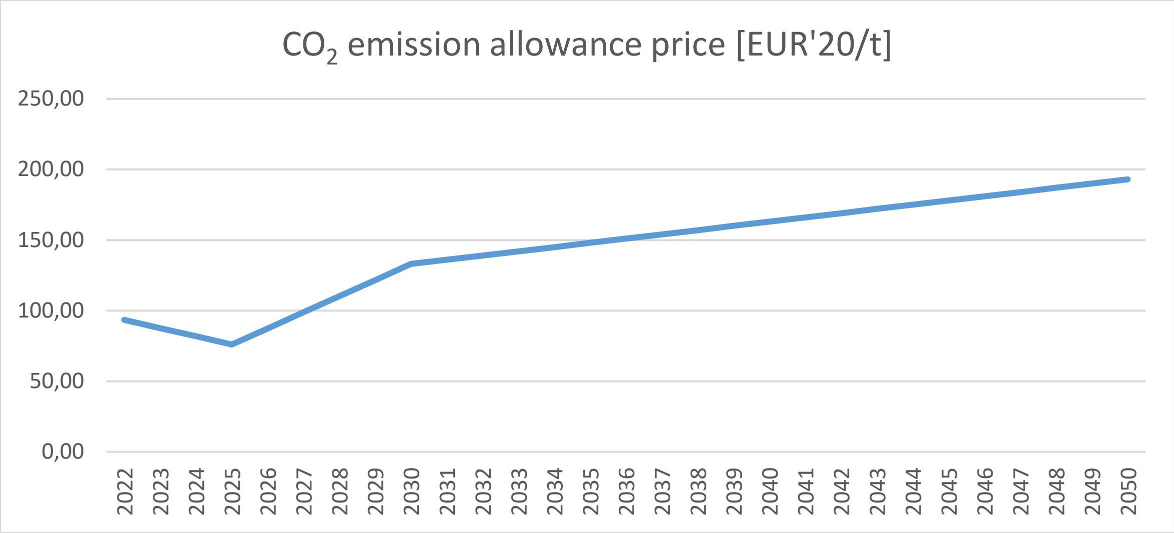


Chart 13: Projection of CO_2 emission allowances prices[35]

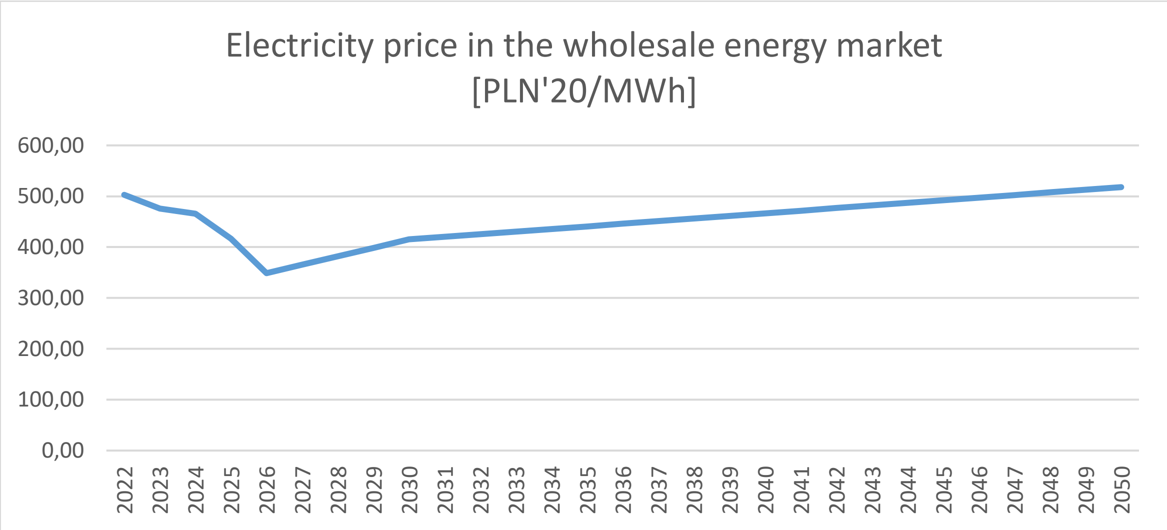


Chart 14: Projection of electricity prices[36]

3.2 Technical and economic assumptions

This subsection outlines the key technical and economic assumptions for each type of technology. Detailed data are presented in Table 7.

In addition, other assumptions included:

- Remuneration costs at the level of PLN 10 thousand / month / FTE; the number of FTEs was varied depending on the technological mix in the option.
- The weighted average cost of capital WACC was assumed at 8% (post tax nominal).
- CIT tax = 19%.

[35] PTEZ's own study based on current ratings and analyses *CAKE REFORM OF THE MARKET STABILITY RESERVE (MSR) IN THE "FIT FOR 55" PACKAGE; scenario: fit for 55.*

[36] PTEZ's own study based on the adopted cost assumptions and the assumption of an electricity market margin of 30 PLN/MWh for the more profitable technology among condensing coal-fired units and new CCGT gas units.

- Efficiency, CAPEX, OPEX (excluding remuneration costs and taxes) are given in the table below, with values in 2021 prices. The analysis does not take into account the costs of the so-called Balance of Plant due to the different conditions of the various district heating systems in Poland. Thus, it should be assumed that for gas-fired units these costs will amount to an additional 10 –15% of CAPEX.

Table 7: Technical and economic assumptions[37]

Technology	unit	Coal-fired cogeneration	Coal-fired boilers (WR)	Gas-fired boilers	OCGT	CCGT	Gas engines	Oil-fired boilers	Biomass-fired boilers	Heat pumps	Geothermal energy	Electrode boilers	WTE with energy recovery
Fuel	#	hard coal	hard coal	high methane natural gas	high methane natural gas	high methane natural gas	high methane natural gas	high methane natural gas	biomass	electricity	electricity	electricity	waste
Overall efficiency	%	85%	85%	95%	82%	86%	85%	95%	90%	200%		99%	48%
CAPEX	mPLN/MWe	N.A.	N.A.	N.A.	6	7	5,6	N.A.	N.A.	N.A.	N.A.	N.A.	40
CAPEX	mPLN/MWt	1,2	1,2	0,7	N.A.	N.A.	N.A.	0,7	3	4	10	0,5	N.A.
OPEX	% CAPEX	5%	5%	1%	3%	2,20%	5%	0,5%	5%	1%	3,10%	0,50%	5,00%

3.3 Benchmark heat markets

This subsection presents the adopted benchmark structure of individual large-scale heat markets in Poland.

Figure 9 presents the heat market for contracted capacity between 0 and 20 MW_t (non-ETS market). In Poland, more than 90% of such markets have no hot water and the district heating network is used for central heating. Domestic hot water is provided by local heating facilities in buildings.

[37] PTEZ's own study based on experience.

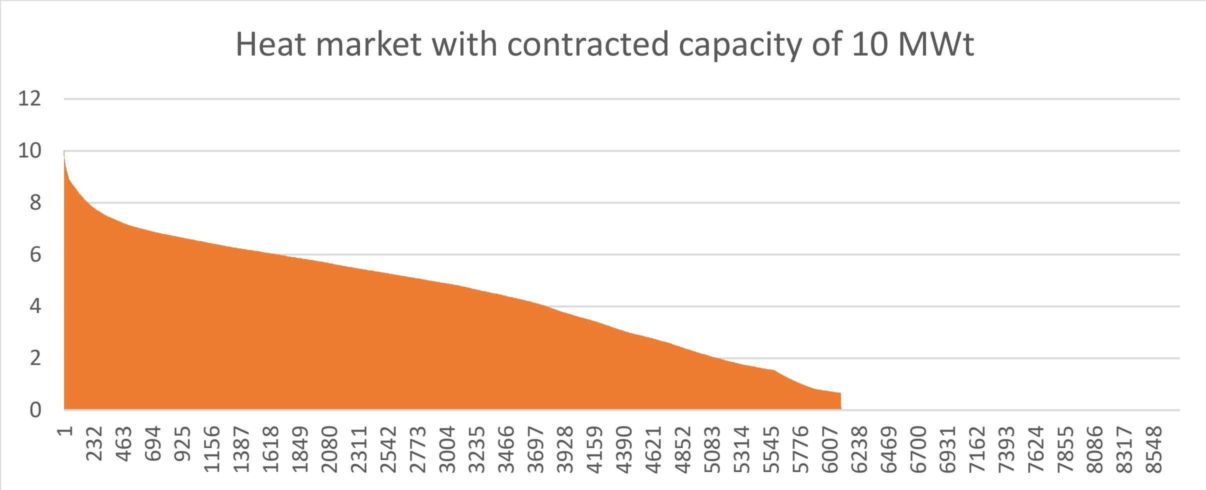


Chart 15: Heat market with contracted capacity of 10 MWt[38]

Figure 16 and Figure 17 present the benchmark heat markets in the capacity ranges of 20 to 50 MW_t and 50 to 100 MW_t. These markets are characterized by a relatively low share of hot water demand relative to larger cities and systems. This demand is particularly evident during the summer.

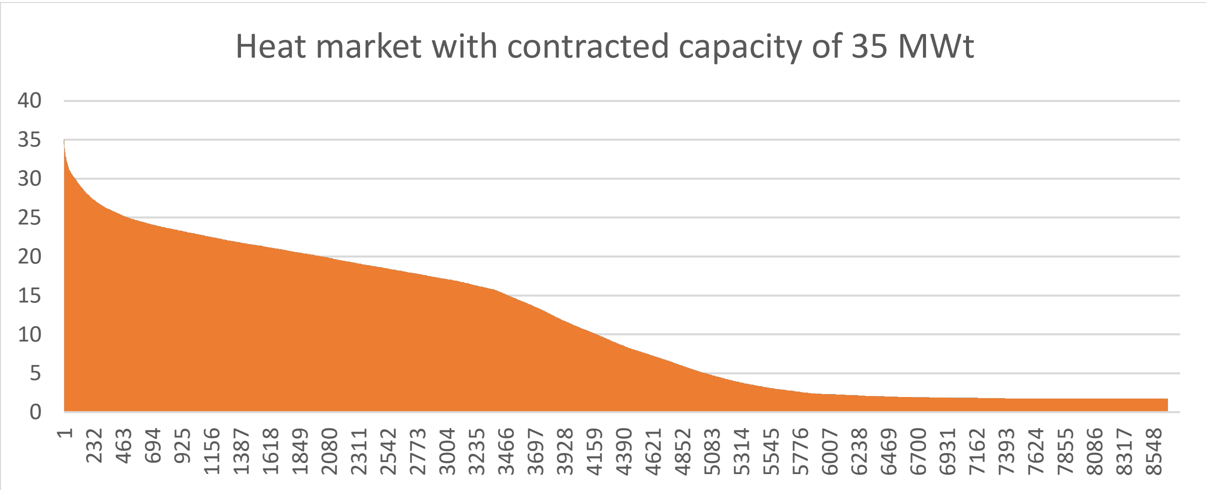


Chart 16: Heat market with contracted capacity of 35 MWt[39]

[38] PTEZ's own study
[39] PTEZ's own study

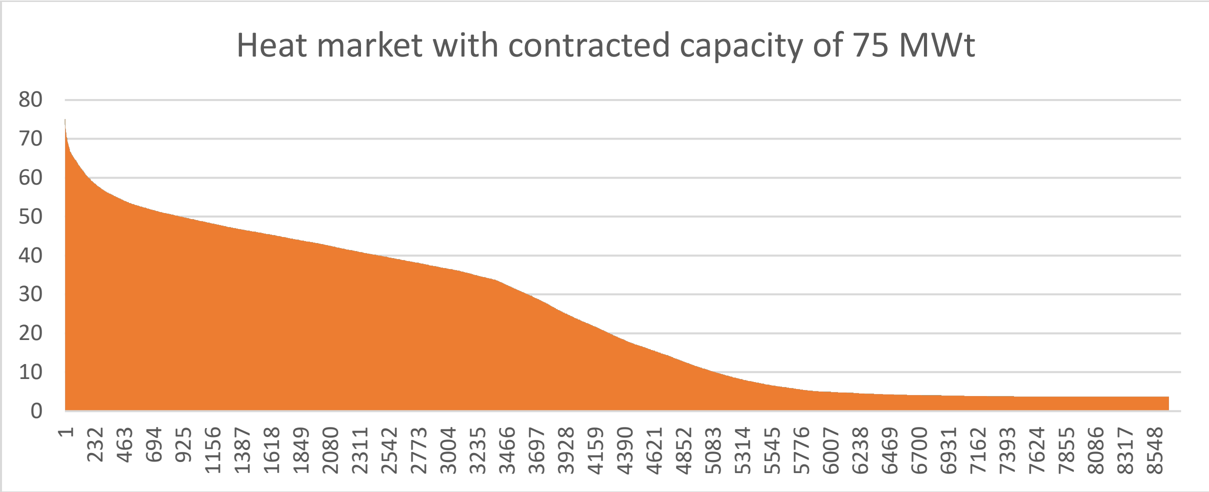


Chart 17: Heat market with contracted capacity of 75 MWt[40]

Charts 18 through 20 present the heat demand of Poland's largest district heating systems, which are located in cities of more than 200,000 people.

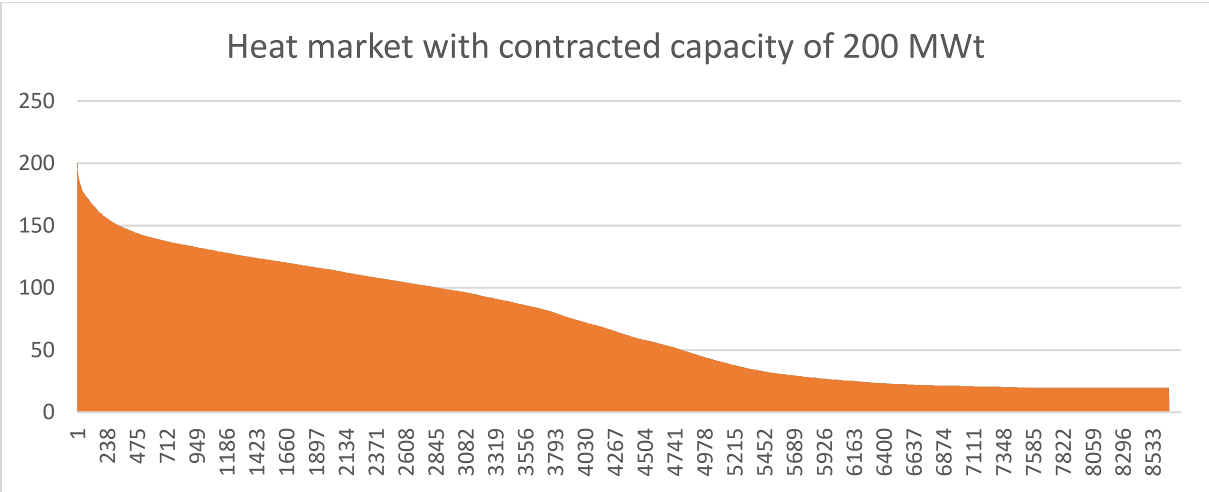
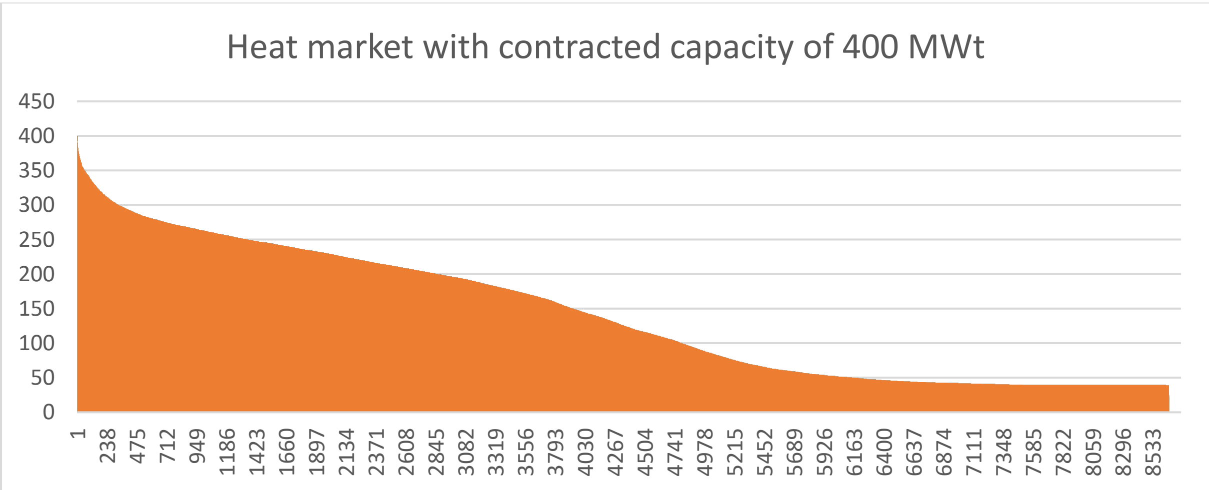


Chart 18: Heat market with contracted capacity of 200 MWt[41]



[40] PTEZ's own study
[41] PTEZ's own study

Chart 19: Heat market with contracted capacity of 400 MWt[42]

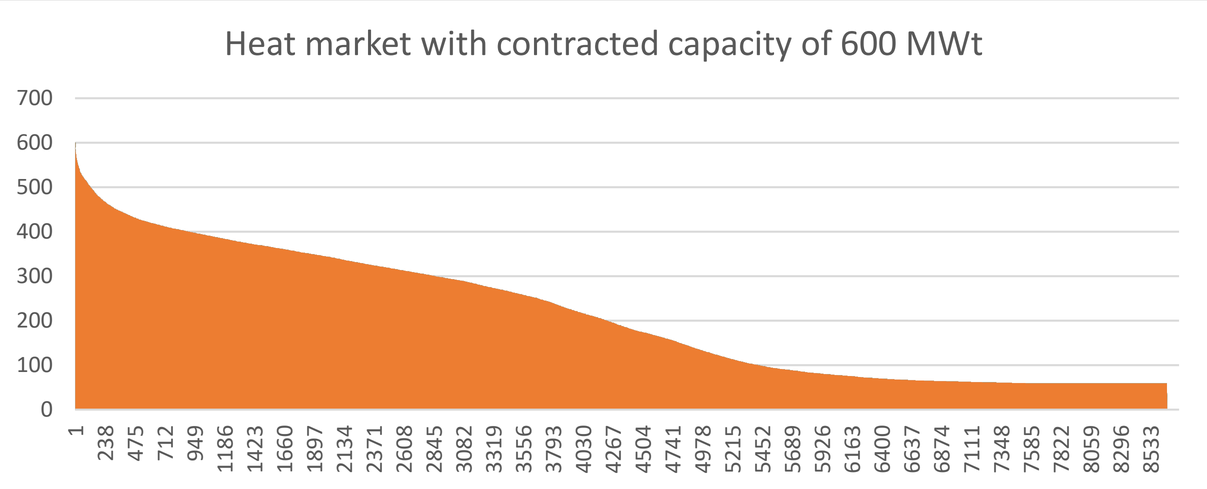


Chart 20: Heat market with contracted capacity of 600 MWt[43]

The analysis was performed for the above benchmark heat markets. For each market, 4 different technology options were analyzed that are technically feasible and can meet the requirements of the Fit for 55 package. These options meet the requirements for efficient district heating systems by 2045. After this period, it was assumed that gas-fired generating units would burn (non-investment) green hydrogen. Since there are currently no price projections for this type of fuel, hydrogen prices were assumed to be at the level of the gas price projection.

3.4 Technology options

This subsection presents the technology options that were analyzed for each of the aforementioned heat markets. A detailed description of each technology option is presented below.

Heat market from 0 to 20 MWt (located outside the EU ETS) for the purposes of the analysis, a 10 MWt market was assumed:

- Option 1:
  - WR-type (coal-fired) water grate boilers are in operation until 2025
  - As of 2026, 5 MW gas engines and 10 MW gas-fired water boilers are in operation
  - As of 2035, 10 MW biomass-fired boilers and further 5 MW gas engines are in operation
- Option 2:
  - WR-type (coal-fired) water grate boilers are in operation until 2025
  - As of 2026, 10 MW biomass-fired water boilers and 10 MW gas-fired water boilers are in operation
- Option 3:
  - WR-type (coal-fired) water grate boilers are in operation until 2025
  - As of 2026, 2 MW heat pumps are in operation, the district heating network is supplied with 0.5 MW waste heat, and 10 MW biomass-fired boilers are in operation
- Option 4:
  - WR-type (coal-fired) water grate boilers are in operation until 2025

[42] PTEZ's own study
[43] PTEZ's own study

    - As of 2026, 5 MW gas engines are in operation, the district heating network is supplied with 0.5 MW waste heat, and 10 MW biomass-fired boilers are in operation

The heat market from 20 to 50 MWt for the purposes of the analysis was assumed to be a 35 MWt market:

- Option 5:
    - WR-type (coal-fired) water grate boilers are in operation until 2025
    - As of 2026, the district heating network is supplied with 0.5 MW waste heat, 15 MW gas engines are in operation, and 30 MW gas boilers are installed,
    - Biomass-fired boilers with a capacity of 25 MW are installed starting in 2036
- Option 6:
    - WR-type (coal-fired) water grate boilers are in operation until 2025
    - As of 2026, the district heating network is supplied with 0.5 MW waste heat, a 15 MW OCGT system is in operation, and 30 MW biomass-fired boilers are installed,
- Option 7:
    - WR-type (coal-fired) water grate boilers are in operation until 2025
    - As of 2026, the district heating network is supplied with 0.5 MW waste heat, a 15 MW CCGT system is in operation, 10 MW electrode boilers and 20 MW biomass boilers are installed
- Option 8:
    - WR-type (coal-fired) water grate boilers are in operation until 2025
    - As of 2026, the district heating network is supplied with 0.5 MW waste heat, 40 MW biomass-fired boilers are in operation, and 4 MW heat pumps are installed,

The heat market from 50 to 100 MWt for the purposes of the analysis was assumed to be a 75 MWt market:

- Option 9:
    - WR-type (coal-fired) water grate boilers are in operation until 2025
    - As of 2026, the district heating network is supplied with 1.0 MW of waste heat, 30 MW of gas engines are in operation, 30 MW biomass-fired boilers are in operation, and 30 MW gas-fired water boilers are in operation (except that only until 2036)
- Option 10:
    - WR-type (coal-fired) water grate boilers are in operation until 2025
    - As of 2026, the district heating network is supplied with 1.0 MW of waste heat, a 30 MW CCGT system is in operation, 40 MW electrode boilers are in operation, and 10 MW heat pumps are in operation.
- Option 11:
    - WR-type (coal-fired) water grate boilers are in operation until 2025
    - As of 2026, the district heating network is supplied with 1.0 MW of waste heat, a 30 MW OCGT system is in operation, and 30 MW gas boilers are in operation (except that only until 2036),
    - As of 2036, 40 MW biomass-fired boilers
- Option 12:
    - WR-type (coal-fired) water grate boilers are in operation until 2025
    - As of 2026, the district heating network is supplied with 1.0 MW of waste heat, 80 MW biomass-fired boilers are in operation, and 4 MW heat pumps are in operation,

The heat market from 100 to 300 MWt for the purposes of the analysis was assumed to be a 200 MWt market:

- Option 13:
    - Coal-fired cogeneration and WR-type water grate boilers are in operation until 2025
    - As of 2026, the district heating network is supplied with 3.0 MW of waste heat, 70 MW gas engines are in operation, a 40 MW waste incineration plant is in operation, 70 MW gas-fired boilers are in operation (except that only until 2036), and 70 MW electrode boilers are in operation.
- Option 14:
    - Coal-fired cogeneration and WR-type water grate boilers are in operation until 2025
    - As of 2026, the district heating network is supplied with 3.0 MW of waste heat, a 70 MW CCGT system is in operation, 50 MW heat pumps are in operation, 50 MW biomass-fired boilers are in operation, and 80 MW electrode boilers are in operation.
- Option 15:
    - Coal-fired cogeneration and WR-type water grate boilers are in operation until 2025
    - As of 2026, the district heating network is supplied with 3.0 MW of waste heat, a 70 MW OCGT system is in operation, a 40 MW incineration plant is in operation, 50 MW of biomass-fired boilers are in operation, and 90 MW electrode boilers are in operation.
- Option 16:
    - Coal-fired cogeneration and WR-type water grate boilers are in operation until 2025
    - As of 2026, the district heating network is supplied with 3.0 MW of waste heat, 70 MW biomass-fired boilers are in operation, 30 MW gas engines are in operation, 150 MW gas-fired boilers are in operation

The heat market from 300 to 500 MWt for the purposes of the analysis was assumed to be a 400 MWt market:

- Option 17:
    - By 2025, coal-fired cogeneration and WP water boilers are in operation
    - As of 2026, the district heating network is supplied with 6.0 MW of waste heat, a 60 MW waste incineration plant is in operation, 50 MW biomass-fired boilers are in operation, 150 MW gas-fired boilers are in operation, 50 MW gas engines are in operation, 120 MW electrode boilers are in operation
- Option 18:
    - By 2025, coal-fired cogeneration and WP water boilers are in operation
    - As of 2026, the district heating network is supplied with 6.0 MW of waste heat, a 140 MW CCGT system is in operation, 50 MW of biomass-fired boilers are in operation, 20 MW ground-source is in operation, 220 MW gas-fired boilers are in operation
- Option 19:
    - By 2025, coal-fired cogeneration and WP water boilers are in operation
    - As of 2026, the district heating network is supplied with 6.0 MW of waste heat, 140 MW gas engines are in operation, 50 MW heat pumps are in operation, 50 MW biomass-fired boilers are in operation, 190 MW gas-fired boilers are in operation (except that only until 2036)
    - From 2036, 190 MW electrode boilers
- Option 20:
    - By 2025, coal-fired cogeneration and WP water boilers are in operation
    - As of 2026, the district heating network is supplied with 6.0 MW of waste heat, a 60 MW waste incineration plant is in operation, 50 MW heat pumps are in operation, 140 MW gas engines are in operation, 190 MW gas-fired boilers are in operation (except that only until 2036)

- As of 2036 190 MW biomass-fired boilers

The heat market above 500 MWt was assumed to be 600 MWt for the analysis:

- Option 21:
  - By 2025, coal-fired cogeneration and WP water boilers are in operation
  - As of 2026, the district heating network is supplied with 10.0 MW of waste heat, 200 MW CCGT system, 60 MW waste incineration plant, 150 MW biomass-fired boilers, 280 MW gas boilers
- Option 22:
  - By 2025, coal-fired cogeneration and WP water boilers are in operation
  - As of 2026, the district heating network is supplied with 10.0 MW of waste heat, 600 MW biomass-fired boilers, 40 MW electrode boilers,
- Option 23:
  - By 2025, coal-fired cogeneration and WP water boilers are in operation
  - As of 2026, the district heating network is supplied with 10.0 MW of waste heat, a 60 MW waste incineration plant, 200 MW biomass-fired boilers, 30 MW ground source, and 350 MW gas-fired boilers,
- Option 24:
  - By 2025, coal-fired cogeneration and WP water boilers are in operation
  - As of 2026, the district heating network is supplied with 10.0 MW of waste heat, 200 MW gas engines, 150 MW biomass-fired boilers, 100 MW heat pumps, 190 MW electrode boilers

3.5 Data on large-scale heat markets in Poland

The following subsection presents the actual large-scale heat markets in Poland, divided by contracted thermal capacity in the following ranges:

- up to 20 MWt (located outside the EU ETS),
- 20 to 50 MWt,
- 50 to 100 MWt,
- 100 to 300 MWt,
- 300 to 500 MWt,
- above 500 MW (the analysis adopted a 600 MWt heat model).

Table 8: Division of heat markets in Poland into benchmark markets[44]

Capacity range [MW]	Total rated capacity [MW]	Total available capacity [MW]	Heat generation [GJ]	Rated capacity / Total market [%]	Available capacity / Total market [%]	Heat generation / Total market [%]
0 - 20	1,992	1,593	12,229,197	4.2%	4.1%	4.6%
20 - 50	4,402	3,587	23,668,458	9.3%	9.1%	8.9%
50 - 100	5,876	4,750	32,182,001	12.4%	12.1%	12.0%
100 - 300	9,062	7,269	47,491,829	19.2%	18.5%	17.8%
300 - 500	6,035	5,235	25,315,476	12.8%	13.3%	9.5%
500 +	19,903	16,797	126,335,239	42.1%	42.8%	47.3%

[44] PTEZ's own study based on KOBIZE data

Total	47,270	39,231	267,222,200	100%	100%	100%

In order to estimate the scale of capital expenditures, the amount of fuel required and the impact on final heat prices for consumers, this analysis uses a benchmark calculated on the basis of heat generation in each capacity range, as presented in Table 9.

Table 9: Scaling the analysis[45]

Capacity range [MW]	Heat generation in actual heat markets in Poland [GJ]	Benchmark heat markets for analysis [GJ]	Number of heat markets in given capacity ranges [#]
0 - 20	12,229,197	99,387	**123**
20 - 50	23,668,458	348,774	**68**
50 - 100	32,182,001	747,372	**43**
100 - 300	47,491,829	2,203,239	**22**
300 - 500	25,315,476	4,406,478	**6**
500 +	126,335,239	6,609,718	**19**

4 Analysis results

This section presents the results of an economic analysis to determine the capital expenditures that need to be incurred to bring Poland's district heating sector into compliance with the Fit for 55 package. A key assumption of the analysis is that district heating systems will meet the criteria for an "efficient district heating system" based on the conditions described in Article 24(1) of the draft EED, which are indicated in subsection 2.1 of this analysis.

The adoption as a boundary condition of a given modeled district heating system's fulfillment of the "efficient district heating system" criterion is due to the crucial importance of having this status for the operation of a given system. Its loss is associated with serious consequences for both energy companies engaged in heat generation and heat transmission and distribution, i.e., among others:

- significantly limiting the possibility of obtaining investment support for retrofit,
- destabilizing the operation of the district heating network by connecting a large number of small RES plants (which will not equate to a large volume of heat from RES),
- the emergence of stranded costs resulting from the construction of generating units that guarantee energy security,
- allowing end users to disconnect from the district heating network,
- the emergence of more individual heat sources (which are not necessarily RES plants),

but also for air quality in individual locations, as emissions of harmful substances and greenhouse gases will increase due to the aforementioned effects, and the phenomenon of low emissions and smog will worsen. Thus, it has important implications for all parties involved in local heat markets.

[45] PTEZ's own study based on KOBIZE data

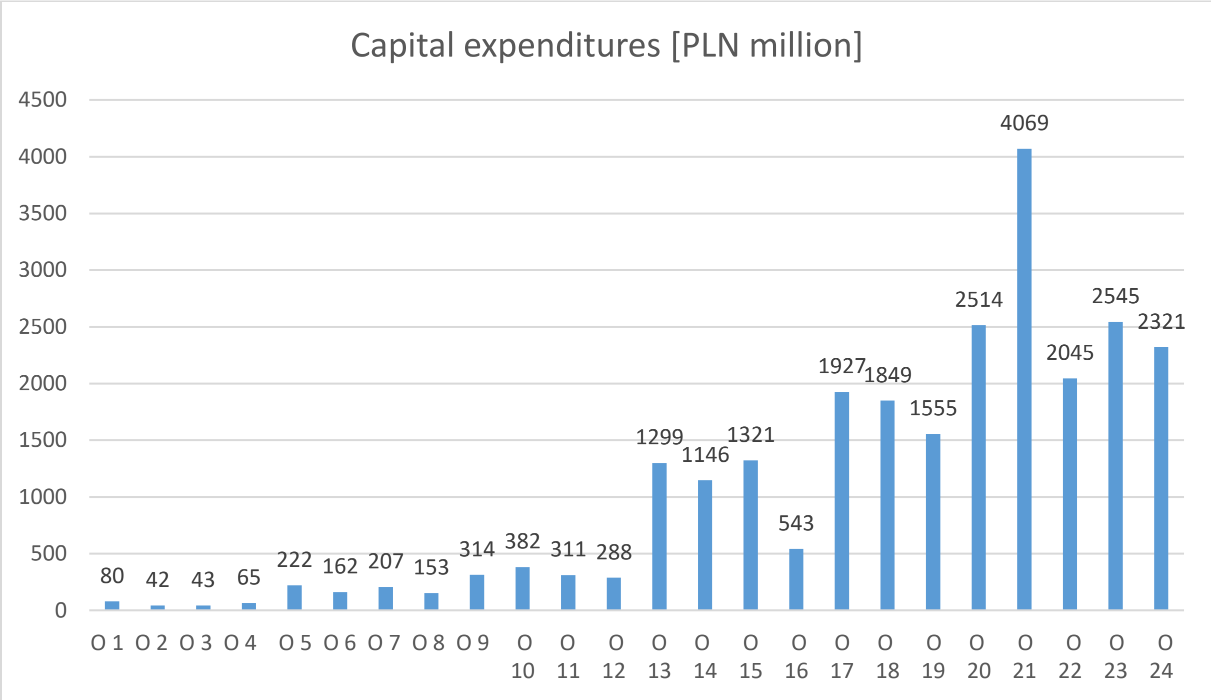


Chart 21: Undiscounted capital expenditures for the respective development alternatives identified in subsection 3.4[46]

Based on the results of the model, it should be assumed that in individual heat markets, depending on the contracted capacity and the option of development of generation sources, it is necessary to invest between PLN 40 million and PLN 4,000 million in a single market (for a market with a capacity of 600 MWt, in the case of larger heat markets, it should be expected to incur more expenditures than those described in options 21-24 (see the case study of the Cracow metropolitan area in Appendix 1).

Table 10: The level of capital expenditures to bring individual system heat markets in line with the requirements of an efficient district heating system[47]

Capacity range [MW]	Minimum expenditures [million PLN]	Average expenditures [million PLN]	Maximum expenditures [million PLN]
0 - 20	42	57	80
20 - 50	153	186	222
50 - 100	288	324	382
100 - 300	543	1,077	1,321
300 - 500	1,555	1,961	2,514
500 +	2,045	2,745	4,069

Taking into account the number of heat markets in Poland (presented in Table 10) in the proposed capacity ranges, it should be concluded that meeting the requirements set forth in the draft

[46] Results of the economic model
[47] PTEZ's own study

Fit for 55 package regulations will cost Poland from PLN 95 billion in the minimum CAPEX option, to PLN 170 billion in the maximum CAPEX option, taking into account additionally the BoP-related CAPEX for the gas options. However, it is important to point out the likelihood of a non-inflationary increase in capital expenditures due to: the need to modernize the entire segment at the same time (the opening of a large work site), the saturation of the Contractors' market, the interruption of the supply chain due to the geopolitical situation. These aspects are also important given the assumed schedule and the need to meet further milestones for the definition of an efficient district heating system. The capital expenditures shown above are for generation sources and do not include expenditures related to retrofit of district heating networks and consumer facilities. Capital expenditures for this segment were estimated to range from PLN 76 billion to PLN 100 billion (details are presented in subsection 4.2) and from PLN 106 billion to PLN 140 billion (details are presented in subsection 4.3), respectively.

The effect of development and retrofit of the district heating sector is an integral part of the increase in the price of heat for end users. The single-component heat price, through which investors will be able to allocate funds for the development of generating units and ensure the profitability of their enterprises, is shown in Figure 22. The prices shown are the price of heat generation, and do not include the cost of heat distribution and transmission.

The model was developed using Excel. It is a mathematical optimization model whose main objective is to minimize the total cost of heat generation in district heating.
It comprises the following components:

- CAPEX – including capital expenditures and financing costs
- OPEX – including the cost of fuel, the cost of CO_2 emission allowances, fixed operating costs
- Time of analysis – 2022 – 2050

Based on a typical ordered heat demand curve, the rated thermal capacity of the sources is calculated. Nominal thermal capacity is calculated based on the thermal efficiency of the sources, the heat sources operate in order from the most efficient source at variable cost and at the highest margin I generated, so arranged the stack of units fills the demand of the district heating market in each option.

The model is intended to calculate the averaged discounted unit heat price on generation, which ensures the profitability of a given option at IRR = 8% over the period 2022 – 2050.

The model discounts all expenses (CAPEX, OPEX), includes revenues from electricity sales and CHP support at PLN 100/MWh, and looks for a heat price that yields NPV = 0 over the entire projection period.

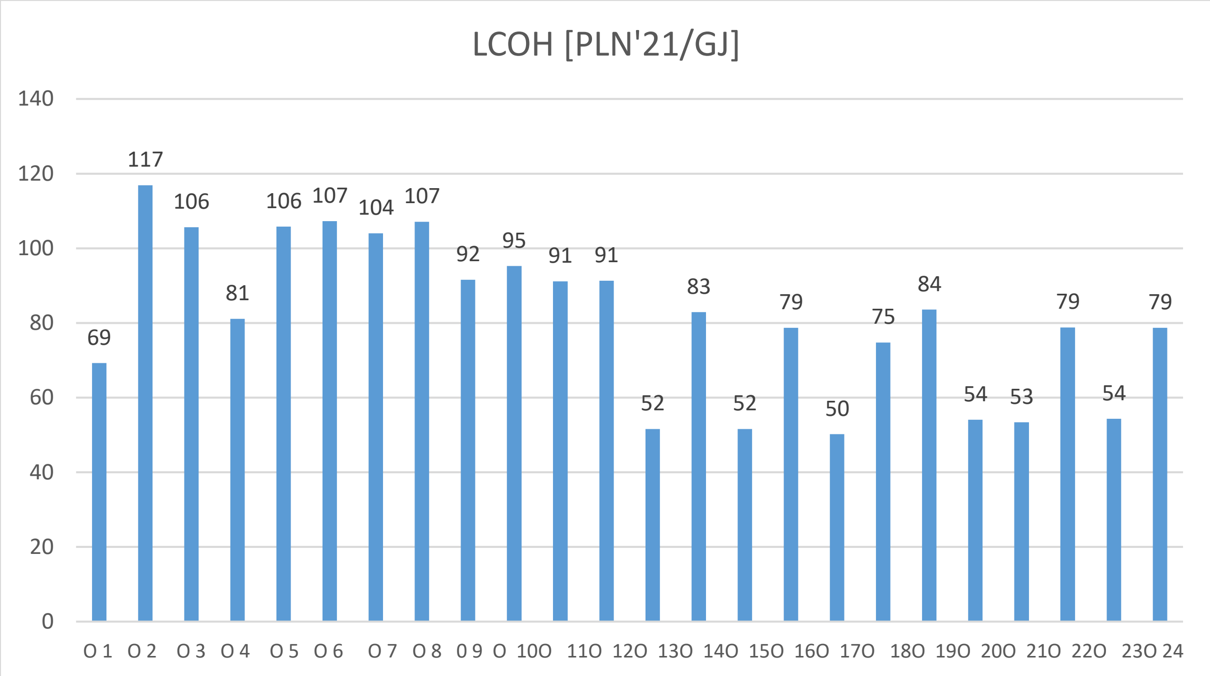


Chart 22: Heat prices on generation for end users[48]

It is also necessary to draw attention to the following element – in the context of the feasibility of the implementation of the necessary investments, in order for district heating systems in Poland to meet the criterion of an efficient district heating system, it is also necessary to adjust the dates of entry into force of the next significant milestones in such a way that it is possible to provide the required amount of time in relation to the investment cycle. According to publicly available information on the implementation schedules of large-scale investment projects in the heat and power sector, the process of obtaining all approvals and formal, legal and administrative permits, followed by the selection of the Contractor takes approx. 1-2 years, and then the works performed by the EPC Contractor – from 3 to 5 years. It should be noted here that the timing depends on local conditions and may vary for capacity- and technology-identical projects. Project completion times for reference large-scale CCGT units are summarized below:

	Electric power [MWe]	District heating capacity [MWt]	Lead time [months]
Żerań CHPP	497	326	40
Stalowa Wola CHPP	396	210	108
Płock CHPP	600	520	37
Włoclawek PP	463	-	43
Lausward CHPP (Germany)	595	300	48
Diemen CHPP (Netherlands)	435	360	42

[48] PTEZ's own study

Donaustadt CHPP (Austria)	383	250	40

It should also be noted that gas connections must be built by the entity to be connected. Therefore, regardless of the technological arrangement, it is necessary to route gas infrastructure to the premises of generating units well ahead of the start of construction works, which, depending on the site conditions and the proximity of a gas transmission or distribution network, is a process that takes approx. 60 months from the date technical connection conditions are issued. Furthermore, as is the case with projects carried out on the sites of existing generating units, it is often required to adjust the schedule of the final stage of implementation (trial run, adjustment run) to current production capacity and heat demand. It is often impossible to perform all testing procedures and equipment parameter tests during the summer periods, when there is low heat demand.

Also summarized below are the administrative decisions and permits necessary to carry out investment projects relating to generating units:

1. Decision on environmental conditions: depending on local conditions and the possible requirement to file a full environmental impact report – between 3 and 14 months, and the waiting time for the decision of the issuing authority – up to 2 months.
2. Building permit – a decision is issued within a period of 65 days, before that: a building permit design must be drawn up – depending on its complexity, its development takes from 3 to 9 months.
3. Connection to the power system – waiting time of several months depending on the scope of work – the time is set out in the connection agreement.
4. Integrated permit – waiting time is approx. 6 months.
5. Obtaining a license amendment – waiting time for a decision is 1-2 months.
6. Approval for operation by the Office of Technical Inspection – waiting time is approx. 1-2 months.
7. Issuance of an occupancy permit by the District Building Inspectorate – waiting time is approx. 1-2 months.

In addition, in the case of some power companies and the investments they make, due to limited land capacity, there is a need to purchase land for the development of new generating units, which, in addition to increasing capital expenditures, can also generate a longer project life cycle.

At the same time, it is also worth noting that in the case of making generating units into smaller ones, all formal, preparatory and implementation activities are multiplied, which also significantly increases the implementation time of the investment process.

4.1 Fuel demand considerations

If investors are willing to implement technology options with the maximization of the share of biomass in heat generation, the demand for this fuel in the first period would be approx. 23 million tons per year, which, given the conditions of the biomass sector, is an unrealistic option. In the scenario of minimizing the share of biomass in the district heating sector in the long term, the share of this fuel will be approx. 5 million tons per year after 2040 anyway. Until then, the biomass segment should be constructed. From the viewpoint of demand and fuel supply logistics, these aspects are technically impossible to implement from a practical viewpoint as described in subsection 1.4. For comparison –

during one of the best years for the biomass market in Poland, 6.5 million tons of biomass were burned across the electricity and district heating sectors, followed by problems with lack of availability.

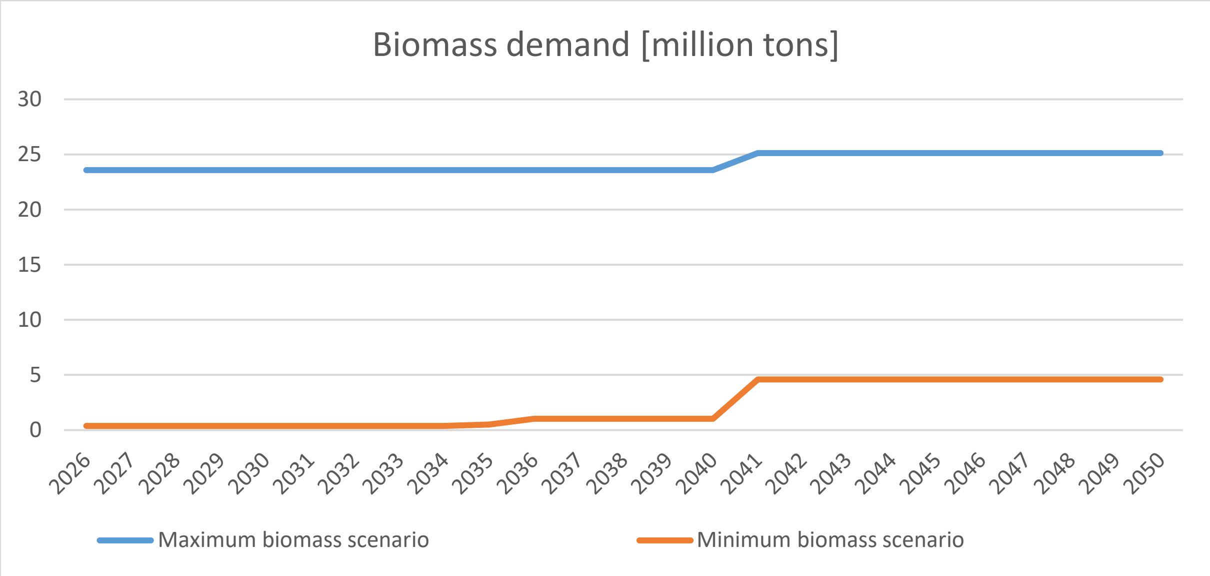


Chart 23: Biomass demand[49]

In the case of biomass fuel demand, it should be noted that in Poland CHP and heating plants are located in cities, which further creates logistical problems. This causes numerous protests from residents due to significant inconvenience on the side of congested streets and social unrest, which ultimately translates into the inability to implement scenarios with high biomass use in CHP plants.

In addition, it should be noted that the maximum potential for biomass use in the sector is approx. 5 million tons per year (currently less than 4 million tons per year are burned in the sector), assuming a developed and secure biomass sector. This results in the fact that only small heat markets with contracted heat capacity of less than 50 MWt can meet the requirements of the Fit for 55 package for the required amount (increment) of heat from RES in the district heating system. In the case of large district heating systems such as, for example, Wrocław, Kraków, Warsaw, Gdańsk, when there is a lack of available generation technologies on an appropriate scale, an adequate volume of fuel (albeit biomass) is not available, and with the current proposed form of regulation in the draft revision of the RED directive, on the basis of which there is no possibility to qualify heat generated from RES electricity as RES heat, there is also no possibility to meet the goals of the Fit for 55 package in terms of the amount (growth) of heat from RES in district heating systems. For example, in order to meet the goal of 20% of heat from RES in Warsaw's district heating system, approx. 1.2 million tons of biomass would have to be obtained annually, which is impossible due to both demand and logistical considerations. The maximum share of RES heat generated from biomass in these heat markets could be 5%, assuming that the difficulties associated with the unstable market for this fuel are overcome. This is because it is characterized by very little predictability, with the vast majority of fuel contracted on a month-to-month basis, and market tools such as long-term contracts, the stock market or price indexes do not function.

To a significant extent, this is due to the fact that the biomass supply market faces significant logistical, regulatory and geopolitical barriers. As indicated above, especially in large cities, the transportation and storage of biomass poses a major logistical challenge. Another factor that

[49] PTEZ's own study based on model results.

significantly limits the use of biomass is the requirement to certify the entire production chain of these fuels against sustainability criteria (SDC), which stems from the implementation of the RED II directive. The certification system affects the supply and price of biomass fuels, and applies from the stage of raw material acquisition to the stage of final use, taking into account all links in the supply chain. Poland's geopolitical location is also not without influence on the biomass market. The armed conflict in Ukraine has significantly reduced the supply of fuel, as it has resulted in the blocking of Belarus and Ukraine, the two main import destinations (Poland currently imports approx. half of the needed fuel). In conclusion, the biomass market in prospect will face deepening constraints that will not have a positive impact on investment decisions in this type of generation source,

Figure 24 shows the gas demand in the scenario with the selection of options with the largest share of gas sources and the minimum share of gas sources.

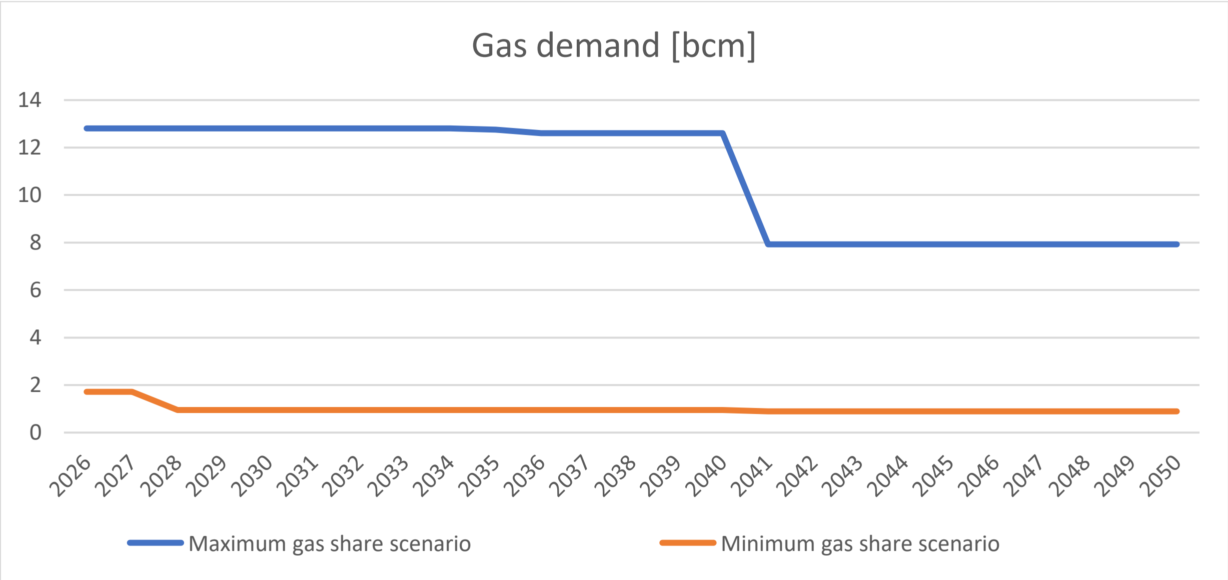


Chart 24: Gas demand[50]

Based on ERO data for 2020[51], gas use in the district heating sector is approx. 3 billion cubic meters. This data, compared to Chart 24, illustrates the scale of the technological and investment challenges facing Poland's district heating sector and associated infrastructure. It is also important to point out the considerations related to the network gas market and the overall shape of the investments carried out, related, among other things, to the need for energy companies to cover the full costs associated with the construction of connection pipelines.

Based on Charts 23 and 24, it is clear that in order to minimize the share of coal consumption in the overall district heating sector, it is necessary to develop gas infrastructure and develop the biomass sector in Poland, as, today, there are no other technologies available with which it will be technically possible to meet the regulatory requirements of the Fit for 55 package.

The analyses also assessed the impact of the implementation of the Fit for 55 package on the carbon performance of the district heating sector in Poland. The results in the two scenarios are presented in Chart 25, which shows that if the most ambitious scenarios for the use of RES in the district heating sector in Poland are to be pursued, the sector's carbon performance will be marginal,

[50] PTEZ's own study based on the results of the model
[51] ERO report “Heat power engineering in numbers – 2020”

but at this point it should be noted that there will be a logistical and technical problem related to the lack of fuel availability. In a scenario in which gas is used to a greater extent in cogeneration units, the sector's carbon performance will also be significantly reduced and the requirements of the Fit for 55 package will be met, but gas demand will increase nearly 4-fold from year to year, which is also technically unfeasible in terms of securing sufficient supplies of the fuel. This may also be hampered by the scope of planned investments specified by GAZ-SYSTEM, i.e. the gas transmission system operator in Poland, in the National Ten-Year Transmission System Development Plan for 2022 – 2031[52], which, despite its high level of ambition in terms of the investments to be made, did not foresee the need to switch to gas as an intermediate fuel in such a short timeframe as the proposed definition of an efficient district heating system.

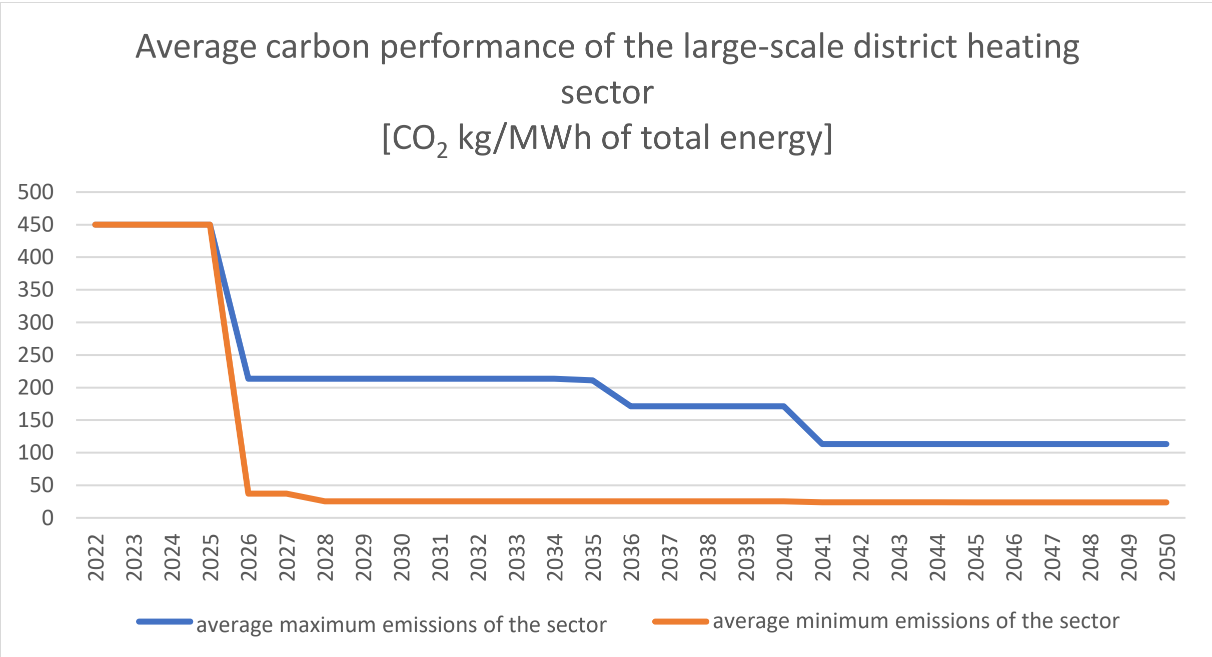


Chart 25: Projection of CO_2 performance of the heating sector in Poland depending on the development scenario[53]

4.2 Conditions of the district heating networks

In Poland, the district heating sector, as shown in subsection 1.2, is highly developed compared to other countries in Europe. In Poland, heat generation in cities is centralized and heat is supplied by district heating systems over large areas. It supplies an average of 40 to 60% of the population in a given region. Accordingly, the number of district heating networks and district heating customers is significantly higher than in other European countries. The following table presents data on the total length of district heating networks in Poland according to the size of district heating systems.

Table 11: Lengths of district heating networks in Poland[54]

[52] National Ten-Year Transmission System Development Plan for 2022 – 2031 developed by OGP-Gaz-System and agreed with the ERO President in 2021.
[53] PTEZ's own study
[54] ERO report "Heat power engineering in numbers – 2020"

Length of district heating network [km]	[km]
3 and below	36.3
3-5	90.8
5 - 7	90.9
7 - 10	335.2
10 - 20	1,269.5
20 -50	3,075,5
More than 50	17,224,9
Total	**22,123.1**

In Poland, district heating networks have a total length of more than 22,000 kilometers. Adapting the heat generation sector to future regulatory requirements will involve great expenditures to modernize such extensive heat transmission and distribution infrastructure. As part of this analysis, due to the impossibility of obtaining accurate data on the diameters of individual district heating networks, it was decided to estimate the scale of capital expenditures necessary for this segment in order to adapt high-temperature networks (present in Poland) to the requirements under the Fit for 55 package for heat quantity and quality, i.e. upgrading to low-temperature pre-insulated networks. In order to estimate the scale of capital expenditures, the 2020 price list for replacement of district heating networks was used, as shown in Table 12, and assumptions were made regarding the diameter of individual district heating networks.

Table 12: Pricing for replacement of district heating networks according to diameter[55]

	Unit of measure	Unit price in PLN
District heating networks made of pre-insulated pipes		
32/110 mm (two-pipe system in a trench)	m	1,506
40/110 mm	m	1,873
50/125 mm	m	2,241
65/140 mm	m	2,608
80/160 mm	m	2,975
100/200 mm	m	3,343
125/225 mm	m	3,710
150/250 mm	m	4,078
200/315 mm	m	4,445
250/400 mm	m	4,812
300/450 mm	m	5,180
350/500 mm	m	6,539
400/560 mm	m	9,407
500/630 mm	m	12,058

As part of the analysis, the average diameters of the district heating networks in each system were assumed based on Table 11.

[55] Source: PTEZ's own study based on market price lists

Table 13: Average diameters of district heating networks[56]

Diameter of district heating pipes in Polish systems [mm]	Average distribution of pipe diameters using several district heating systems as an example [%]	Length of district heating networks in Poland with a given cross-section [km]
up to 100	54%	11,946
100-200	23%	5,088
200-300	7%	1,549
300-400	3%	664
400-500	7%	1,549
> 500	6%	1,327

Table 14: Adopted price list and diameters for valuation of capital expenditures[57]

Adopted diameter	Pricing [PLN/m]
50/125	2,241
100/200	3,343
150/250	4,078
200/315	4,445
250/400	4,812
500/630	12,058

Based on the above data and the assumptions made, it should be concluded that the modernization of the heat transmission and distribution infrastructure to adapt it to low-temperature networks on the capital expenditure side will amount to approx. PLN 76 billion. Assuming that some of the assumptions made are subject to the risk of data inaccuracy, and taking into account the current phenomenon of high inflation and the lack of available materials, which also affects price increases, it is estimated that capital expenditures could increase up to PLN 100 billion.

It should also be pointed out that the calculations do not take into account the very difficult to estimate increase in capital expenditures due to claims of landowners in the process of modernization of district heating networks – in Polish conditions there is a large share of land to which distributors do not have legal title.

4.3 Conditions for consumer systems

The most difficult to estimate the necessary investment is the area of modernization of consumer systems in buildings, which includes the modernization, installation or replacement of heat distribution substations and the modernization of the building service systems, without which, as indicated in subsection 1.4, it will not be possible to carry out an effective transformation of the district heating sector. The extent of capital expenditures to be determined in this area is all the more difficult because the technical condition of buildings in Poland and building service systems varies, in addition, in some buildings heat is supplied from group heat distribution substations. However, it has been assumed, taking into account the calculations shown in subsection 4.2, that the capital expenditures necessary to be incurred for the modernization of network heat receiving facilities will amount to 1.4

[56] PTEZ's own study
[57] PTEZ's own study

times the expenditures necessary for the modernization of transmission and distribution infrastructure. The size of these expenditures will thus amount to PLN 106-140 billion.

5 Summary and recommendations

5.1 Summary

- Heat from large-scale district heating network is used for heating purposes in 40.4% of households in Poland, or approx. 6 million households. At the level of the European Union as a whole, the district heating sector satisfies approx. 13% of heat demand. This means that in Poland the district heating sector is much more developed than in most EU countries – the Polish sector is the second largest in Europe, after Germany, in terms of the amount of heat delivered to end users, and at the same time the largest market in Europe in terms of the number of heat consumers at 16 million (one in four large-scale heat consumers in Europe is a resident of Poland).
- The burden on households in terms of the share of heat purchase costs in the household budget in Poland is twice as high as in Germany (10% share of the budget in Poland versus 5% of the budget in Germany). These figures refer to disposable income. Significant increases in end-user heat prices resulting from such a rapidly implemented energy transition process in the district heating sector, as implied by the milestones set forth in the proposed definition of an efficient district heating system, will result in a significant increase in the incidence of energy poverty in Poland.
- In 2020, the value of installed thermal capacity in Poland was 53,271.1 MW, with a network infrastructure of 22,123.1 km and a heat sales volume of 343,690.7 TJ. Of the 387 licensed district heating companies in Poland, 10 have an installed capacity of sources exceeding 1,000 MW each, and their total generating capacity accounted for more than one-third of the generating capacity of all sources. Given the lack of availability of suitable RES technologies for systems of this scale and the limited availability of fuels such as biomass and renewable gases, there is a need for a different approach to the transformation of large district heating systems.
- Of the total heat generation of licensed energy companies in 2020, the share of heat generated in cogeneration was 65.2%. This group of companies is dominated by coal fuels, but a third are other fuels, including 10.1% of renewable sources, 10.6% of natural gas and 4.8% of fuel oil.
- According to the standards, Poland is divided into five climate zones, which allow to determine the basic design parameters of outdoor air, with buildings located in the east and south of the country characterized by much higher energy consumption than those located in central and western Poland. In 2020, the number of heating degree-days, which expresses the scale of demand for system heat, was approx. 9% higher in Poland than the EU average, confirming the significantly higher importance of the district heating area in Poland.
- In Poland, metropolitan areas are heated and supplied with heat for domestic hot water by large district heating systems with high generating capacities. Dividing large district heating systems into smaller ones, especially in large cities, involves a number of technical, logistical and formal and legal challenges. These include but are not limited to difficulties in acquiring land for the development of distributed RES plants, the adaptation of the separated network and the adaptation of building service systems to operate on low-temperature parameters, formal and logistical problems associated with the performance of network investments, including the arrangement of ownership, services, land, etc., the need for possible expansion

of electricity infrastructure. In this regard, it should be pointed out that it is virtually impossible to divide large district heating systems into smaller ones.

- There is a shortage of RES technologies that could on a wider scale ensure that the temperature of the medium supplied into the network is sufficiently high. Reducing the temperature on the receiving side of the district heating system requires large capital expenditures and is not feasible in a reasonable and responsible manner within a few years. The solutions that can be considered include:
    - Waste-to-Energy Plants (WTE plants) converting municipal waste and sewage sludge from wastewater treatment plants;
    - sources fueled by RDF – an alternative fuel as a method of managing high-heating value waste fraction and using it as fuel;
    - ground source heating – in selected locations where suitable geological conditions exist;
    - large-scale solar collectors;
    - heat pumps, which, due to their relatively small installed capacity, can operate as a supplement to another heat source, and the RES participation obligation would be fulfilled by supplying such a pump with RES electricity; use of renewable gases (green hydrogen, biomethane, biogas).
- Works are being undertaken for the construction of hybrid systems, in which central generating units will be supplemented by renewable sources of heat generation (thermal waste conversion, ground-source heating, solar panels, heat pumps, etc.) – limited applicability.
- The analysis was carried out for characteristic heat markets in Poland, classified by contracted capacity. The model is based on detailed macroeconomic, market and technology assumptions for reference heat markets for the period 2022-2050. Four technology options were proposed for each market to meet the definition of an efficient heating and cooling system, as proposed by the European Commission.
- The model developed as part of the analyses, for each year, based on the variable costs of production, determines the stack of units in a given system, which is then written into a demand curve derived from the heat profile for a given heat market. This allows us to determine the most cost-effective option for each heat market considered.
- **Taking into account the number of heat markets in Poland in the capacity ranges considered, the analysis showed that adapting the Polish district heating sector to the requirements proposed in the draft regulations of the Fit for 55 package will cost:**
    - **from PLN 95 billion to PLN 170 billion – capital expenditures for generation infrastructure,**
    - **from PLN 76 billion to PLN 100 billion – capital expenditures for transmission and distribution infrastructure,**
    - **from PLN 106 billion to PLN 140 billion – capital expenditures for modernization of heat distribution substations.**

  In total, this means at least PLN 277 billion to PLN 410 billion in capital expenditures to be incurred in the prospect to 2045 for the transformation of the district heating sector, with a significant portion of capital expenditures needed to be spent as early as 2026 – capital expenditures of PLN 145 billion to 250 billion. The accumulation of such large investments in such a short period of time throughout the country may generate problems with the physical feasibility of the works, as well as cause an increase in the cost of investment implementation. It is also worth pointing out, for example, that in 2020, the value of Poland's gross domestic product was *PLN*2,323.9 billion*, which means that the total value of expenditures until 2026 for the transformation of the district heating sector alone, would account for approx. 6.24% – 10.76% of Poland's annual GDP*. Similarly, showing the example of the National Reconstruction Plan, under which Poland is expected to receive a total of approx. PLN 270 billion, capital expenditures solely for the transformation of the district heating sector, even in the most optimistic scenario, exceed the value of this aid.

- The analysis also showed that, depending on the choice of the transformation scenario (technology option), even in the scenario of minimizing the share of biomass in the district heating sector, which is one of the few RES technologies that can be used in large district heating systems, in the long term the share of this fuel will be approx. 5 million tons per year after 2040, while for comparison – during one of the best years for the biomass market in Poland, 6.5 million tons of biomass were burned in the entire power and district heating sector (after which there were problems caused by its unavailability). If investors are willing to implement technology options maximizing the share of biomass in heat generation, the demand for this fuel in the first period would be approx. 23 million tons per year.
- As part of the developed model and with the adoption of actual macroeconomic assumptions, it was found that meeting the requirements proposed in the “Fit for 55” package as submitted by the European Commission will be impossible in practice in Poland. This is primarily due to the size of this heat market, its location and its specificity, distinguished from other European markets.
- Assumed in the “Fit for 55” package such a rapid increase in the share of zero-carbon heat sources, in practice will force a temporary increase of nearly 4 times the demand for gaseous fuels, which requires long-term investment in infrastructure and diversification of supply routes. A similar situation is currently observed in the biomass market, which is underdeveloped, causing logistical problems in the centers of major cities due to the location of generating units.
- The analysis showed that it is necessary for the draft revision of the EED to take into account the specificity and dissimilarities of large district heating systems and to propose criteria that will be technically and economically achievable for them. As indicated above, the simulation results presented confirmed that this is not possible based on the European Commission's proposal.

5.2 Recommendations

- Investment in high-efficiency gas-fired cogeneration (with renewable hydrogen or renewable gases in the future) is the most preferred direction that can underpin the operation of the district heating system under Polish district heating conditions. However, they require a predictable regulatory environment that will ensure the status of an efficient district heating system for as long as possible for systems using this technology. In particular, given the current sources of power for district heating systems in Poland, the entry into force of the mandatory emission rate for high-efficiency cogeneration contained in the draft EED should be postponed, allowing for appropriate investments. In addition, these units can be easily adapted in the future to burn, for example, “green hydrogen”. In this context, it should also be emphasized that cogeneration units play an important role in ensuring the proper operation of the national power system – in this context, their sudden replacement by, for example, heat pumps, which have a high demand for electricity, could result in a large gap that could not be balanced.

- In the context of effectively carrying out the transformation of district heating systems, it should be remembered that gas-fired cogeneration units are characterized by high flexibility of operation in terms of the safety of district heating system operation, but have limitations in the form of technical minimums – hence the construction of new RES plants and their connection to the district heating network should be performed in a sustainable manner.
- The analysis proved that for large district heating systems, of which there are many in Poland, there are two main constraints currently preventing their transformation in line with the "Fit for 55" package. The first obstacle is the lack of available RES generating unit technologies to produce RES heat at a level that meets demand in large systems. Undertaken with the best intentions of meeting the designed requirements, the modeling attempt revealed the technology's current shortcomings. The second obstacle relates to fuel availability. Even where technologies exist, such as biomass-fired boilers or plants ready to burn renewable gases or green hydrogen, these fuels are not currently available on the market. In fact, markets for fuels such as hydrogen and biomethane are currently virtually non-existent. When making an investment decision worth billions of PLN, a rational investor cannot assume that a supply market at an appropriate level will be created, let alone invest in technology that is not there. Taking the above into account, it should be pointed out that in the case of large district heating systems, it is necessary to **properly adjust the schedule of changes of these systems to the available technologies and fuels**. Ensuring time flexibility is key to meeting the stated goals of transforming Poland's large district heating systems.
- At the same time, it is not possible to abandon the use of large district heating systems used in Poland. Given the unique characteristics of large-scale district heating in Poland, as described in the analysis, compared to European Union member states, including in particular (i) its universality, (ii) ensuring security of supply to millions of customers, (iii) the extensive infrastructure, (iv) the fact that the system supplies customers in large, densely populated cities, (v) the characteristics of supply to customers, a move away from district heating in Poland would be economically and technologically unjustified, and could lead to the **risk of a lack of supply to millions of end users, especially the poorest**.
- Taking into account the size of the capital expenditures to be incurred for adaptation of only the generation infrastructure to the requirements of the proposed revision of the EED in the 2026 perspective at the level of **PLN 80 billion to PLN 150 billion** confirms the necessity of moving the entry into force of the regulation on the extension of the criterion of high-efficiency cogeneration by verification of meeting the unit CO_2 emission rate of 270 g CO_2/kWh by January 1, 2030. Otherwise, such high necessary transition costs are highly likely to prove socially unacceptable – it should be pointed out that this is not the only area that will require high capital expenditures in the near term. Alternatively, this indicator should only apply to new and significantly retrofitted cogeneration units.
- In addition, if investments in generating units were to be made on such a large scale by January 1, 2026, they would have to be at an advanced stage of the investment process by that point – and it should be pointed out that there is still uncertainty about the direction of regulations in this area, so it is difficult to make investment decisions in this area on such a large scale. The

availability of equipment, materials and contractors for so many projects in such a short period of time can also be a very significant problem.

- The lack of availability of RES technologies that can be implemented in large district heating systems, due to the operating characteristics of these systems and the very high cost of their implementation, means that without the introduction of solutions for the mechanism of qualifying heat from RES electricity as RES heat, these district heating systems will be deprived of one of the few technologies that allow to obtain heat increase from RES.

Appendix 1: Case study of the transformation of the district heating system in the Kraków metropolitan area

Statistical data for the city of Kraków:

- Surface area of the city – 327 km2
- Extent: from south to north – 18 km, from west to east – 31 km
- Population: 780,796 (June 2021)

1. Heat market – Overview:

The district heating network operates in an annular-radial system with the possibility of supplying from individual independent sources. The existing layout of the district heating networks facilitates the distribution of energy not only for central heating during the heating season, but also for hot water and air conditioning throughout the year. The operator of the municipal district heating network is Miejskie Przedsiębiorstwo Energetyki Cieplnej S.A. (MPEC S.A.). Currently, Krakow's MPEC manages nearly 950-kilometer network, of which as much as 70 percent is pre-insulated. The company covers almost **65 percent of the city's area and supplies heat to almost 10,000 facilities in Kraków**. Among others, residential blocks, schools, hospitals, shopping malls, sports facilities, museums, churches are supplied. Nearly **78 percent of Krakow's residents use MPEC district heat**.

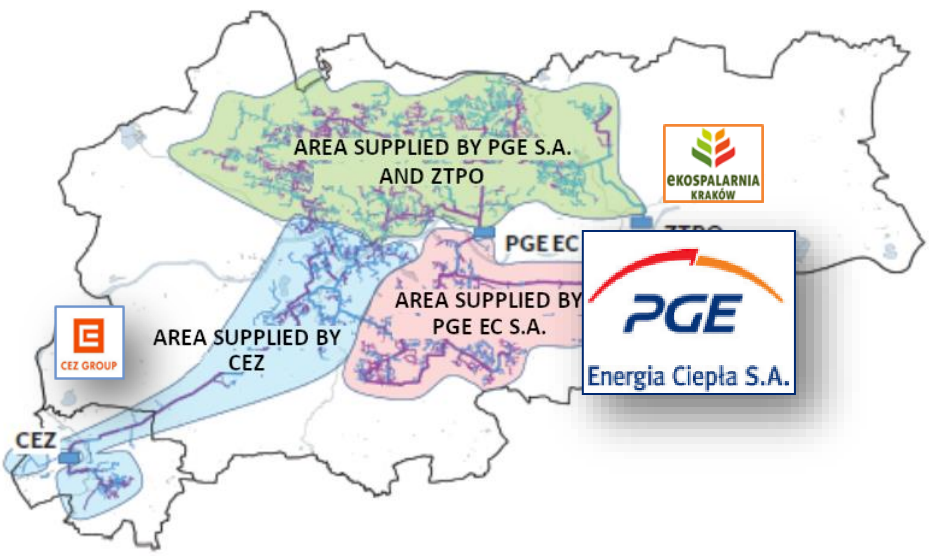


Fig. 1.1: Map of the area of the district heating system in the Kraków metropolitan area

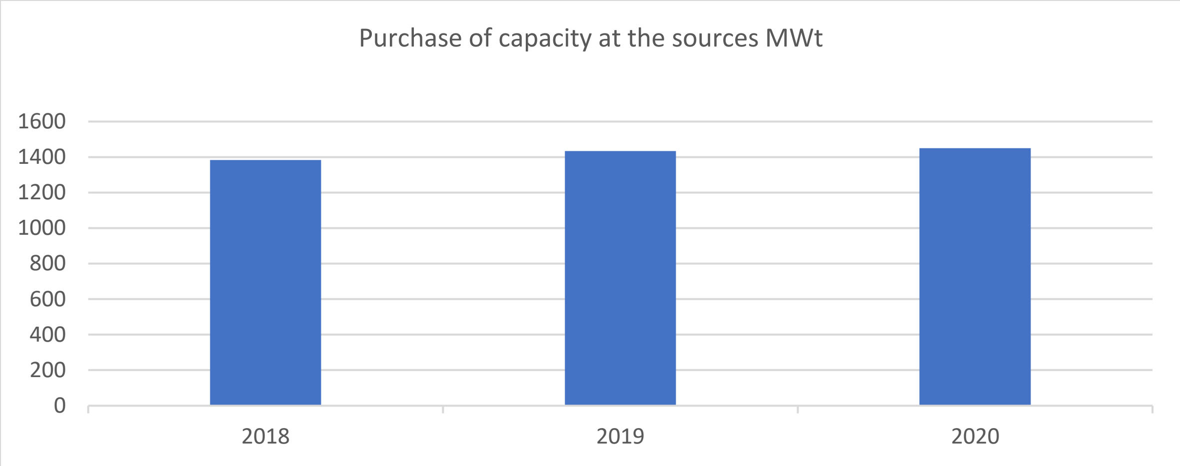


Chart 1.1: Purchase of capacity at the sources [MWt][58]

The volume of heat purchased from generation sources has fluctuated in recent years in the range of **10 to 12 PJ** (depending on weather conditions, among other factors).

Currently:

As of December 31, 2021, up to 10% of the heat volume is generated by ZTPO (municipal waste incineration plants), while the remaining volume is generated by PGE EC S.A. and CEZ Skawina, mostly based on hard coal cogeneration supplemented by the operation of peak-load boilers. In the near future, the ZTPO plant will be retrofitted with flue gas heat recovery, which will increase its production volume at the expense of other units.

The current layout of generating facilities should meet the requirements for an efficient district heating system effective from January 1, 2026, provided that other regulations, such as emission regulations, do not preclude the use of coal-fired cogeneration.

The main challenge for heat generators will be to achieve rates according to the guidelines for 2035 and beyond where it will be necessary to replace coal-fired units with other technologies.

The following section presents 4 technological options for adapting the heat market of the Kraków location to the new requirements for an efficient district heating system.

In Kraków, there is currently a potential for the construction of another ZTPO process line (an additional 35 MWt), which has been taken into account in the options presented below for adaptation to new regulatory requirements.

The analysis was based on the source heat demand curve for Kraków under 2021 weather conditions. A constant heat market was assumed throughout the analysis projection period.

[58] Source: years 2018-2019 – "Reports on the City condition", year 2020 – own data

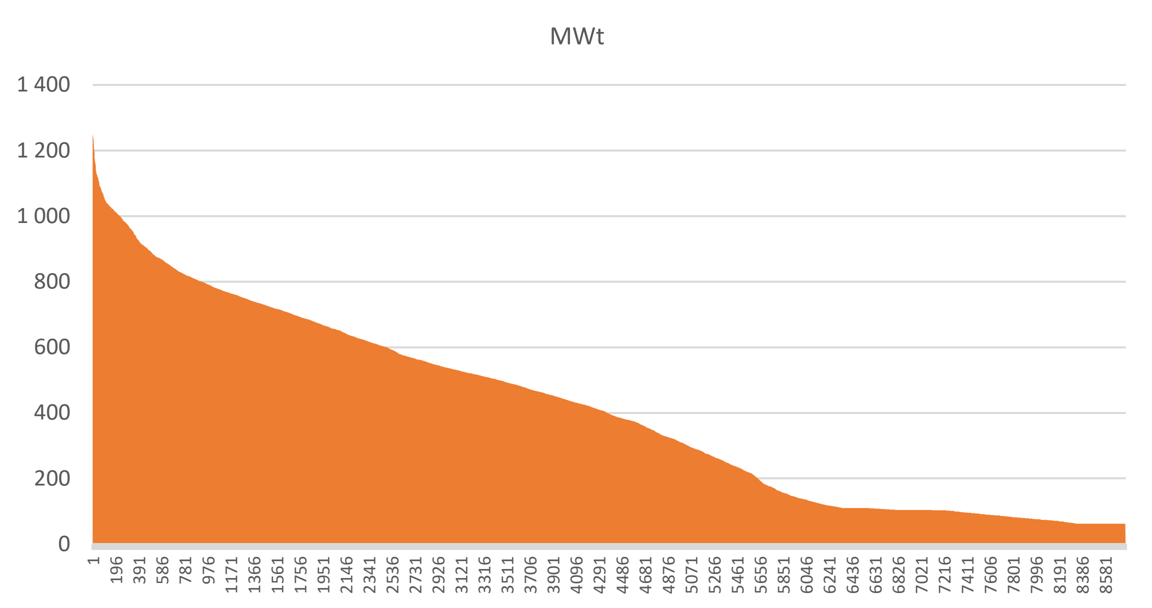


Chart 1.2: Heat market in Kraków

2. Macroeconomic and market assumptions

The analysis uses macroeconomic and market assumptions detailed in subsection 3.1 of this document.

3. Technical and economic assumptions

The analysis uses the technical and economic assumptions detailed in subsection 3.2 of this document.

4. Technology options

Technology options that have been analyzed for Kraków's heat market are presented below. Most of the current generation fleet will need to be replaced (some units around 2030 will reach the end of their technical life).

For meeting the requirements for 2035:

MWt	Option 1	Option 2	Option 3	Option 4
ZTPO (existing + heat recovery)	45 MWt	45 MWt	45 MWt	45 MWt
ZTPO (new)	35 MWt	35 MWt	35 MWt	35 MWt
Heat pumps			190 MWt	130 MWt
Biomass-fired cogeneration	190 MWt			
Biomass-fired boilers		190 MWt		
OCGT	130 MWt			
CCGT		130 MWt		
Gas engines			130 MWt	190 MWt
Gas-fired boilers	600 MWt	600 MWt	600 MWt	600 MWt
Electrode boilers	300 MWt	300 MWt	300 MWt	300 MWt
Total	**1,300 MWt**	**1,300 MWt**	**1,300 MWt**	**1,300 MWt**

For compliance with the requirements in 2045 and beyond:

In order to reach the next threshold of RES and waste heat participation requirements, it was assumed that the simplest solution would be co-firing or converting a part of gas-fired units to green hydrogen.

The biomass-based units proposed in the options have a hypothetical dimension due to the difficult logistics of supplying the fuel in the necessary quantities to the optimal regions for thermal power output. In contrast, limitations on the available capacity of heat pumps during periods of high network supply temperatures mean that the construction of more units requires alternative peak demand provision anyway.

Due to the lack of assumptions regarding hydrogen prices in the long term, the LCOH results presented hereafter do not include the cost of fuel price increases and assume that the equipment will be ready to make the conversion without additional expenditures.

5. Analysis results

The following expenditures will be required for the adaptation of Kraków's system to meet the criteria for an "efficient district heating system" in 2035, resulting from the conditions described in Article 24 (1) of the draft revision of the EED:

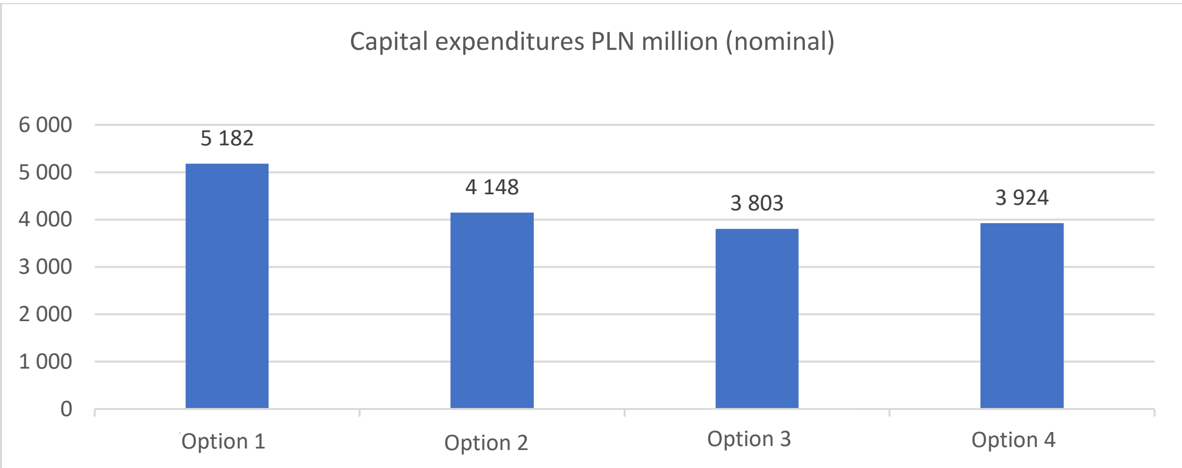


Chart 1.3: Capital expenditures for each development option in nominal terms without discounting=

The chart below shows the unit discounted cost of heat generation by options:

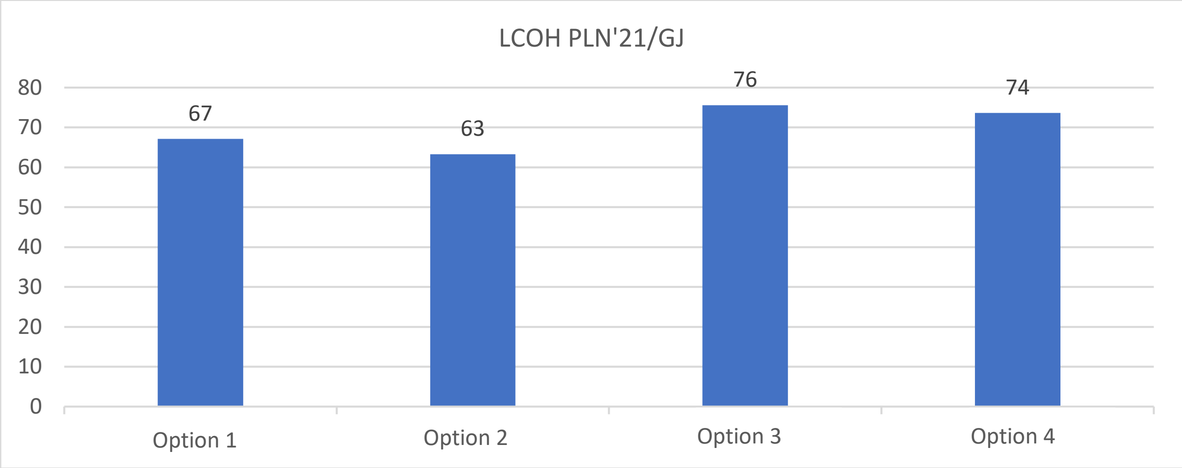


Chart 1.4 Heat prices on generation for end users[59]

Fuel demand from 2030:

	Option 1	Option 2	Option 3	Option 4
Waste (thousand t)/year	350,000	350,000	350,000	350,000
Biomass (thousand tons)	826,321	489,290	0	0
Gas (thousand m3 or GJ)	267,199*	286,143*	265,444*	342,073*
Electricity (GWh)	15.5**	15.5**	477.6**	347.3**

* planned partial fuel change to green hydrogen from 2045.

** electricity supply from own auxiliaries and from the network.

Summary:

- Adapting a single large heat market to the conditions of the Fit for 55 package will cost between PLN 3.8 billion and PLN 5.2 billion (in the part dealing with generation infrastructure only).
- The required biomass volumes exceed the logistical capacity of the city of Kraków and there are no available biomass markets nearby to provide the required volumes.
- Meeting the requirements of the Fit for 55 package is feasible in theory, but impossible in practice under current actual conditions.

Recommendations:

- It is necessary to significantly reduce the requirements for the amount of RES/waste heat in the overall heat stream in the market in order to meet the requirement for an efficient district heating system,
- Cogeneration heat should be allowed to participate in order to meet the requirement of an efficient district heating system regardless of fuel (excluding coal) in order to be able to fully and responsibly ensure the energy security (heat and electricity supply) for each region.

[59] PTEZ's own study