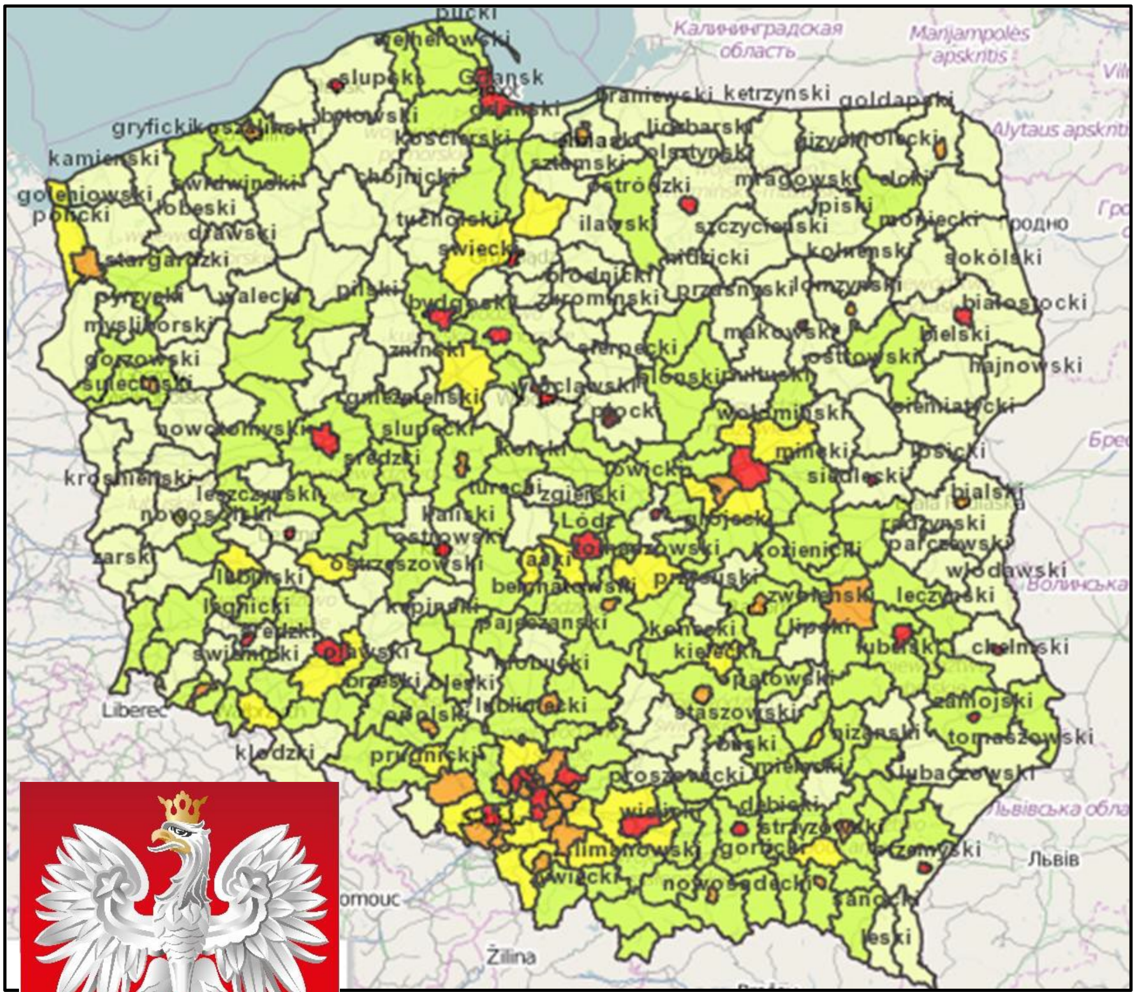
# Comprehensive assessment of the potential for the application of high-efficiency cogeneration and efficient district heating and cooling in Poland



## Background

This report has been prepared to comply with the obligation imposed on the Member States of the European Union in Article 14(1) of Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 *on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC (EED).*

This report contains results obtained by means of studies designed to determine, for Poland, the potential for the application of high-efficiency cogeneration and efficient district heating and cooling. The report is based on the results of the analysis: 'Assessment of the national heating and cooling capacities in Poland' carried out by the British company Ricardo-AEA Ltd at the request of the Minister for the Economy. To prepare this assessment, Ricardo-AEA Ltd used the statistical data provided by the Ministry of the Economy, the National Centre of Emission Balancing and Management (*Krajowy Ośrodek Bilansowania i Zarządzania Emisjami, KOBiZE*) and its own data sources, as well as an original projection and analytical model. The authors of the report also relied on the results of analyses carried out by experts from the Warsaw University of Technology.

Based on the data provided, Ricardo-AEA Ltd also created an interactive *Heat and Cooling Map* available at: www.mapaciepla.me.gov.pl.

However, the analytical work carried out for the report has identified significant problems in carrying out the analysis required under the Energy Efficiency Directive (EED), including as regards the system for collecting information on generation and heating needs, especially for small customers. In the current system, sufficient data have not been gathered on heating systems (territorial scope, the assignment of sources and customers to a heating system, lack of data on cooling). The information required for this report was obtained through the use of different data sources, therefore the results will not necessarily be consistent.

Since there is a scarcity of data sets for Poland in a number of fields and the results presented in the study by Ricardo-AEA Ltd are limited in scope and include large underestimates, the data should be used for illustrative purposes only.

To meet the requirements of the applicable Directive when preparing subsequent assessment reports on the potential for the application of high-efficiency cogeneration and efficient district heating and cooling, as well as to enable the cyclical update of the interactive *Heat and Cooling Map* service, it is necessary to set up a new system for collection of data, including statistical data, that would comply with the requirements of the Directive and statistical confidentiality obligations.

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# 1 Introduction

Under Article 14(1) of Directive 2012/27/EU on energy efficiency[1] (EED), Member States shall carry out and notify to the Commission by 31 December 2015 a comprehensive assessment of the potential for the application of high-efficiency cogeneration and efficient district heating and cooling, containing the information set out in Annex VIII thereto. This information can be summarised as follows:

a) a description of heating and cooling demand;
b) a forecast of how this demand will change in the next 10 years, taking into account in particular the evolution of demand in buildings and the different sectors of industry;
c) a map of the national territory, identifying, while preserving commercially sensitive information:
d) identification of the heating and cooling demand that could be satisfied by high-efficiency cogeneration, including residential micro-cogeneration, and by district heating and cooling;
e) identification of the potential for additional high-efficiency cogeneration, including from the refurbishment of existing and the construction of new generation and industrial installations or other facilities generating waste heat;
f) identification of energy efficiency potentials of district heating and cooling infrastructure;
g) strategies, policies and measures that may be adopted up to 2020 and up to 2030 to realise the potential in point (e) in order to meet the demand in point (d), including, where appropriate, proposals to:
h) the share of high-efficiency cogeneration and the potential established and progress achieved under Directive 2004/8/EC[2];
i) an estimate of the primary energy to be saved;
j) an estimate of public support measures to heating and cooling, if any, with the annual budget and identification of the potential aid element. This does not prejudge a separate notification of the public support schemes for a State aid assessment.

The potential for the application of energy efficient technologies depends on the results of cost-benefit analysis (CBA) and the assumptions made. For the purposes of the Directive, the procedure for carrying out a national CBA analysis, covering socio-economic and environmental factors, required under Article 14(3), is set out in Part 1 of Annex IX.

## 1.1 Objectives of the study

The aim of the study conducted by Ricardo-AEA Ltd was to present results which would meet, to the greatest possible extent, the requirement to conduct the comprehensive analysis set out in the EED Directive.

[1] http://eur-lex.europa.eu/legal-content/PL/TXT/PDF/?uri=CELEX:32012L0027&from=EN
[2] http://eur-lex.europa.eu/legal-content/PL/TXT/PDF/?uri=CELEX:32004L0008&from=EN

## 1.2 Limitations

As with any such report, the results are very much dependent on the quality of input data used for the preparation of maps and the analytical modelling system, as well as on the assumptions made. The quality, consistency and level of detail and resolution of energy data in Poland is a significant area of improvement. A number of Member States are not yet familiar with how to comply with the data parameters such as spatial extent and the level of detail, and any measures aimed at improving the availability of appropriate, consistent and reliable data will be time- and resource-consuming.

The quality and the results of such assessment are entirely dependent on the level of detail and consistency of the available data sources.

Unfortunately, the data that were available for assessment did not fully meet the requirements relating to quality, form and level of detail, or else no detailed data were available, therefore the relevant maps and analyses could not be sufficiently disaggregated. The key to achieving useful assessment results are the input data which must have an appropriate level of spatial detail. When preparing maps and analyses, the data were disaggregated by municipality (and by city borough in the case of Warsaw, Łódź, Kraków, Poznań and Wrocław as subdivisions of urban counties (*powiaty grodzkie*), with each city borough being classified as a single municipality) as a spatial disaggregation level. However, this required the breakdown of data available only at a higher level and their subsequent disaggregation by municipality, based solely on the population size.

The main data gaps that would need to be covered in order to improve the modelling system relate to the breakdown of fuel consumption by individual type for each large industrial installation and district heating network. KOBiZE's data sets provide information on individual heat consumption, but are not sufficient to identify the facilities involved. The identification of the facilities would allow for the comparison with other data used in EU ETS and E-PRTR registers. Furthermore, the provision of coordinates would allow for more precise positioning of the facilities on the heat map.

Another type of necessary data are those on the energy performance of service sector buildings (at the municipal level or, if possible, even for smaller areas) not connected to district heating networks. At present, the energy data at the municipal level are only available for schools and kindergartens.

Heat and building density, as well as the coverage of the existing district heating networks are the factors that significantly affect the cost-effectiveness of new district heating networks. There is a high probability that parameters vary significantly between municipalities, therefore an assessment of the cost-effectiveness of the new district heating networks, based on the energy data and data relating to buildings at the municipal level, will most likely underestimate the potential of the new district heating networks for achieving cost-effectiveness. Therefore, the ideal solution would be to collect data on energy consumption and the number of buildings, followed by their disaggregation by fuel and sector, e.g. industry, district heating networks, services sector and residential sector, for the areas smaller than municipalities – in order to facilitate the assessment of smaller geographical areas.

A large portion of the data on energy sector are subject to statistical confidentiality due to being classified as commercially sensitive information. Therefore, the Ministry of Energy initiated measures to introduce a new data collection system that would enable the partial use of these data for the preparation of a periodic analysis of the assessment of heating and cooling potentials and an online service for the heat and cooling map.

Therefore, the results of the analysis based on the currently available data are lacking in terms of quantity and quality. These results should, therefore, be viewed with caution and used for illustrative purposes only. This is only the beginning of the process of creating a reliable assessment of the heating and cooling sector in Poland.

## 1.3 Results

This report

- provides a comprehensive assessment of the potential for the application of high-efficiency cogeneration and efficient district heating and cooling in Poland in accordance with Article 14(1) of Directive 2012/27/EU;
- contains an online service with the interactive heat and cooling map of the Polish territory, described in Chapter 4 of this Report. The map meets the requirements set out in point 1(c) of Annex VIII to the above Directive.

# 2 Description of heating and cooling demand in Poland

There is no consistent database in Poland that would allow the reliable estimation of heating and cooling demand. A number of data sources exist but are mutually inconsistent. These include:

- Statistics published by the Energy Market Agency (*Agencja Rynku Energii, ARE*) and the Central Statistical Office (*Główny Urząd Statystyczny, GUS*), i.e. Statistics on electrical power, Statistics on district heating,
- URE's data (Energy Regulatory Office [*Urząd Regulacji Energetyki, URE*])
- KOBiZE's data (National Centre of Emission Balancing and Management [*Krajowy Ośrodek Bilansowania i Zarządzania Emisjami, KOBiZE])*
- Eurostat.

GUS collects selected statistics on heat demand and production. The main data sources that can be used include: 'Fuel and energy management in 2013 and 2014', 'Heat consumption by households in 2012' and the results of the national population census of 2011. 'Fuel and energy management...' contains general information on fuel without disaggregation by intended use, allowing the estimation of heating demand. The relevant data are those relating to the population census, which provides a compendium of knowledge on dwellings, allowing the estimation of the number of dwellings and the floor area for which heat is supplied from central systems and from local systems.

The main disadvantage of the statistics prepared by the Energy Regulatory Office, including 'Thermal energy in numbers', is that the analysis covers only the companies licensed by the President of URE to carry out heat supply activities, i.e. the sources with a total thermal installed capacity equal to or greater than 5 MW. In 2014, a total of 448 companies were covered by the analysis. The reported volume of heat sales in that year was 341 775.9 PJ, of which 250 029.9 PJ was returned back to the network.

The Eurostat database contains data identical to those published as part of national statistics and does not provide any information relevant to the preparation of the heat balance at national level.

When determining the demand for useful heat in terms of the potential for cogeneration development, account should be taken of the heat net production – that value should be treated as useful heat that contributes to the development of cogeneration.

Currently, no official data on cooling demand and generation are collected for Poland. Cooling is generated almost exclusively by compressor installations, and a noticeable increase in demand for electricity during the summer months highlights the fact that the demand is on the increase. If cooling demand was satisfied using the absorption or adsorption heat-powered installations, it could contribute to the potential for developing cogeneration.

The data obtained and processed by KOBiZE are relevant to this report.

Heating and cooling demand was determined in terms of geographical area for 2 372 areas specified in the data sets created by KOBiZE, covering 2 479 municipalities and 37 city boroughs of Warsaw, Łódź, Kraków, Poznań and Wrocław as sub-categories of urban counties (*powiaty grodzkie*), with each city borough being classified as a single municipality) at the spatial disaggregation level for the purposes of preparing the map and the analysis. However, this required the breakdown of data available only at a higher level and their subsequent disaggregation by municipality, based solely on the population size.

In the case of district heating networks, information on heat generated in high-efficiency cogeneration and heat generation plants was provided taking into account transmission losses.

The analysis was carried out based on the same data, therefore the reliability of results is limited due to the insufficient amount of data.

The following tables show the current annual figures for heat and cooling supplied in Poland, based on data from 2012.

Table 2.1 shows a breakdown of low temperature heat (hot water or steam) supplied to the following six end-use ‘sectors’:

- District heating networks
- Large-scale industry
- Small-scale industry
- Residential buildings
- Schools and kindergartens
- Other service sectors

Heat supply for the first three sectors is broken down by heat from high-efficiency cogeneration and from heat generation plants. The table provides figures for each province, collected for the same parameters at the municipal level.

## Table 2.1: Heat supply by end-users for 16 provinces

| Province | To district heating networks from high-efficiency cogeneration GWh/year | To district heating networks from heat generation plants GWh/year | To large-scale industry from high-efficiency cogeneration GWh/year | To large-scale industry from heat generation plants GWh/year | To small-scale industry from high-efficiency cogeneration GWh/year | To small-scale industry from heat generation plants GWh/year | Residential sector not connected to district heating networks GWh/year | Schools and kindergartens not connected to district heating networks GWh/year | Other service sectors not connected to district heating networks GWh/year | Total heat supplied GWh/year |
|---|---|---|---|---|---|---|---|---|---|---|
| Dolnośląskie | 3 274 | 1 220 | 910 | 932 | 6 | 184 | 5 314 | 607 | 1 825 | ***14 273*** |
| Kujawsko-Pomorskie | 2 328 | 1 717 | 4 332 | 1 085 | - | 75 | 3 935 | 4 | 1 318 | ***14 794*** |
| Łódzkie | 4 723 | 1 457 | 139 | 515 | 16 | 81 | 7 262 | 2 150 | 1 583 | ***17 925*** |
| Lubelskie | 1 761 | 1 161 | 1 129 | 3 036 | 2 | 115 | 6 493 | 1 | 1 358 | ***15 055*** |
| Lubuskie | 533 | 267 | 351 | 103 | - | 29 | 1 781 | 151 | 643 | ***3 859*** |
| Małopolskie | 3 397 | 853 | 1 860 | 452 | 0 | 135 | 7 981 | 653 | 2 117 | ***17 448*** |
| Mazowieckie | 12 221 | 2 640 | 5 415 | 3 748 | 30 | 164 | 13 063 | 412 | 3 349 | ***41 042*** |
| Opolskie | 527 | 827 | 1 546 | 1 108 | 0 | 65 | 2 234 | 623 | 633 | ***7 563*** |
| Podkarpackie | 1 509 | 769 | 228 | 581 | - | 125 | 5 494 | 850 | 1 341 | ***10 897*** |
| Podlaskie | 1 252 | 771 | 30 | 437 | 6 | 53 | 3 136 | - | 753 | ***6 437*** |
| Pomorskie | 3 292 | 1 150 | 3 102 | 265 | 2 | 95 | 5 359 | 6 | 1 446 | ***14 717*** |
| Śląskie | 6 627 | 3 997 | 953 | 2 670 | 13 | 195 | 11 073 | 3 016 | 2 897 | ***31 441*** |
| Świętokrzyskie | 1 080 | 818 | 34 | 277 | - | 75 | 3 060 | 0 | 799 | ***6 144*** |
| Warmińsko-Mazurskie | 537 | 1 239 | 345 | 679 | - | 51 | 2 706 | 730 | 911 | ***7 199*** |
| Wielkopolskie | 3 116 | 980 | 332 | 1 057 | 2 | 149 | 8 846 | 358 | 2 184 | ***17 024*** |
| Zachodniopomorskie | 1 256 | 1 299 | 1 496 | 507 | 0 | 85 | 2 980 | 606 | 1 083 | ***9 311*** |
| **Total for the country** | **47 434** | **21 164** | **22 199** | **17 452** | **77** | **1 678** | **90 717** | **10 168** | **24 241** | **235 129** |

*Note:* For district heating networks, the table shows the heat generated by central combined heat and power plants and boilers, taking into account pipeline transmission losses.

Table 2.2 provides an estimate of the cooling generated for each capital of the province. *Note:* The following data are based on the breakdown of a single figure for cooling at national level by capital of the province based on the population size.

**Table 2.2: Total cooling generated for the capitals of 16 provinces**

| **province** | **capital of the province** | **Total cooling generated GWh/year** |
|---|---|---|
| Dolnośląskie | Wrocław | 24 |
| Kujawsko-Pomorskie | Bydgoszcz | 14 |
| Łódzkie | Łódź | 27 |
| Lubelskie | Lublin | 13 |
| Lubuskie | Gorzów Wielkopolski | 5 |
| Małopolskie | Kraków | 29 |
| Mazowieckie | Warsaw | 65 |
| Opolskie | Opole | 5 |
| Podkarpackie | Rzeszów | 7 |
| Podlaskie | Białystok | 11 |
| Pomorskie | Gdańsk | 17 |
| Śląskie | Katowice | 12 |
| Świętokrzyskie | Kielce | 8 |
| Warmińsko-Mazurskie | Olsztyn | 7 |
| Wielkopolskie | Poznań | 21 |
| Zachodniopomorskie | Szczecin | 15 |
| **Total – Poland** | | **278** |

The preparation of a more detailed and extensive cooling map would require the provision of more detailed geographical information concerning the number of buildings in each sector and the demand for surface cooling (these are usually commercial sectors). The most appropriate data would be those concerning cooling or electricity consumption in the case where electricity is used only for cooling purposes, in accordance with metre readings. Since such data are not readily available, more realistic figures on cooling consumption would be based on floor area, sector type, cooling indicators and regional cooling degree-days.

The ideal method for estimating data on cooling would be based on the floor area of individual buildings and, if such data were not available, on the aggregated data on the total area of buildings in different sectors by municipality or (smaller) region. Cooling indicators (MWh/square metre) would be developed based on the design guidelines, serving as models for which data are available, or based on the process monitoring results.

# 3 Forecast of how demand will evolve over the next 10 years

The EED Directive requires Member States to prepare a forecast of heating and cooling demand for the next 10 years. However, if a cost-benefit analysis is planned for more than 10 years, a time frame for the forecast must be extended accordingly.

The analysis was based on the heat demand forecasts presented in the report submitted by Poland as an EU Member State *'Forecast of demand for fuel and energy up to 2050'*, Table 21: '*Structure of district heating demand by sector, [PJ]'*.

The analysis also involved the use of the cooling demand forecasts included in the report of 16 February 2012 submitted by Poland as an EU Member State: *'Assessment of the progress achieved in increasing the share of electricity production from high-efficiency cogeneration in the total electricity production in Poland'*. Due to the cooling sector being relatively small and the scarcity of data, cooling was not included in the modelling.

**Table 3.1: Report by Poland as a Member State: forecast of heat and cooling demand, plus extrapolation up to 2025.**

| Sector | | 2010 | 2015† | 2020† | 2025 ‡ |
|---|---|---|---|---|---|
| Industry, construction and agriculture | TWh | 60.0 | 65.7 | 72.0 | 75.4 |
| | *Index (2010 = 1)* | *1.000* | *1.095* | *1.200* | *1.257* |
| Residential sector | TWh | 194.9 | 200.4 | 210.4 | 209.3 |
| | *Index (2010 = 1)* | *1.000* | 1.028 | 1.080 | 1.074 |
| Services | TWh | 37.5 | 37.0 | 37.9 | 38.5 |
| | *Index (2010 = 1)* | *1.000* | 0.987 | 1.011 | 1.027 |
| **Total heat** | **TWh** | **292.5** | **303.1** | **320.3** | **323.1** |
| | ***Index (2010 = 1)*** | ***1.000*** | 1.036 | 1.095 | 1.105 |

| | | | | | |
|---|---|---|---|---|---|
| **Total cooling** | **TWh** | **0.14** | **0.28** | **0.56** | **0.83** |
| | ***Index (2010 = 1)*** | ***1.000*** | ***2.000*** | ***4.000*** | ***6.000*** |

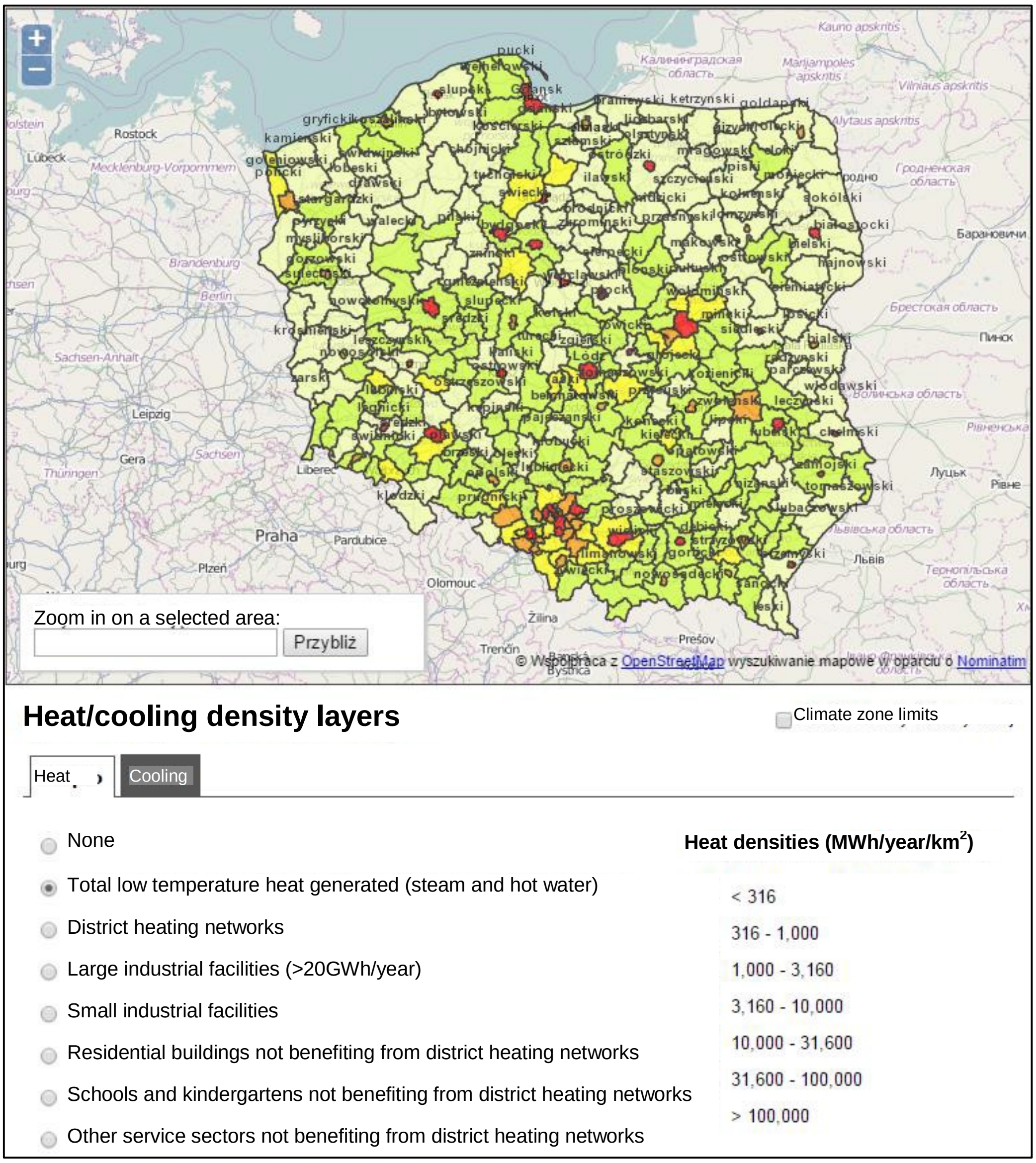
Assuming that the measurement unit for the above report is TWh – the total of 303.1 TWh, being the aggregate figure for heat in 2010 resulting from the report by the Member State, is slightly higher than the aggregate figure for heat in 2012 calculated for the purposes of this report, which amounts to 235 TWh (see Table 2.1). For modelling purposes, the above-mentioned indicators were used to estimate the heat demand in 2025 in absolute terms.

# 4 Heat and cooling map

A significant part of this assessment was to develop an online service of the interactive heat and cooling map for Poland. Based on available data, the current annual levels of heat consumption density (MWh/year/km2) were determined at the municipal level and split into the following 'sectors':

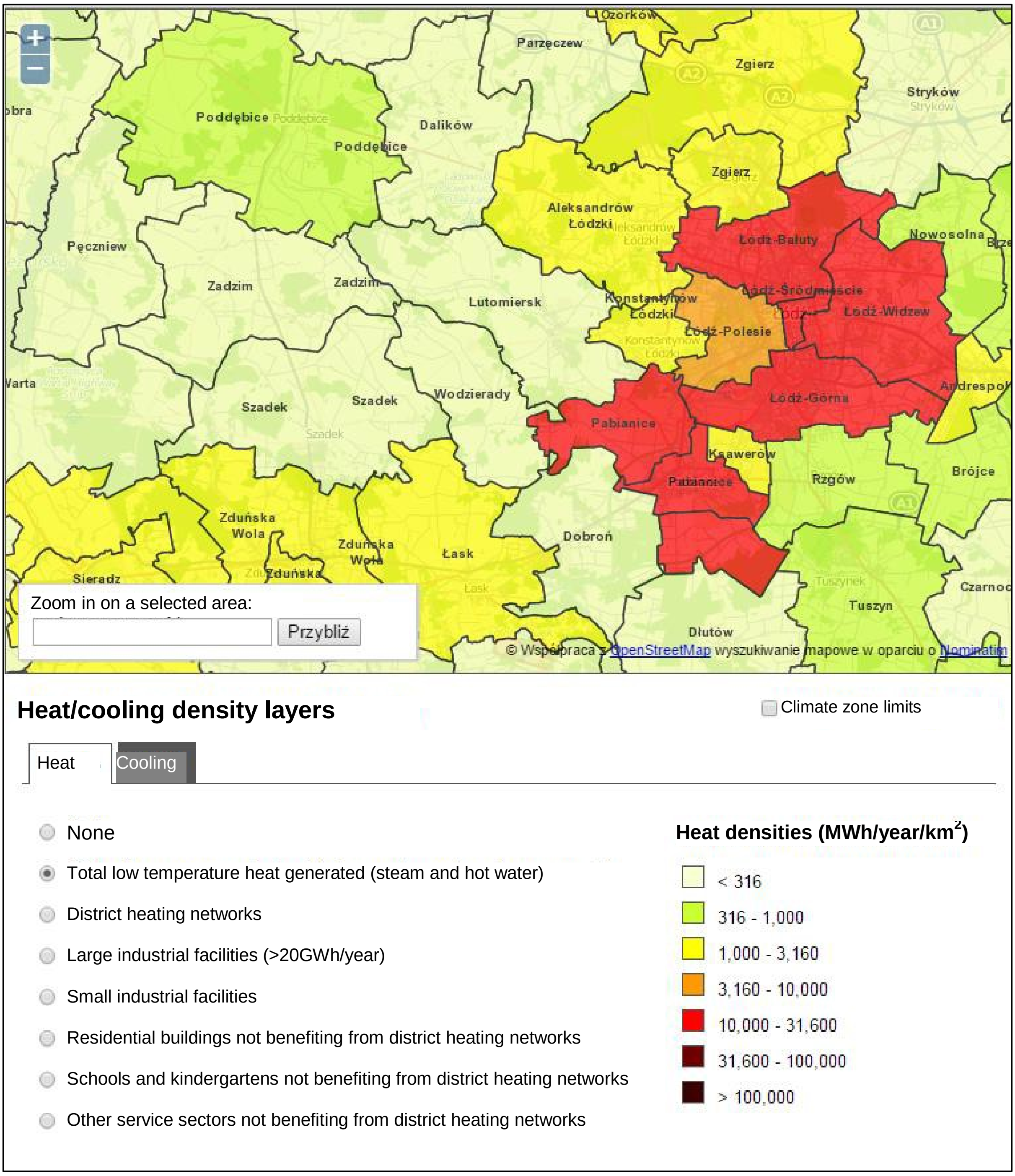
- Heat supplied to district heating networks (district heating networks were included as part of heat demand and not as a source of heat).
- Heat supplied to facilities other than district heating networks, including in particular:
  - Large-scale (>20 GWh/year) low temperature industry
  - Small-scale low temperature industry
  - Residential buildings
  - Schools and kindergartens
  - Other service sectors (primarily commercial and public buildings)

**Fig. 4.1: Heat consumption density and sectors by county (*powiat*)**



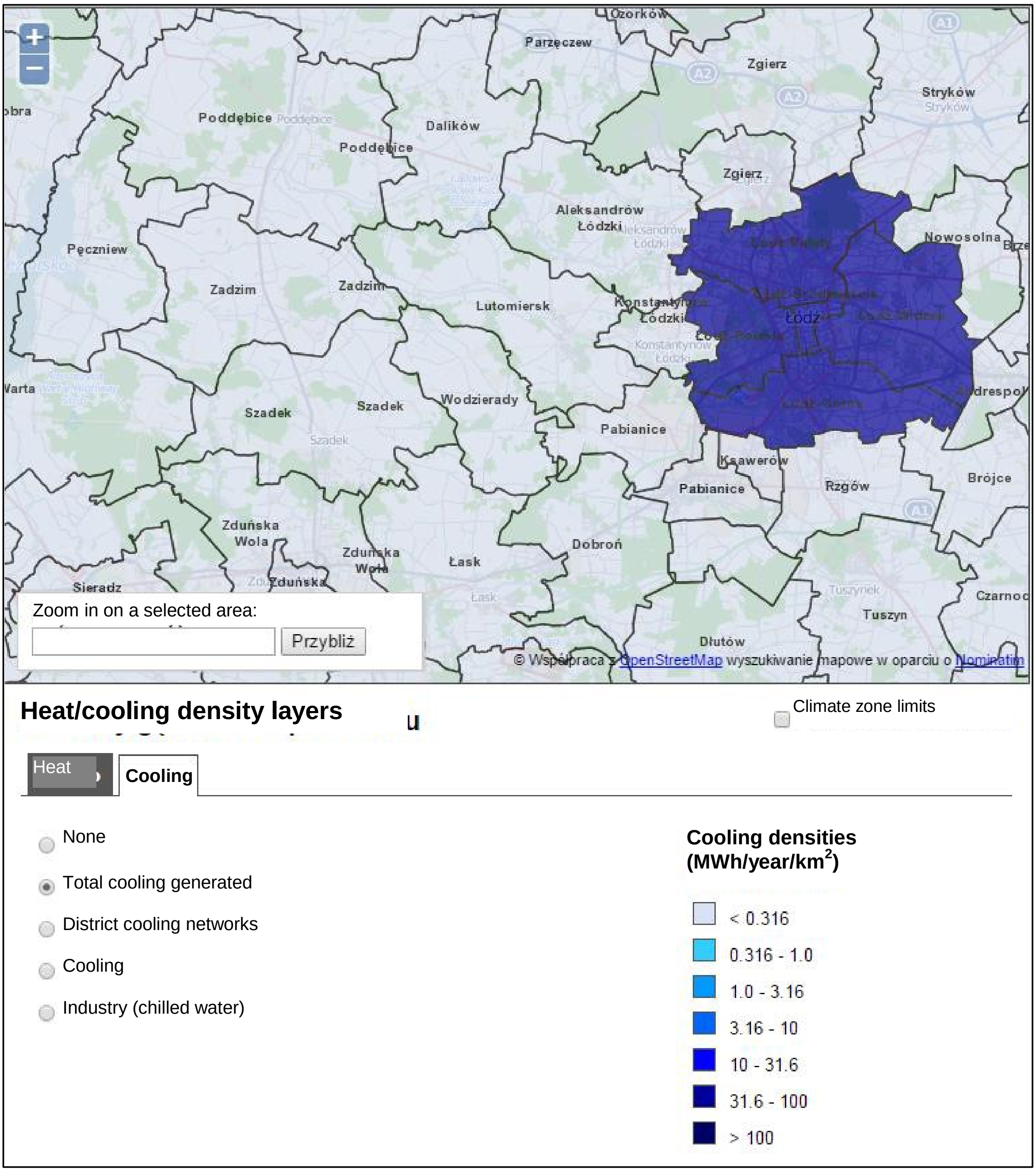
The screenshot (Fig. 4.1) shows a map zoomed out to the view of the whole country. This option allows you to display the total low temperature heat generated in the country. At this level you can see the boundaries of counties (*powiaty*). The colour of heat density indicates the average value for each county. When you zoom in on the map, your view will change from county level to municipality level, and the aggregate value of energy consumption density will be displayed for each municipality (Fig. 4.2).

**Fig. 4.2: You can zoom in on a selected area at the municipal level**



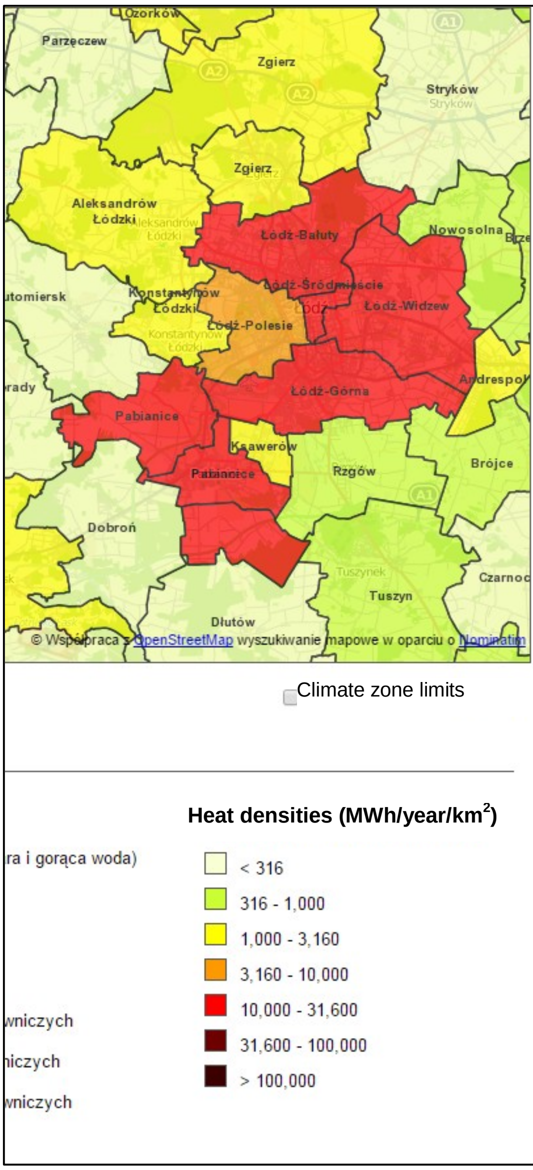
To display the values of cooling consumption density (MWh/year/km2) by municipality, select the tab ‘Cooling’ (Fig. 4.3). The data on cooling were only available as an estimate for the entire country, which was subsequently divided between the capitals of each province based on the relative size of population. Fig. 4.3 shows that the city of Łódź has a much higher cooling density than the surrounding areas. The map can be updated as soon as more detailed data are available.

**Fig. 4.3. Cooling density**



Click on one of the municipalities on the map to display the values of total annual heat (or cooling) consumption (MWh/year) for the municipality selected. As an example, Fig. 4.4 shows data for the municipality of Aleksandrów Łódzki.

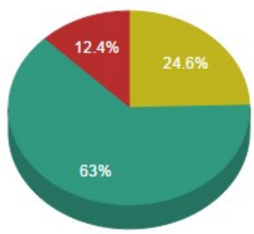
### Fig. 4.4: Breakdown of heat consumption for the municipality




**Aleksandrów Łódzki**

Heat | Cooling

| Sectors and heat sources | Share in the total value | Heat consumption in MWh/year |
|---|---|---|
| Total low temperature heat generated | 100% | 151.445 |
| **Heat supplied to municipal heating networks** | | |
| From cogeneration | 0% | 0 |
| From heat generation plants | 25% | 37.225 |
| **Individual heat supply** | | |
| For large industrial facilities from cogeneration | 0% | 0 |
| For large industrial facilities from heat generation plants | 0% | 0 |
| For small industrial facilities from cogeneration | 0% | 0 |
| For small industrial facilities from heat generation plants | 0% | 0 |
| Households | 63% | 95.410 |
| Schools and kindergartens | 0% | 0 |
| All other service sectors | 12% | 18.810 |

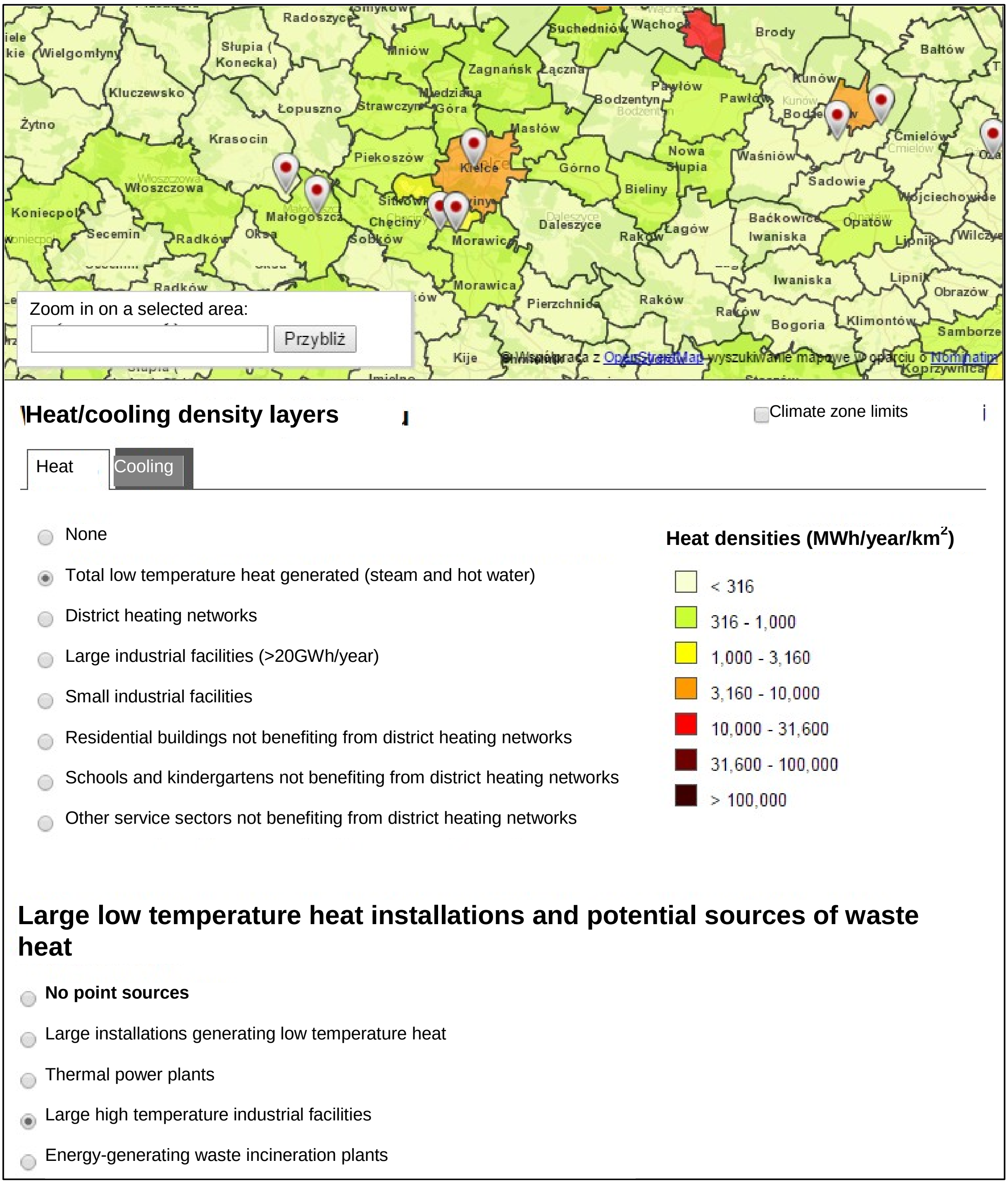



In addition to the display of density values for each area and the annual heat and cooling consumption at municipal level, as described above, the map also provides a view of the following individual installations, which is available from the menu below the menu for heat/cooling density – see Fig. 4.5:

- Large high temperature heat installations
- Power plants
- Main Activity Producer CHP Plants
- Autoproducer CHP Plants
- Large high temperature industrial facilities
- Waste incineration plants

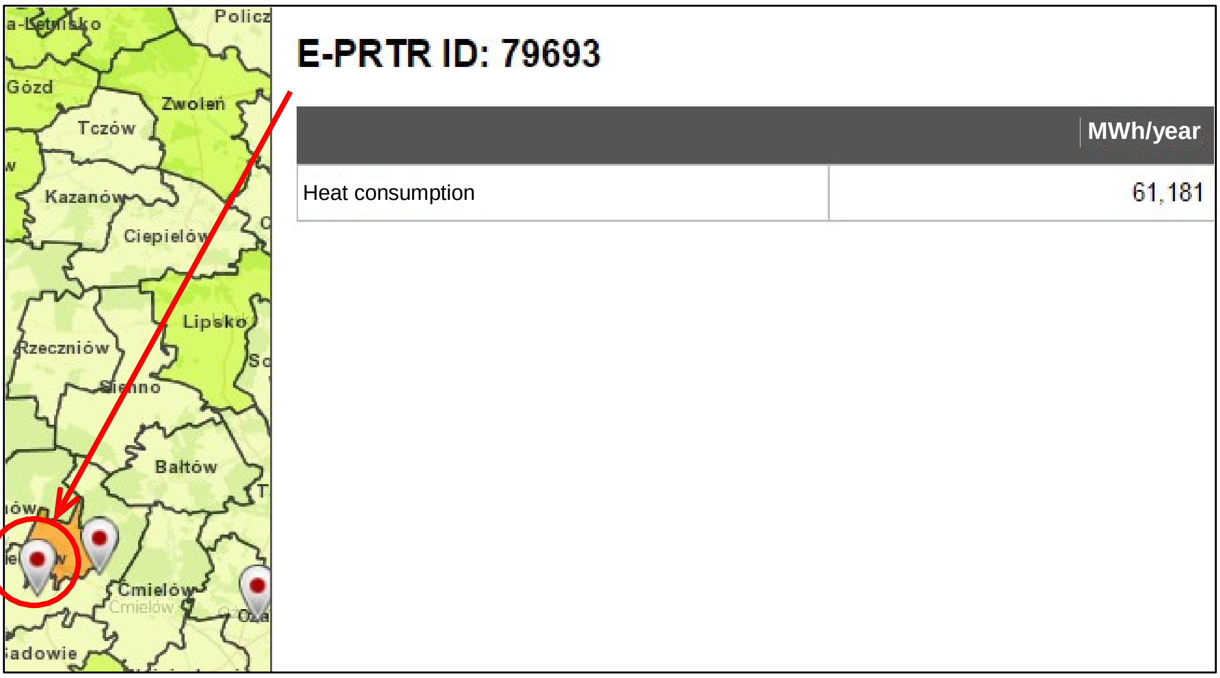
In this example, large high temperature industrial facilities were selected and then displayed as point markers on the map. These facilities, together with waste incineration plants and thermal power plants, constitute potential heat sources that could supply district heating networks.

**Fig. 4.5: Selected, individual large high temperature industrial facilities**



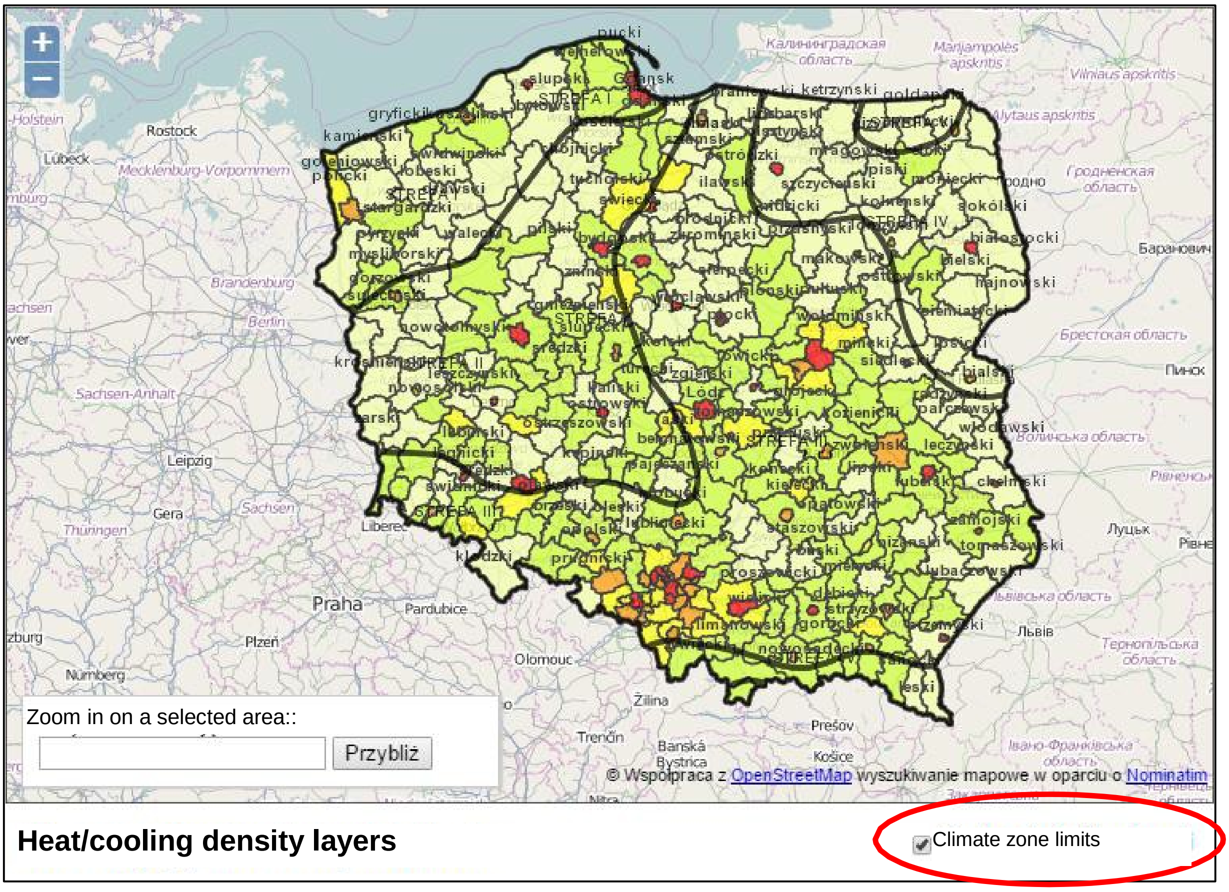

Click on the marker to display, on the right side of the map, a table with detailed data on the selected installation (Fig. 4.6). In the example shown, the selected high temperature industrial facility consumes annually 61 181 MWh of heat. However, these figures do not represent the waste heat of lower temperature that could be available for use in district heating networks. The figures for waste heat could only be determined after a thorough examination of the specific installation and the surrounding circumstances.

**Fig. 4.6: Details of the selected installation**




The map also has an option to display the limits of five climate zones in Poland, as shown in Fig. 4.7.

**Fig. 4.7: Display of climate zone limits**



# 5 Outline of methodology

The aim of the first stage of the assessment was to obtain the information required as input data for the cost-benefit analysis of the various energy efficient national heating and cooling systems comprising high-efficiency cogeneration and technologies based solely on thermal energy derived from renewable energy sources, which could meet individual (decentralised) heat/cooling demand, or district heating networks designed to meet a number of heat/cooling needs, which could utilise different types of fuels and technologies. The technical potential for each of these solutions (aggregated, as presented in Chapter 6) constitutes the estimated projected heating/cooling potential of the facility that would be installed where possible, regardless of the associated costs and benefits, without the need to make significant investments in the supporting infrastructure such as, for example, a new gas network. Each solution has been valued and included in a social cost-benefit analysis, as explained in detail in Chapter 7. However, it is first necessary to define such terms as ‘social cost-effectiveness’ and ‘net present value’ (NPV).

## 5.1 Definition of social cost-effectiveness and NPV

The term ‘social cost-effectiveness’ refers to the costs and benefits to society as a whole and not to the assessment of profitability or other aspects. In determining the social net present value (NPV), cash flows are discounted at the Social Rate of Time Preference, which is lower than the standard commercial discount rate and reflects the preference of society as a whole for present returns rather than future returns. In determining the social NPV, account was also taken of external factors such as the costs of a reduction in air quality and the costs associated with carbon dioxide emissions into the atmosphere.

## 5.2 Segmentation of individual heat/cooling demand

To ensure a consistent and reliable calculation of the potential for individual and network solutions, individual heat loads were split into 2 372 zones – municipalities/city boroughs.

The potential for high-efficiency cogeneration with supplementary heat being provided by boilers was modelled for each of the 2 447 existing industrial/network installations on an individual basis, since the heat loads involved are significant and data on heat consumption are available on an individual basis. It should also be noted that there are no precise data on heat consumption for individual buildings. Therefore, these data were modelled as the average values for buildings of a given category (segment) in accordance with the type of fuel/heating currently being used and the type of residential building. Four segments were identified for schools based on the assumed fuel type (gas or coal, depending on the availability of gas in the municipality) and 10 segments for residential buildings based on five individual heating types and two categories of residential buildings (flats and houses).

For each municipality/city borough (zone) residential buildings and schools were split into: 14 [*sic*] segments for schools and 10 segments for residential buildings (5 types of heating systems x 2 types of buildings). 2 447 industrial sites/heating networks + 14 segments x 2 372 zones = 35 655 segments, for many of which complete data are not available, since not all combinations occur in each zone. The segments without data were excluded from the model, therefore reducing the above value to 23 917.

## 5.3 Identification of high-efficiency heating/cooling options

It is possible to use a number of potential high-efficiency heating and cooling options in order for district heating networks to meet the individual/segment-modelled demand for heat or cooling or (spatially designated) groups of individual demands. According to this analysis, high-efficiency cogeneration and heat pumps are the two primary technologies with potential for cost savings.

### 5.3.1 Existing technology

A currently used technology which, according to the model, is to be replaced by any of the following technologies before the end of its useful life.

### 5.3.2 Basic technology

A technology which, according to projections, is to be selected if no change is made, i.e. no new incentives are offered for high-efficiency heating technologies. It serves as an alternative against which to compare all possible high-efficient technologies. As explained in Section 5.4.1., gas has been assumed to be primary heating fuel where gas is available, and coal – where gas is not available. Where there are high-efficiency cogeneration installations with supplementary heat provided by heat generation plants, the assumption was to replace them by gas- or coal-fired high-efficiency cogeneration and provide with supplementary heat from boilers, depending on the availability of gas.

### 5.3.3 Individual high-efficiency heating options

The following high-efficiency technologies were considered:

- **Individual heat energy production options**
  - high-efficiency gas-fired cogeneration based on natural gas (micro-cogeneration, reciprocating engines, gas turbines, steam turbines and combined cycle gas turbines) with supplementary heat being provided by gas-fired heat generation plants;
  - coal-fired high-efficiency cogeneration (steam turbines) with supplementary heat being provided by coal-fired heat generation plants;
  - biomass-based high-efficiency cogeneration (steam turbines) with supplementary heat being provided by biomass-fired heat generation plants;
  - air-source heat pumps.

  Where appropriate, these options would supply the existing district heating networks, schools and residential buildings which are currently not connected to district heating.

- **Supply options related to new district heating networks**

  Where appropriate, these new networks would supply hot water to schools and residential buildings not currently connected to the district heating networks supplied from:

  - high-efficiency cogeneration based on natural gas with supplementary heat being provided by natural gas-fired heat generation plants;
  - coal-fired high-efficiency cogeneration with supplementary heat being provided by coal-fired heat generation plants;
  - biomass-fired high-efficiency cogeneration with supplementary heat being provided by biomass-fired heat generation plants.

  The use of absorption cooling was not included due to the lack of cooling data.

## 5.4 Suitability of high-efficiency heating/cooling options

Not all of the above-described options are suitable for all sectors. It was assumed that air-source heat pumps and solar thermal energy are not suitable for industry or district heating networks due to the low temperature of generated heat and the scale of heat demand to be met. For the purpose of assessing the social net present value (NPV) of high-efficiency individual or network heating solutions, it was assumed that the primary technology would be applied in the segments unsuitable for high-efficiency heating technologies.

It was also assumed that high-efficiency cogeneration based on natural gas was an appropriate option only where high-efficiency cogeneration or gas-fired boilers were selected as the primary technology, as described in Section 5.4.1.

Furthermore, the assumption was that district heating networks would not be suitable for industry due to the high temperature of heat energy required by the majority of industry. Therefore, it would be inappropriate to connect these networks to the installations that supply both industry and the existing district heating networks. The set of data provided by KOBiZE concerning the heat consumption by industry clearly shows that a number of installations supply both industry and the district heating networks. However, no information is available on the characteristics of the heat energy supplied to these facilities, hence it has been assumed that such installations are located in the area of industrial facilities and supply high temperature heat energy to industry and low temperature heat energy to district heating networks. In that case, it would be possible to increase the amount of heat produced by heat generation plants and to expand existing networks, but such option is uncertain, since the capacity of the existing transmission networks may not be sufficient.

### 5.4.1 Availability of natural gas and its effects on technical options

It was assumed that gas-based high-efficiency cogeneration would be suitable only for the zones where natural gas was available.

Data on the current availability of natural gas in each municipality and the anticipated availability of gas in 2018 were entered into the model. On this basis and on the basis of the fuel data provided by KOBiZE, it was estimated that natural gas was currently available in about 1 479 of the total of 2 372 zones, and that the number was expected to increase to 1 531 by 2018. In addition, information was obtained that, for the time being, gas was consumed only in 578 zones by industry/district heating networks and in 101 zones by schools/kindergartens.

- The data on fuel provided by KOBiZE do not include the breakdown into fuel type for each location. Therefore, in the case of industry/existing district heating networks and schools, the primary technology was assumed to be gas heating where gas was currently available, or coal heating where gas was unavailable.

  For residential buildings, the current breakdown of fuels by type of residential building in each district was determined through a deductive process of analysing different data sources, including ‘*Mieszkania wg sposobu ogrzewania_pl_en.xls*’, as described in the appendices. The same breakdown was used as a basis for analysis. The majority of heating systems used for residential buildings is based on coal.

- In determining the basic development scenario for district heating systems under the assumption of ‘business as usual’, the following three approaches can be adopted:

1) Assuming that the breakdown of fuels remains unchanged, i.e. coal-based boilers would be replaced by coal-fired boilers.
2) Assuming that all boilers are replaced by gas boilers where gas is currently available.
3) Assuming that all boilers are replaced by gas boilers where gas will be available in 2019.

The first assumption was adopted, since no information was received that would indicate that the other two assumptions were likely to be valid. The probability of occurrence of options 2) and 3) could be determined by comparing the economic aspects of the action to replace existing heating systems with the same or gas-based systems. This, however, lies outside the scope of this comprehensive assessment, which does not aim to compare low-efficient conventional solutions (e.g. gas-based boilers against coal-based boilers) in order to establish the basis of reference. To maintain consistency, it was assumed that individual gas-based micro-cogeneration units would be installed only in gas-heated residential buildings.

## 5.5 Summary of the assumed options

### Table 5.1. Summary of the assumed options

| Type of facility | Basic technology | High-efficiency option 1 (Individual natural gas-fired high-efficiency cogeneration) | High-efficiency option 2 (individual coal-fired high-efficiency cogeneration) | High-efficiency option 3 (individual biomass-fired high-efficiency cogeneration) | High-efficiency option 4 (individual heat pumps) | High-efficiency option 5 (New district heating networks with natural gas-fired cogeneration) | High-efficiency option 6 (New district heating networks with coal-fired cogeneration) | High-efficiency option 7 (New district heating networks with biomass-fired cogeneration) | High-efficiency option 8 (Solar and thermal energy, including the primary source) |
|---|---|---|---|---|---|---|---|---|---|
| **1 479 zones with gas currently available** | | | | | | | | | |
| **Industry/Existing district heating networks** | Individual gas-fired boiler | Individual natural gas-fired high-efficiency cogeneration with supplementary heat from boilers | Individual coal-fired high-efficiency cogeneration with supplementary heat from boilers | Individual biomass-fired high-efficiency cogeneration with supplementary heat from boilers | Not applicable | Not applicable | Not applicable | Not applicable | Not applicable |
| **Schools/kindergartens (not connected to district heating networks)** | Individual gas-fired boiler | Individual natural gas-fired high-efficiency cogeneration with supplementary heat from boilers | Individual coal-fired high-efficiency cogeneration with supplementary heat from boilers | Individual biomass-fired high-efficiency cogeneration with supplementary heat from boilers | Individual heat pumps | New district heating networks with natural gas-fired cogeneration | New district heating networks with coal-fired cogeneration | New district heating networks with biomass-fired cogeneration | Solar thermal with individual gas-fired boilers |
| **Residential buildings (not connected to district heating networks)** | Existing heating system and fuel | Natural gas-fired micro-cogeneration where gas is the currently available fuel | Not applicable | Not applicable | Individual heat pumps | | | | Solar thermal with existing heating system and fuel |
| **893 zones without gas being currently available** | | | | | | | | | |
| **Industry/Existing district heating networks** | Individual high-efficiency coal-fired boiler | Individual coal-fired high-efficiency cogeneration with supplementary heat from boilers | Individual coal-fired high-efficiency cogeneration with supplementary heat from boilers | Individual biomass-fired high-efficiency cogeneration with supplementary heat from boilers | Not applicable | Not applicable | Not applicable | Not applicable | Not applicable |
| **Schools/kindergartens (not connected to district heating networks)** | Individual high-efficiency coal-fired boiler | Individual coal-fired high-efficiency cogeneration with supplementary heat from boilers | Individual coal-fired high-efficiency cogeneration with supplementary heat from boilers | Individual biomass-fired high-efficiency cogeneration with supplementary heat from boilers | Individual heat pumps | Not applicable | New district heating networks with coal-fired high-efficiency cogeneration and supplementary heat from boilers | New district heating networks with biomass-fired high-efficiency cogeneration and supplementary heat from boilers | Solar thermal with individual coal-fired boilers |
| **Residential buildings (not connected to district heating networks)** | The currently used fuel/type | Not applicable | Not applicable | Not applicable | Individual heat pumps | Not applicable | | | Solar thermal with existing heating system and fuel |

## 5.6 Outline of the technical assessment model and the assessment model for costs and benefits

The model functions as follows:

1. For each of the 23 917 segments described in Section 5.1, the model is used to calculate the required power in the case of the primary technology and individual high-efficiency heating options (individual high-efficiency cogeneration based on natural gas, coal and biomass, heat pumps and solar thermal energy) and the required capacity of district heating network connections in the case where each technology is suitable for the segment concerned.
2. For each of the 2 372 municipalities, the model is used to calculate the total heat consumption for schools and buildings not currently connected to district heating networks, the number of district heating networks necessary to supply them (including heat losses) and the size of the central facility generating energy in high-efficiency cogeneration based on natural gas, biomass or coal.
3. The technical potential of each individual and network option is aggregated for all segments and municipalities in terms of generated heat and electricity, the annual production and the number of facilities.
4. The model allows users to calculate the capital costs and the annual maintenance costs of individual solutions and district heating networks.
5. The model is used to calculate the annual production of heat and electricity and the amount of fuel for each heating option, taking into account the need for supplementary heat supply from boilers.
6. The model is used to calculate the discounted cash flow and the Present Value (PV) in the period between 2015 and 2044 for all primary options and individual high-efficiency heating options for each of the 23 917 segments, taking into account capital costs, maintenance costs, the long-term fuel price volatility, external costs and the social discount rate. In addition, calculations are made to determine the Present Value (PV) of the primary pipeline and the cost of central facilities generating energy for each of the new district heating options in each of the 2 372 municipalities, as well as the Present Value (PV) for district heating connection provided to each of the 23 917 segments and their total for each municipality in order to calculate the Present Value (PV) for each potential new district heating network.
7. For each of the 23 917 segments, the model identifies the most socially and economically effective individual heating option (the one with the highest PV value). In some cases, the identified option is a primary option.
8. For each municipality, the total Present Value (PV) for the best mix of individual heating solutions for schools and buildings not currently connected to district heating is compared against the Present Value (PV) for new district heating networks based on gas, coal and biomass, and then the best solution is selected for schools and buildings not currently connected to district heating.

9. Total generated heat and electricity, as well as annual production and the number of facilities are aggregated based on the criterion for selecting the most socially and economically effective mix of individual and new heating solutions in each municipality.
10. The basic Present Value (PV) is subtracted from the PV for each high-efficiency solution in order to calculate the Net Present Value (NPV) for each of the high-efficiency options, and then aggregated according to the same rules.

## Table 5.2 Technical assumptions and cost estimates for heating technologies

| Type of facility | Fuel | Technology | Output range | Heat-to-power ratio | Minimum output range – Heat energy | Total electrical efficiency in condensing mode | Z ratio (heat/reduction in electricity) | Total electrical efficiency in cogeneration mode | Heat efficiency | Proportion of the heat demand met (with the difference met by boilers only) | Cost parameter (electricity/thermal energy) | Capital costs PLN/kW = A x MWe^n: A | Capital costs: n | Maintenance costs: Variables on power | Maintenance costs: Constants | Maintenance costs: Variables on production | Operating costs | Average period of use |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Description | | MWt | % GCV | | % GCV | % GCV | | | PLN/ kW | | PLN/ kW/ year | PLN/ year | *PLN/ MWh* | PLN/ MWh | Years |
| Micro-cogeneratio | Gas | Stirling engine | 1 kWe | 11.83 | 0.012 | 6.0% | not applicable | 6.00% | 71.00% | 100% | Electricity | 10 552 | 0 | 0.00 | 0.00 | 86.87 | 212.04 | 15 |
| High-efficiency cogeneration | Gas | Reciprocating engine | 5 kWe | 2.33 | 0.012 | 22.3% | not applicable | 22.30% | 52.00% | 63.4% | Electricity | 7 175 | 0 | 0.00 | 0.00 | 27.14 | 66.40 | 15 |
| High-efficiency cogeneration | Gas | Reciprocating engine | 13 kWe | 2.33 | 0.030 | 22.3% | not applicable | 22.30% | 52.00% | 63.4% | Electricity | 8 117 | 0 | 0.00 | 0.00 | 27.14 | 66.40 | 15 |
| High-efficiency cogeneration | Gas | Reciprocating engine | 13 to 50 kWe | 2.33 | 0.033 | 22.3% | not applicable | 22.30% | 52.00% | 63.4% | Electricity | 2 029 | -0.15 | 0.00 | 0.00 | 27.14 | 66.40 | 15 |
| High-efficiency cogeneration | Gas | Reciprocating engine | 50 to 100 kWe | 1.50 | 0.075 | 31.7% | not applicable | 31.70% | 47.70% | 63.4% | Electricity | 1 973 | -0.15 | 0.00 | 0.00 | 26.39 | 64.06 | 15 |
| High-efficiency cogeneration | Gas | Reciprocating engine | 100 to 200 kWe | 1.31 | 0.131 | 33.8% | not applicable | 33.80% | 44.20% | 63.4% | Electricity | 1 973 | -0.15 | 0.00 | 0.00 | 26.39 | 64.06 | 15 |
| High-efficiency cogeneration | Gas | Reciprocating engine | 200 to 1 000 kWe | 1.20 | 0.240 | 38.0% | not applicable | 38.00% | 45.60% | 63.4% | Electricity | 1 973 | -0.15 | 0.00 | 0.00 | 26.39 | 64.06 | 15 |
| High-efficiency cogeneration | Gas | Reciprocating engine | 1 to 4 MWe | 1.60 | 1.600 | 30.0% | not applicable | 30.00% | 48.00% | 63.4% | Electricity | 1 973 | -0.15 | 0.00 | 0.00 | 20.93 | 50.81 | 20 |
| 4 to 7 MWe | Gas | Small-scale open cycle gas turbines (OCGT) | | 1.60 | 6.400 | 30.0% | not applicable | 30.00% | 48.00% | 63.4% | Electricity | 3 530 | -0.23 | 0.00 | 0.00 | 19.73 | 47.88 | 20 |

| Type of facility | Fuel | Technology | Output range | Heat-to-power ratio | Minimum output range – Heat energy | Total electrical efficiency in condensing mode | Z ratio (heat/reduction in electricity) | Total electrical efficiency in cogeneration mode | Heat efficiency | Proportion of the heat demand met (with the difference met by boilers only) | Cost parameter (electricity/thermal energy) | Capital costs PLN/kW = A x MWe^n: A | Capital costs PLN/kW = A x MWe^n: n | Maintenance costs: Variables on power | Maintenance costs: Constants | Maintenance costs: Variables on production | Operating costs | Average period of use |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Description | | MWt | % GCV | | % GCV | % GCV | | | PLN/ kW | | PLN/ kW/ year | PLN/ year | *PLN/ MWh* | PLN/ MWh | Years |
| High-efficiency cogeneration | Gas | Small-scale OCGT | 7 to 25 MWe | 1.20 | 8.400 | 30.0% | not applicable | 30.00 % | 36.00% | 63.4% | Electricity | 3 530 | -0.23 | 0.00 | 0.00 | 17.54 | 42.56 | 20 |
| High-efficiency cogeneration | Gas | Large-scale OCGT | 25 to 40 MWe | 1.20 | 30.000 | 35.0% | not applicable | 35.00 % | 42.00% | 63.4% | Electricity | 3 530 | -0.23 | 0.00 | 0.00 | 17.54 | 42.56 | 20 |
| High-efficiency cogeneration | Gas | Combined cycle gas turbines (CCGT) | 40 to 200 MWe | 0.76 | 30.400 | 45.1% | 4.5 | 38.56 % | 29.30% | 63.4% | Electricity | 2 762 | -0.1 | 0.00 | 0.00 | 13.15 | 31.92 | 20 |
| High-efficiency cogeneration | Gas | CCGT | >200 MWe | 0.76 | 152.000 | 45.1% | 4.5 | 38.56 % | 29.30% | 63.4% | Electricity | 1 622 | 0 | 0.00 | 0.00 | 13.15 | 31.92 | 20 |
| High-efficiency cogeneration | Coal | Steam turbine | 1 to 10 MWe | 3.00 | 3.000 | 31.0% | 4.5 | 18.60 % | 55.8% | 63.4% | Electricity | 6 810 | 0 | 0.00 | 0.00 | 43.84 | 106.41 | 20 |
| High-efficiency cogeneration | Coal | Steam turbine | 10 to 25 MWe | 3.00 | 30.000 | 31.0% | 4.5 | 18.60 % | 55.8% | 63.4% | Electricity | 6 810 | 0 | 0.00 | 0.00 | 43.84 | 106.41 | 20 |
| High-efficiency cogeneration | Coal | Steam turbine | >25 MWe | 3.00 | 75.000 | 33.0% | 4.5 | 19.80 % | 59.4% | 63.4% | Electricity | 6 810 | 0 | 0.00 | 0.00 | 43.84 | 106.41 | 20 |
| High-efficiency cogeneration | Biomass | Steam turbine | 1 to 10 MWe | 3.00 | 3.000 | 31.0% | 4.5 | 18.60 % | 55.8% | 63.4% | Electricity | 6 810 | 0 | 0.00 | 0.00 | 43.84 | 106.41 | 20 |
| High-efficiency cogeneration | Biomass | Steam turbine | 10 to 25 MWe | 3.00 | 30.000 | 31.0% | 4.5 | 18.60 % | 55.8% | 63.4% | Electricity | 6 810 | 0 | 0.00 | 0.00 | 43.84 | 106.41 | 20 |

| Type of facility | Fuel | Technology | Output range | Heat-to-power ratio | Minimum output range – Heat energy | Total electrical efficiency in condensing mode | Z ratio (heat/reduction in electricity) | Total electrical efficiency in cogeneration mode | Heat efficiency | Proportion of the heat demand met (with the difference met by boilers only) | Cost parameter (electricity/thermal energy) | Capital costs PLN/kW = A x MWe^n | | Maintenance costs | | | Operating costs | Average period of use |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | A | n | Variables on power | Constants | Variables on production | | |
| | | | Description | | MWt | % GCV | | % GCV | % GCV | | | PLN/ kW | | PLN/ kW/ year | PLN/ year | *PLN/ MWh* | PLN/ MWh | Years |
| High-efficiency cogeneration | Biomass | Steam turbine | >25 MWe | 3.00 | 75.000 | 33.0% | 4.5 | 19.80% | 59.4% | 63.4% | Electricity | 6 810 | 0 | 0.00 | 0.00 | 43.84 | 106.41 | 20 |
| Heat generation plant | Gas | Boiler | 20 kWt | not applicable | - | not applicable | not applicable | not applicable | 84.6% | 100% | Thermal energy | 313 | 0 | 18.77 | 0.00 | 0.00 | 0.00 | 15 |
| Heat generation plant | Gas | Boiler | 20 to 180 kWt | not applicable | 0.020 | not applicable | not applicable | not applicable | 84.6% | 100% | Thermal energy | 194 | 0 | 6.26 | 0.00 | 0.00 | 0.00 | 20 |
| Heat generation plant | Gas | Boiler | 180 to 3 600 kWt | not applicable | 0.180 | not applicable | not applicable | not applicable | 81.0% | 100% | Thermal energy | 136 | 0 | 2.09 | 0.00 | 0.00 | 0.00 | 20 |
| Heat generation plant | Gas | Boiler | 3.6 to 100 MWt | not applicable | 3.600 | not applicable | not applicable | not applicable | 81.0% | 100% | Thermal energy | 99 | 0 | 2.09 | 0.00 | 0.00 | 0.00 | 20 |
| Heat generation plant | Gas | Boiler | >100 MWt | not applicable | 100.000 | not applicable | not applicable | not applicable | 81.0% | 100% | Thermal energy | 63 | 0 | 2.09 | 0.00 | 0.00 | 0.00 | 20 |
| Heat generation plant | Coal | Boiler | 8 kWt | not applicable | 0.008 | not applicable | not applicable | not applicable | 80.8% | 100% | Thermal energy | 1 835 | 0 | 39.40 | 0.00 | 0.00 | 0.00 | 20 |
| Heat generation plant | Coal | Boiler | 20 kWt | not applicable | 0.020 | not applicable | not applicable | not applicable | 80.8% | 100% | Thermal energy | 1 367 | 0 | 41.45 | 0.00 | 0.00 | 0.00 | 20 |
| Heat generation plant | Coal | Boiler | 20 to 180 kWt | not applicable | 0.020 | not applicable | not applicable | not applicable | 77.0% | 100% | Thermal energy | 1 250 | 0 | 14.03 | 0.00 | 0.00 | 0.00 | 20 |
| Heat generation plant | Coal | Boiler | 180 kWt to 1 MWt | not applicable | 0.180 | not applicable | not applicable | not applicable | 77.0% | 100% | Thermal energy | 978 | 0 | 42.10 | 0.00 | 0.00 | 0.00 | 20 |
| Heat generation plant | Coal | Boiler | 1 to 5 MWt | not applicable | 1 000.000 | not applicable | not applicable | not applicable | 77.0% | 100% | Thermal energy | 891 | 0 | 38.86 | 0.00 | 0.00 | 0.00 | 20 |
| Heat generation plant | Coal | Boiler | >5 MWt | not applicable | 5 000.000 | not applicable | not applicable | not applicable | 77.0% | 100% | Thermal energy | 682 | 0 | 30.22 | 0.00 | 0.00 | 0.00 | 20 |

| Type of facility | Fuel | Technology | Output range | Heat-to-power ratio | Minimum output range – Heat energy | Total electrical efficiency in condensing mode | Z ratio (heat/reduction in electricity) | Total electrical efficiency in cogeneration mode | Heat efficiency | Proportion of the heat demand met (with the difference met by boilers only) | Cost parameter (electricity/thermal energy) | Capital costs PLN/kW = A x MWe^n | | Maintenance costs | | | Operating costs | Average period of use |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | A | n | Variables on power | Constants | Variables on production | | |
| | | | Description | | MWt | % GCV | | % GCV | % GCV | | | PLN/ kW | | PLN/ kW/ year | PLN/ year | *PLN/ MWh* | PLN/ MWh | Years |
| Heat generation plant | Oil | Boiler | 20 kWt | not applicable | - | not applicable | not applicable | not applicable | 84.6% | 100% | Thermal energy | 341 | 0 | 10.01 | 0.00 | 0.00 | 0.00 | 15 |
| Electric heating | Electricity | Boiler | 10 to 23 kWt | not applicable | - | not applicable | not applicable | not applicable | 90.0% | 100% | Thermal energy | 365 | 0 | 0.00 | 0.00 | 0.00 | 0.00 | 15 |
| Furnaces and ovens | Coal | Boiler | 8 kWt | not applicable | 0.008 | not applicable | not applicable | not applicable | 70.0% | 100% | Thermal energy | 1 835 | 0 | 39.40 | 0.00 | 0.00 | 0.00 | 20 |
| Furnaces and ovens | Coal | Boiler | 20 kWt | not applicable | 0.020 | not applicable | not applicable | not applicable | 70.0% | 100% | Thermal energy | 1 299 | 0 | 39.40 | 0.00 | 0.00 | 0.00 | 20 |
| Heat pump | Electricity | Heat pump | 6 kWt | not applicable | 0.006 | not applicable | not applicable | not applicable | 300.0% | 100% | Thermal energy | 2 586 | 0 | 18.08 | 0.00 | 0.00 | 0.00 | 20 |
| Heat pump | Electricity | Heat pump | 10 kWt | not applicable | 0.010 | not applicable | not applicable | not applicable | 300.0% | 100% | Thermal energy | 2 347 | 0 | 10.85 | 0.00 | 0.00 | 0.00 | 20 |
| Heat pump | Electricity | Heat pump | 20 kWt | not applicable | 0.020 | not applicable | not applicable | not applicable | 300.0% | 100% | Thermal energy | 1 929 | 0 | 5.42 | 0.00 | 0.00 | 0.00 | 20 |
| Heat pump | Electricity | Heat pump | 50 kWt | not applicable | 0.050 | not applicable | not applicable | not applicable | 320.0% | 100% | Thermal energy | 1 683 | 0 | 38.38 | 0.00 | 0.00 | 0.00 | 20 |
| Heat pump | Electricity | Heat pump | 300 kWt | not applicable | 0.300 | not applicable | not applicable | not applicable | 320.0% | 100% | Thermal energy | 1 197 | 0 | 8.69 | 0.00 | 0.00 | 0.00 | 20 |
| Solar thermal | None | Flat plate collector | 1 to 5 kWt | | 0.001 | not applicable | not applicable | not applicable | not applica ble | 10.3% | Thermal energy | 2 900 | 0 | 80.00 | 0.00 | 0.00 | 20 | |

| Type of facility | Fuel | Technology | Output range | Heat-to-power ratio | Minimum output range – Heat energy | Total electrical efficiency in condensing mode | Z ratio (heat/reduction in electricity) | Total electrical efficiency in cogeneration mode | Heat efficiency | Proportion of the heat demand met (with the difference met by boilers only) | Cost parameter (electricity/thermal energy) | Capital costs PLN/kW = A x MWe^n | | Maintenance costs | | | Operating costs | Average period of use |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | A | n | Variables on power | Constants | Variables on production | | |
| | | | Description | | MWt | % GCV | | % GCV | % GCV | | | PLN/ kW | | PLN/ kW/ year | PLN/ year | *PLN/ MWh* | PLN/MWh | Years |
| Solar thermal | None | Flat plate collector | 5 to 10 kWt | | 0.005 | not applicable | not applicable | not applicable | not applicable | 10.3% | Thermal energy | 2 900 | 0 | 80.00 | 0.00 | 0.00 | 20 | |
| Solar thermal | None | Flat plate collector | 10 to 20 kWt | | 0.010 | not applicable | not applicable | not applicable | not applicable | 10.3% | Thermal energy | 2 500 | 0 | 40.00 | 0.00 | 0.00 | 20 | |
| Solar thermal | None | Flat plate collector | 20 to 32 kWt | | 0.020 | not applicable | not applicable | not applicable | not applicable | 8.1% | Thermal energy | 2 500 | 0 | 40.00 | 0.00 | 0.00 | 20 | |
| Solar thermal | None | Flat plate collector | >32 kWt | | 0.032 | not applicable | not applicable | not applicable | not applicable | 8.1% | Thermal energy | 1 600 | 0 | 15.00 | 0.00 | 0.00 | 20 | |

# 6 Technical potential for high-efficiency cogeneration and alternatives

The current technical potential for the application of high-efficiency cogeneration was calculated on the basis of the current annual heat consumption.

The first step was to identify the existing capacities of high-efficiency cogeneration based on the current report on cogeneration[2] in order to compare technical potentials, as shown below.

This was followed by a calculation of the potential for replacing the existing capacities of high-efficiency cogeneration (with supplementary heat being provided by boilers) with new high-efficiency cogeneration (with supplementary heat being provided by boilers) with a view to covering the annual consumption of heat by industry and district heating networks, which, according to the available information, were the only sectors with cogeneration in place. The potentials for gas, coal and biomass were calculated separately due to them having different ratio of heat energy to electricity and being subject to different limitations on their suitability for use.

The last step was to calculate the technical potential for the application of new high-efficiency cogeneration to supply the existing district heating networks, industrial installations, schools and residential buildings which currently did not have a cogeneration system. These calculations were made for two different scenarios: in the first scenario, only district heating networks already in existence were to be retained, without installing new ones, while the second scenario involved the installation of district heating networks that would supply schools and residential buildings not currently connected to district heating. The results of these calculations are presented below.

[2] Statement of the Minister for the Economy of 16 February 2012 concerning the report on the progress achieved in increasing the share of electricity produced from high-efficiency cogeneration in the total national electricity production in Poland http://ec.europa.eu/energy/efficiency/cogeneration/cogeneration_en.htm

## 6.1 Existing capacity of high-efficiency cogeneration

**Table 6.1. Existing capacity of high-efficiency cogeneration**

| Parameter | Electricity generating capacity from high-efficiency cogeneration (MWe) |
|---|---|
| Total installed electricity generating capacity (MWe) | 35 949 |
| Installed capacity of Main Activity Producer Electricity Plants and high-efficiency CHP plants (GWh/year)* | 32 757 |
| Installed capacity of high-efficiency cogeneration limited to only Main Activity Producer CHP Plants | 6 163 |

The vast majority of Polish electricity generating capacity (91 %) is the installed capacity of Main Activity Producer Electricity Plants and Main Activity Producer CHP Plants, which provide a certain amount of heat, i.e. have a certain degree of cogeneration, but only 6 163 MWe of their heat output can be classified as high-efficiency cogeneration.

## 6.2 Technical potentials in 2015

The following tables show the total national demand for heat and the maximum potential for heat supply for each heating solution. The heat load of new district heating networks is equal to the combined consumption of heat by schools and residential buildings not connected to district heating. In the case of district heating networks, the heat generated by central combined heat and power plants (CHP plants) and boilers was presented following the consideration of transmission losses.

**Table 6.2. Technical potential for heat generation in new high-efficiency cogeneration and alternatives in 2015**

| 2015 Technical potential for heat GWh/year | Contribution by sector and of district heating | | | | |
|---|---|---|---|---|---|
| | **Existing district heating networks** | **Industry** | **Individual heating in schools and kindergartens not connected to district heating networks** | **Individual heating in residential buildings not connected to district heating networks** | **New district heating networks supplying schools and residential buildings** |
| **Total heat demand** | 68 598 | 41 406 | 10 168 | 93 395 | 119 097 |
| | | | | | |
| **Breakdown: cogeneration and supplementary heat from boilers** | | | | | |
| Proportion from high-efficiency cogeneration | 63% | 63% | 63% | 100% | 63% |
| Proportion from boilers | 37% | 37% | 37% | 0% | 37% |
| | | | | | |
| **Locations with existing cogeneration** | | | | | |
| Gas-fired high-efficiency cogeneration with supplementary heat from boilers | 24 343 | 14 694 | - | - | - |
| Coal-fired high-efficiency cogeneration with supplementary heat from boilers | 24 634 | 14 869 | - | - | - |
| | | | | | |
| **Locations without existing cogeneration** | | | | | |
| Gas-fired high-efficiency cogeneration with supplementary heat from boilers | 33 023 | 19 933 | 10 145 | - | 90 730 |
| Coal-fired high-efficiency cogeneration with supplementary heat from boilers | 67 842 | 40 950 | 9 687 | - | 109 316 |
| Biomass-fired high-efficiency cogeneration with supplementary heat from boilers | 66 822 | 40 334 | 9 664 | - | 109 316 |
| Micro-cogeneration – gas | - | - | - | 12 511 | - |
| | | | | | |
| **Alternative high-efficiency solutions** | | | | | |
| Heat pumps | - | - | 10 168 | 93 395 | - |
| Solar and thermal (the remainder from supplementary boilers) | - | - | 823 | 9 657 | - |

## Table 6.3 Technical potential for new high-efficiency cogeneration in 2015, expressed as electrical capacity

| **2015 Technical potential for high-efficiency cogeneration MWe** | **Contribution by sector and of district heating** | | | | |
|---|---|---|---|---|---|
| | **Existing district heating networks** | **Industry** | **Individual heating in schools and kindergartens not connected to district heating networks** | **Individual heating in residential buildings not connected to district heating networks** | **New district heating networks supplying schools and residential buildings** |
| Gas-fired high-efficiency cogeneration | **7 063** | **4 263** | **753** | **-** | **10 528** |
| Coal-fired high-efficiency cogeneration | **3 148** | **1 900** | **333** | **-** | **6 759** |
| Biomass-fired high-efficiency cogeneration | **3 148** | **1 900** | **333** | **-** | **6 759** |
| | | | | | |
| **Locations with existing cogeneration** | | | | | |
| Gas-fired high-efficiency cogeneration | 3 136 | 1 893 | - | - | - |
| Coal-fired high-efficiency cogeneration | 848 | 512 | - | - | - |
| | | | | | |
| **Locations without existing cogeneration** | | | | | |
| Gas-fired high-efficiency cogeneration | 3 927 | 2 370 | 753 | - | 10.528 |
| Coal-fired high-efficiency cogeneration | 2 300 | 1 388 | 333 | - | **6 759** |
| Biomass-fired high-efficiency cogeneration | 2 300 | 1 388 | 333 | - | **6 759** |
| Micro-cogeneration – gas | - | - | - | 417 | - |

## Table 6.4 Technical potential for electricity generation in new high-efficiency cogeneration in 2015

| **2015 Technical potential for high-efficiency cogeneration GWhe/year** | **Contribution by sector and of district heating** | | | | |
|---|---|---|---|---|---|
| | **Existing district heating networks** | **Industry** | **Individual heating in schools and kindergartens not connected to district heating networks** | **Individual heating in residential buildings not connected to district heating networks** | **New district heating networks supplying schools and residential buildings** |
| Gas-fired high-efficiency cogeneration | **43 336** | **26 158** | **4 623** | **-** | **35 965** |
| Coal-fired high-efficiency cogeneration | **19 319** | **11 661** | **2 041** | **-** | **23 090** |
| Biomass-fired high-efficiency cogeneration | **14 115** | **8 520** | **2 041** | **-** | **23 090** |
| | | | | | |
| | | | | | |
| **Locations with existing cogeneration** | | | | | |
| Gas-fired high-efficiency cogeneration | 19 240 | 11 614 | - | - | - |
| Coal-fired high-efficiency cogeneration | 5 204 | 3 141 | - | - | - |
| | | | | | |
| **Locations without existing cogeneration** | | | | | |
| Gas-fired high-efficiency cogeneration | 24 096 | 14 544 | 4 623 | - | 35 965 |
| Coal-fired high-efficiency cogeneration | 14 115 | 8 520 | 2 041 | - | 23 090 |
| Biomass-fired high-efficiency cogeneration | 14 115 | 8 520 | 2 041 | - | 23 090 |
| Micro-cogeneration – gas | - | - | - | 1 055 | - |

Following the comparison of cogeneration potentials for new district heating networks against the potential of individual cogeneration supplying schools and residential buildings, it can be clearly seen that the investment in the new heating networks would significantly increase the technical potential for high-efficiency cogeneration. As explained in Section 5.3, no potential was assumed for supplying industry or combining the existing district heating networks with the new district heating networks.

## 6.3 Technical potentials in 2025

**Table 6.5 Technical potential for heat generation in new high-efficiency cogeneration and alternatives in 2025**

| Technical potential for heat GWh/year | Contribution by sector and of district heating | | | | |
|---|---|---|---|---|---|
| | Existing district heating networks | Industry | Individual heating in schools and kindergartens not connected to district heating networks | Individual heating in residential buildings not connected to district heating networks | New district heating networks supplying schools and residential buildings |
| **Total heat demand** | **78 726** | **47 519** | **10 580** | **97 543** | **124 386** |
| | | | | | |
| **Breakdown: cogeneration and supplementary boilers** | | | | | |
| Proportion from high-efficiency cogeneration | | | | | |
| Proportion from supplementary boilers | **63%** | **63%** | **63%** | **100%** | **63%** |
| | 37% | 37% | 37% | 0% | 37% |
| **Locations with existing cogeneration** | | | | | |
| Gas-fired high-efficiency cogeneration with supplementary heat from boilers | | | | | |
| Coal-fired high-efficiency cogeneration with supplementary heat from boilers | 27 937 | 16 863 | - | - | - |
| | 28 271 | 17 065 | - | - | - |
| **Locations without existing cogeneration** | | | | | |
| Gas-fired high-efficiency cogeneration with supplementary heat from boilers | | | | | |
| Coal-fired high-efficiency cogeneration with supplementary heat from boilers | 37 899 | 22 876 | 10 556 | - | 94 759 |
| Biomass-fired high-efficiency cogeneration with supplementary heat from boilers | 77 859 | 46 996 | 10 080 | - | 114 171 |
| Micro-cogeneration – gas | 76 688 | 46 289 | 10 056 | - | 114 171 |
| | - | - | - | 13 066 | - |
| **Alternative high-efficiency solutions** | | | | | |
| Heat pumps | | | | | |
| Solar and thermal (the remainder from supplementary boilers) | - | - | 10 580 | 97 543 | - |

**Table 6.6 Technical potential for new high-efficiency cogeneration in 2025, expressed as electrical capacity**

| **2025 Technical potential for high-efficiency cogeneration MWe** | **Contribution by sector and of district heating** | | | | |
|---|---|---|---|---|---|
| | **Existing district heating networks** | **Industry** | **Individual heating in schools and kindergartens not connected to district heating networks** | **Individual heating in residential buildings not connected to district heating networks** | **New district heating networks supplying schools and residential buildings** |
| Gas-fired high-efficiency cogeneration | **8 105** | **4 892** | **784** | **-** | **10 996** |
| Coal-fired high-efficiency cogeneration | **3 613** | **2 181** | **346** | **-** | **7 059** |
| **Biomass-fired high-efficiency cogeneration** | **2 640** | **1 593** | **346** | **-** | **7 059** |
| | | | | | |
| **Locations with existing cogeneration** | | | | | |
| Gas-fired high-efficiency cogeneration | 3 598 | 2 172 | - | - | - |
| Coal-fired high-efficiency cogeneration | 973 | 587 | - | - | - |
| | | | | | |
| **Locations without existing cogeneration** | | | | | |
| Gas-fired high-efficiency cogeneration | 4 507 | 2 720 | 784 | - | 10 996 |
| Coal-fired high-efficiency cogeneration | 2 640 | 1 593 | 346 | - | 7 059 |
| Biomass-fired high-efficiency cogeneration | 2 640 | 1 593 | 346 | - | 7 059 |
| Micro-cogeneration – gas | - | - | - | 436 | - |

## Table 6.7 Technical potential for electricity generation in new high-efficiency cogeneration in 2025

| **2025 Technical potential for high-efficiency cogeneration GWhe/year** | **Contribution by sector and of district heating** | | | | |
|---|---|---|---|---|---|
| | **Existing district heating networks** | **Industry** | **Individual heating in schools and kindergartens not connected to district heating networks** | **Individual heating in residential buildings not connected to district heating networks** | **New district heating networks supplying schools and residential buildings** |
| Gas-fired high-efficiency cogeneration | **49 734** | **30 020** | **5 305** | **-** | **41 275** |
| Coal-fired high-efficiency cogeneration | **22 171** | **13 382** | **2 343** | **-** | **26 499** |
| **Biomass-fired high-efficiency cogeneration** | **16 199** | **9 778** | **2 343** | **-** | **26 499** |
| | | | | | |
| **Locations with existing cogeneration** | | | | | |
| Gas-fired high-efficiency cogeneration | 22 081 | 13 328 | - | - | - |
| Coal-fired high-efficiency cogeneration | 5 972 | 3 605 | - | - | - |
| | | | | | |
| **Locations without existing cogeneration** | | | | | |
| Gas-fired high-efficiency cogeneration | 27 653 | 16 692 | 5 305 | - | 41 275 |
| Coal-fired high-efficiency cogeneration | 16 199 | 9 778 | 2 343 | - | 26 499 |
| Biomass-fired high-efficiency cogeneration | 16 199 | 9 778 | 2 343 | - | 26 499 |
| Micro-cogeneration – gas | - | - | - | 1 211 | - |

# 7 Socio-economic potential for high-efficiency cogeneration, heat pumps and solar thermal sources

The economic potential was estimated with a view to replacing the existing technologies with high-efficiency technologies over the next 30 years (i.e. from 2014 to 2044) based on the net present value (NPV), according to the discount rate, with the following elements being taken into account:

- Technical potential based on the current heat consumption and the increase/decrease in heat consumption between 2014 and 2044.
- Financial costs and benefits of these technologies for the whole country.
- Effects of carbon dioxide emissions and air quality determined in monetary terms.

An additional potential for development of cogeneration is, above all, demand for heat currently generated in heat generation plants, which, due to the construction of new systems, can be met from high-efficiency cogeneration.
The heat currently produced in coal-fired cogeneration should also be considered an additional potential for high-efficiency cogeneration. The replacement of these systems with the gas systems with a significantly higher combination ratio will not increase the heat produced in cogeneration, but the amount of electricity produced. The currently existing cogeneration systems with low combination ratio such as coal-based systems with steam turbine can also be considered a potential for developing electricity production from cogeneration. Additional potential may be met from waste heat, e.g. waste incineration plants, industrial installations or other facilities generating waste heat. The amount of heat and cooling currently produced cannot be met from identified sources, but it is technically feasible to utilise such heat.
As for the additional potential of detached houses, it is equal to the entire technical potential. It is recognised that currently there are no cogeneration systems in detached houses.

## 7.1. Results for the average values

The results of a country-level cost-benefit analysis are summarised in the following tables showing the proportions of annual heat production, electricity generation options for high-efficiency cogeneration and the electricity that could be produced through the use of the most socially cost-effective mix of high-efficiency district heating technologies. That potential is based on the current annual heat consumption and its realisation would be socially and economically justified within the next 30 years – at the time when the replacement of existing heating systems will be required. As in the case of the technical potential of district heating networks, the heat generated by central CHP plants and boilers was presented taking account of transmission losses.

### 7.1.1 Summary of results at national level

**Table 7.1. Socio-economic potential for heat GWh/year**

| Socio-economic potential for heat GWh/year | Contribution by sector and of district heating | | | | | |
|---|---|---|---|---|---|---|
| **Low discount rate = 5.0 % Central costs of capital Central fuel price forecasts** | **Existing district heating networks** | **Industry** | **Individual heating in schools and kindergartens not connected to district heating networks** | **Individual heating in residential buildings not connected to district heating networks** | **New district heating networks supplying schools and residential buildings** | **Total** |
| **Grand total** | **68 598** | **41 406** | **10 141** | **77 350** | **17 857** | **215 352** |
| **High-efficiency solutions (excluding supplementary boilers in cogeneration)** | **43 003** | **25 665** | **6 434** | **65 779** | **11 316** | **152 198** |
| | | | | | | |
| **High-efficiency cogeneration and supplementary heat from boilers** | | | | | | |
| Total | 67 860 | 40 501 | 10 117 | - | 17 857 | **136 334** |
| High-efficiency cogeneration | 43 003 | 25 665 | 6 411 | - | 11 316 | **86 396** |
| Supplementary boilers | 24 857 | 14 835 | 3 706 | - | 6 541 | **49 939** |
| **Locations with existing cogeneration** | | | | | | |
| Gas-fired high-efficiency cogeneration with supplementary heat from boilers | 15 670 | 23 366 | - | - | - | **39 037** |
| Coal-fired high-efficiency cogeneration with supplementary heat from boilers | - | - | - | - | - | **-** |
| **Locations without existing cogeneration** | | | | | | |
| Gas-fired high-efficiency cogeneration with supplementary heat from boilers | 9 803 | 4 108 | 10 117 | - | 17 857 | **41 885** |
| Coal-fired high-efficiency cogeneration with supplementary heat from boilers | - | - | - | - | - | **-** |
| Biomass-fired high-efficiency cogeneration with supplementary heat from boilers | 42 386 | 13 027 | - | - | - | **55 413** |
| Micro-cogeneration – gas | - | - | - | - | - | **-** |
| **Alternative high-efficiency solutions** | | | | | | |
| Heat pumps | - | - | 23 | 65 779 | - | **65 802** |
| Solar thermal | - | - | - | - | - | **-** |
| | | | | | | |
| **Conventional solutions supplying heat only** | | | | | | |
| **Total** | **738** | **905** | **1** | **11 571** | **-** | **13 216** |
| Heat generation plants – gas | 3 | 5 | 1 | 11 187 | - | **11 196** |
| Heat generation plant – coal | 735 | 901 | - | 384 | - | **2 020** |
| Electric heating | - | - | - | - | - | **-** |
| Heat generation plants – other fuels | - | - | - | - | - | **-** |

## Table 7.2 Socio-economic potential – breakdown of annual heat generation

| Socio-economic annual potential breakdown of heat | Contribution by sector and of district heating | | | | | |
|---|---|---|---|---|---|---|
| | Existing district heating networks | Industry | Individual heating in schools and kindergartens not connected to district heating networks | Individual heating in residential buildings not connected to district heating networks | New district heating networks supplying schools and residential buildings | Total |
| **Grand total** | **31.85%** | **19.23%** | **4.71%** | **35.92%** | **8.29%** | **100.00%** |
| **High-efficiency solutions (excluding supplementary boilers in cogeneration)** | **19.97%** | **11.92%** | **2.99%** | **30.54%** | **5.25%** | **70.67%** |
| | | | | | | |
| **High-efficiency cogeneration and supplementary heat from boilers** | | | | | | |
| Total | 31.51% | 18.81% | 4.70% | 0.00% | 8.29% | **63.31%** |
| High-efficiency cogeneration | 19.97% | 11.92% | 2.98% | 0.00% | 5.25% | **40.12%** |
| Supplementary boilers | 11.54% | 6.89% | 1.72% | 0.00% | 3.04% | **23.19%** |
| | | | | | | |
| **Locations with existing cogeneration** | | | | | | |
| Gas-fired high-efficiency cogeneration with supplementary heat from boilers | 7.28% | 10.85% | 0.00% | 0.00% | 0.00% | **18.13%** |
| Coal-fired high-efficiency cogeneration with supplementary heat from boilers | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | **0.00%** |
| **Locations without existing cogeneration** | | | | | | |
| Gas-fired high-efficiency cogeneration with supplementary heat from boilers | 4.55% | 1.91% | 4.70% | 0.00% | 8.29% | **19.45%** |
| Coal-fired high-efficiency cogeneration with supplementary heat from boilers | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | **0.00%** |
| Biomass-fired high-efficiency cogeneration with supplementary heat from boilers | 19.68% | 6.05% | 0.00% | 0.00% | 0.00% | **25.73%** |
| Gas-fired micro-cogeneration | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | **0,00%** |
| **Alternative high-efficiency solutions** | | | | | | |
| Heat pumps | 0.00% | 0.00% | 0.01% | 30.54% | 0.00% | **30.56%** |
| Solar thermal | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | **0.00%** |
| **Conventional solutions supplying heat only** | | | | | | |
| **Total** | **0.34%** | **0.42%** | **0.00%** | **5.37%** | **0,00%** | **6.14%** |
| Heat generation plants – gas | 0.00% | 0.00% | 0.00% | 5.19% | 0.00% | **5.20%** |
| Heat generation plant – coal | 0.34% | 0.42% | 0.00% | 0.18% | 0.00% | **0.94%** |
| Electric heating | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | **0.00%** |
| Heat generation plants – other fuels | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | **0.00%** |

As can be seen, high-efficiency cogeneration is the most socially and economically justifiable solution, capable of covering 40 % of total national consumption of heat (5 % supplying the new district heating networks and 35 % from individual high-efficiency cogeneration installations).

Supplementary heat provided by boilers in high-efficiency cogeneration would account for 23 % of the total (3 % supplying the new district heating networks and 20 % from individual facilities).

Heat pumps provide the most socially and economically effective solution for 31 % of heat consumption (almost entirely in residential buildings).

Solar thermal energy is not a socially and economically effective option due to the excessively high capital expenditures in relation to a small percentage of heat demand which could be satisfied by that technology, thus allowing the replacement of the primary fuel.

As regards the remaining 6 % of heat, none of the high-efficiency options included herein would be socially and economically justifiable in comparison with the conventional heat generation plants included in the basic option. It should be noted, however, that in the case of existing district heating networks and industrial locations with a cogeneration system in place, it is assumed that the current capacity of the CHP and heat generation plant will be replaced by gas- or coal-fired high-efficiency cogeneration with supplementary heat being provided by boilers as a basis, but these potentials have been included in the above-mentioned aggregated data on high-efficiency cogeneration.

## Table 7.3 Socio-economic potential for electricity generation from high-efficiency cogeneration

| Socio-economic potential for high-efficiency cogeneration MWe | Contribution by sector and of district heating | | | | | |
|---|---|---|---|---|---|---|
| | Existing district heating networks | Industry | Individual heating in schools and kindergartens not connected to district heating networks | Individual heating in residential buildings not connected to district heating networks | New district heating networks supplying schools and residential buildings | Total |
| **Grand total** | **4 305** | **3 899** | **752** | **-** | **1 968** | **10 924** |
| | | | | | | |
| **Locations with existing cogeneration** | | | | | | |
| Gas-fired high-efficiency cogeneration | 1 965 | 3 063 | - | - | - | **5 028** |
| Coal-fired high-efficiency cogeneration | - | - | - | - | - | **-** |
| | | | | | | |
| **Locations without existing cogeneration** | | | | | | |
| Gas-fired high-efficiency cogeneration | 881 | 388 | 752 | - | 1 968 | **3 988** |
| Coal-fired high-efficiency cogeneration | - | - | - | - | - | **-** |
| Biomass-fired high-efficiency cogeneration | 1 459 | 448 | - | - | - | **1 908** |
| Gas-fired micro-cogeneration | - | - | - | - | - | **-** |

## Table 7.4 Socio-economic potential for high-efficiency cogeneration – electricity generated annually

| Socio-economic potential for high-efficiency cogeneration – electricity generated annually GWh/year | Contribution by sector and of district heating | | | | | |
|---|---|---|---|---|---|---|
| | Existing district heating networks | Industry | Individual heating in schools and kindergartens not connected to district heating networks | Individual heating in residential buildings not connected to district heating networks | New district heating networks supplying schools and residential buildings | Total |
| **Grand total** | **26 417** | **23 926** | **4 613** | **-** | **6 722** | **61 678** |
| | | | | | | |
| **Locations with existing cogeneration** | | | | | | |
| Gas-fired high-efficiency cogeneration | 12 059 | 18 795 | - | - | - | **30 854** |
| Coal-fired high-efficiency cogeneration | - | - | - | - | - | **-** |
| | | | | | | |
| **Locations without existing cogeneration** | | | | | | |
| Gas-fired high-efficiency cogeneration | 5 405 | 2 379 | 4 613 | - | 6 722 | **19 119** |
| Coal-fired high-efficiency cogeneration | - | - | - | - | - | **-** |
| Biomass-fired high-efficiency cogeneration | 8 953 | 2 752 | - | - | - | **11 705** |
| Gas-fired micro-cogeneration | - | - | - | - | - | **-** |

## Table 7.5 Social NPV of high-efficiency heating options in PLN million

| **Social NPV of high-efficiency heating options in PLN million** | **Contribution by sector and of district heating** | | | | | |
|---|---|---|---|---|---|---|
| **District heating solution** | **Existing district heating networks** | **Industry (individual CHP plants)** | **Individual heating in schools and kindergartens not connected to district heating networks** | **Individual heating in residential buildings not connected to district heating networks** | **New district heating networks supplying schools and residential buildings** | **Total** |
| **Grand total** | **167 353** | **20 525** | **5 547** | **50 800** | **17 810** | **262 035** |
| | | | | | | |
| **High-efficiency cogeneration and supplementary heat from boilers** | | | | | | |
| Total | 167 353 | 20 525 | 5 531 | - | 17 810 | **211 219** |
| | | | | | | |
| **Locations with existing cogeneration** | | | | | | |
| Gas-fired high-efficiency cogeneration with supplementary heat from boilers | - | - | - | - | - | - |
| Coal-fired high-efficiency cogeneration with supplementary heat from boilers | - | - | - | - | - | - |
| | | | | | | |
| **Locations without existing cogeneration** | | | | | | |
| Gas-fired high-efficiency cogeneration with supplementary heat from boilers | 6 334 | 3 349 | 5 531 | - | 17 810 | **33 024** |
| Coal-fired high-efficiency cogeneration with supplementary heat from boilers | - | - | - | - | - | - |
| Biomass-fired high-efficiency cogeneration with supplementary heat from boilers | 161 019 | 17 176 | - | - | - | **178 195** |
| Gas-fired micro-cogeneration | - | - | - | - | - | - |
| | | | | | | |
| **Alternative high-efficiency solutions** | | | | | | |
| Heat pumps | - | - | 16 | 50 800 | - | **50 816** |
| Solar thermal | - | - | - | - | - | - |

## Table 7.6 Socio-economic number of facilities

| Socio-economic number of facilities | Contribution by sector and of district heating | | | | | |
|---|---|---|---|---|---|---|
| **Heating solution** | **Existing district heating*** | **Industry (individual CHP plants)*** | **Individual heating in schools and kindergartens not connected to district heating networks** | **Individual heating in residential buildings not connected to district heating networks** | **New district heating networks supplying schools and residential buildings**** | **Total** |
| **Grand total** | **1 096** | **1 351** | **651** | **6 110 279** | **1 136 879** | **7 250 256** |
| **High-efficiency solutions** | **714** | **534** | **558** | **5 118 754** | **1 136 879** | **6 257 440** |
| | | | | | | |
| **High-efficiency cogeneration and supplementary heat from boilers** | | | | | | |
| **Total** | 714 | 534 | 448 | - | 1 136 879 | **1 138 575** |
| | | | | | | |
| **Locations with existing cogeneration** | | | | | | |
| Gas-fired high-efficiency cogeneration with supplementary heat from boilers | 49 | 52 | - | - | - | **101** |
| Coal-fired high-efficiency cogeneration with supplementary heat from boilers | - | - | - | - | - | - |
| | | | | | | |
| **Locations without existing cogeneration** | | | | | | |
| Gas-fired high-efficiency cogeneration with supplementary heat from boilers | 469 | 377 | 448 | - | 1 136 879 | **1 138 173** |
| Coal-fired high-efficiency cogeneration with supplementary heat from boilers | - | - | - | - | - | - |
| Biomass-fired high-efficiency cogeneration with supplementary heat from boilers | 195 | 106 | - | - | - | **301** |
| Gas-fired micro-cogeneration | - | - | - | - | - | - |
| | | | | | | |
| **Alternative high-efficiency solutions** | | | | | | |
| Heat pumps | - | - | 110 | 5 118 754 | - | **5 118 864** |
| Solar thermal | - | - | - | - | - | - |
| | | | | | | |
| **Conventional solutions supplying heat only** | | | | | | |
| **Total** | **382** | **817** | **93** | **991 525** | **-** | **992 817** |
| Heat generation plants – gas | 52 | 146 | 64 | 928 014 | - | **928 276** |
| Heat generation plant – coal | 330 | 671 | 21 | 63 510 | - | **64 532** |
| Electric heating | - | - | 8 | - | - | **8** |
| Heat generation plants – other fuels | - | - | - | - | - | - |

* In the case of existing district heating networks, the stated number of facilities relates to district heating and not to the number of individual facilities supplied, since the latter number is not known and it is assumed that such heating networks will be retained. In total, there are 2 447 'facilities' (according to the industrial database of KOBiZE) with CHP plants and heat generation plants, some of which supply a district heating network, while others supply an industrial facility and district heating network. The facilities supplying industry and a district heating network were arbitrarily disaggregated by proportion of heat supplied to industry and district heating so that the sum total for the existing district heating networks and industrial networks was 2 447.

** In the case of new heating networks, the stated figures reflect the number of individual facilities supplied.

**Table 7.7 Socio-economic primary energy savings following the application of high-efficiency cogeneration**

| Socio-economic primary energy savings following the application of high-efficiency cogeneration GWh/year | Contribution by sector and of district heating | | | | | |
|---|---|---|---|---|---|---|
| **District heating solution** | **Existing district heating networks** | **Industry (individual CHP plants)** | **Schools and kindergartens (individual CHP plants)** | **Individual dwellings (individual CHP plants)** | **New district heating networks supplying schools and residential buildings** | **Total** |
| **Grand total** | **22 766** | **14 197** | **2 419** | **-** | **5 227** | **44 610** |
| | | | | | | |
| **Locations with existing cogeneration** | | | | | | |
| Gas-fired high-efficiency cogeneration | 5 318 | 8 500 | - | - | - | **13 818** |
| Coal-fired high-efficiency cogeneration | - | - | - | - | - | **-** |
| | | | | | | |
| **Locations without existing cogeneration** | | | | | | |
| Gas-fired high-efficiency cogeneration | 2 558 | 1 182 | 2 419 | - | 5 227 | **11 386** |
| Coal-fired high-efficiency cogeneration | - | - | - | - | - | **-** |
| Biomass-fired high-efficiency cogeneration | 14 890 | 4 516 | - | - | - | **19 407** |
| Gas-fired micro-cogeneration | - | - | - | - | - | **-** |

# 7.2. Effects of variables

### 7.2.1 Summary of the central scenario (5.0% discount rate, the average cost of capital and the average projected fuel prices)

**Table 7.8 Socio-economic annual heat potential and breakdown in the central scenario**

| | Contribution by sector and of district heating | | | | | |
|---|---|---|---|---|---|---|
| **Socio-economic heat potential GWh/year** | **Existing district heating networks** | **Industry** | **Individual heating in schools and kindergartens not connected to district heating networks** | **Individual heating in residential buildings not connected to district heating networks** | **New district heating networks supplying schools and residential buildings** | **Total** |
| **Total generated heat** | **68 598** | **41 406** | **10 141** | **77 350** | **17 857** | **215 352** |
| **High-efficiency solutions** | **43 003** | **25 665** | **6 434** | **65 779** | **11 316** | **152 198** |
| High-efficiency cogeneration | 43 003 | 25 665 | 6 411 | - | 11 316 | **86 396** |
| Heat pumps | - | - | 23 | 65 779 | - | **65 802** |
| Solar thermal | - | - | - | - | - | **-** |
| | | | | | | |
| Supplementary boilers for cogeneration | 24 857 | 14 835 | 3 706 | - | 6 541 | **49 939** |
| Conventional solutions supplying heat only | 738 | 905 | 1 | 11 571 | - | **13 216** |
| | | | | | | |
| **Socio-economic heat potential – percentage of the total** | | | | | | |
| **Total generated heat** | **31.85%** | **19.23%** | **4.71%** | **35.92%** | **8.29%** | **100.00%** |
| **High-efficiency solutions** | **19.97%** | **11.92%** | **2.99%** | **30.54%** | **5.25%** | **70.67%** |
| High-efficiency cogeneration | 19.97% | 11.92% | 2.98% | 0.00% | 5.25% | **40.12%** |
| Heat pumps | 0.00% | 0.00% | 0.01% | 30.54% | 0.00% | **30.56%** |
| Solar thermal | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | **0.00%** |
| | | | | | | |
| Supplementary boilers for cogeneration | 11.54% | 6.89% | 1.72% | 0.00% | 3.04% | **23.19%** |
| Conventional solutions supplying heat only | 0.34% | 0.42% | 0.00% | 5.37% | 0.00% | **6.14%** |

### 7.2.2 Low discount rate (3.5 % discount rate, the average cost of capital and the average projected fuel prices)

**Table 7.9 Socio-economic annual heat potential and breakdown for the scenario with low discount rate**

| | **Contribution by sector and of district heating** | | | | | |
|---|---|---|---|---|---|---|
| **Socio-economic heat potential GWh/year** | **Existing district heating networks** | **Industry** | **Individual heating in schools and kindergartens not connected to district heating networks** | **Individual heating in residential buildings not connected to district heating networks** | **New district heating networks supplying schools and residential buildings** | **Total** |
| **Total generated heat** | **68 598** | **41 406** | **10 138** | **74 231** | **21 326** | **215 699** |
| High-efficiency solutions | **43 004** | **25 666** | **6 432** | **63 368** | **13 515** | **151 984** |
| High-efficiency cogeneration | 43 004 | 25 666 | 6 409 | - | 13 515 | **88 594** |
| Heat pumps | - | - | 23 | 63 368 | - | **63 391** |
| Solar thermal | - | - | - | - | - | **-** |
| | | | | | | |
| Supplementary boilers for cogeneration | 24 857 | 14 836 | 3 705 | - | 7 812 | **51 209** |
| Conventional solutions supplying heat only | 737 | 904 | 1 | 10 863 | - | **12 506** |
| | | | | | | |
| **Socio-economic heat potential – percentage of the total** | | | | | | |
| **Total generated heat** | **31.80%** | **19.20%** | **4.70%** | **34.41%** | **9.89%** | **100.00%** |
| High-efficiency solutions | **19.94%** | **11.90%** | **2.98%** | **29.38%** | **6.27%** | **70.46%** |
| High-efficiency cogeneration | 19.94% | 11.90% | 2.97% | 0.00% | 6.27% | **41.07%** |
| Heat pumps | 0.00% | 0.00% | 0.01% | 29.38% | 0.00% | **29.39%** |
| Solar thermal | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | **0.00%** |
| | | | | | | |
| Supplementary boilers for cogeneration | 11.52% | 6.88% | 1.72% | 0.00% | 3.62% | **23.74%** |
| Conventional solutions supplying heat only | 0.34% | 0.42% | 0.00% | 5.04% | 0.00% | **5.80%** |

Compared to the central scenario, a discount rate reduction from 5 % to 3.5 % is accompanied by a small increase in the percentage of heat supplied, for which new district heating networks are the most cost-effective solution (from 40.12 % to 41.07 %), replacing mainly individual heat pumps whose proportion has decreased (from 30.56 % to 29.39 %). The total proportion of high-efficiency cogeneration has slightly decreased (from 70.76 % to 70.46 %), since high-efficiency cogeneration provides only 63 % of heat, with the remainder being generated by heat generation plants. Total generated heat has increased slightly (from 215 352 TWh to 215 699 TWh) due to the increased potential of district heating, and thus an increase in losses in transmission via pipes.

### 7.2.3 High discount rate (7.5 % discount rate, the average cost of capital and the average projected fuel prices)

**Table 7.10 Socio-economic annual heat potential and breakdown for the scenario with high discount rate**

| Socio-economic heat potential GWh/year | Contribution by sector and of district heating | | | | | |
|---|---|---|---|---|---|---|
| | Existing district heating networks | Industry | Individual heating in schools and kindergartens not connected to district heating networks | Individual heating in residential buildings not connected to district heating networks | New district heating networks supplying schools and residential buildings | Total |
| **Total generated heat** | **68 598** | **41 406** | **10 147** | **81 409** | **13 340** | **214 901** |
| High-efficiency solutions | **42 999** | **25 661** | **6 425** | **59 443** | **8 454** | **142 981** |
| High-efficiency cogeneration | 42 999 | 25 661 | 6 403 | - | 8 454 | **83 516** |
| Heat pumps | - | - | 23 | 59 443 | - | **59 466** |
| Solar thermal | - | - | - | - | - | **-** |
| | | | | | | |
| Supplementary boilers for cogeneration | 24 854 | 14 833 | 3 701 | - | 4 886 | **48 274** |
| Conventional solutions supplying heat only | 745 | 913 | 21 | 21 966 | - | **23 645** |
| | | | | | | |
| **Socio-economic heat potential – percentage of the total** | | | | | | |
| **Total generated heat** | **31.92%** | **19.27%** | **4.72%** | **37.88%** | **6.21%** | **100.00%** |
| High-efficiency solutions | **20.01%** | **11.94%** | **2.99%** | **27.66%** | **3.93%** | **66.53%** |
| High-efficiency cogeneration | 20.01% | 11.94% | 2.98% | 0.00% | 3.93% | **38.86%** |
| Heat pumps | 0.00% | 0.00% | 0.01% | 27.66% | 0.00% | **27.67%** |
| Solar thermal | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | **0.00%** |
| | | | | | | |
| Supplementary boilers for cogeneration | 11.57% | 6.90% | 1.72% | 0.00% | 2.27% | **22.46%** |
| Conventional solutions supplying heat only | 0.35% | 0.42% | 0.01% | 10.22% | 0.00% | **11.00%** |

Compared to the central scenario, a discount rate increase from 5 % to 7.5 % leads to a decrease in the percentage of heat supplied, for which high-efficiency cogeneration and heat pumps are the most cost-effective solution (from 70.67 % to 66.53 % in total; high-efficiency cogeneration: from 40.12 % to 38.86 %, and heat pumps: from 30.56 % to 27.67 %). The total generated heat has slightly decreased (from 215 352 TWh to 214 901 TWh) due to the decreased potential of district heating, translating into lower heat losses in transmission via pipes.

### 7.2.4 Lower cost of capital (5 % discount rate, the cost of capital decreased by 20 % and the average projected fuel prices)

**Table 7.11 Socio-economic annual heat potential and breakdown for the scenario with lower cost of capital**

| Socio-economic heat potential GWh/year | Contribution by sector and of district heating | | | | | |
|---|---|---|---|---|---|---|
| | **Existing district heating networks** | **Industry** | **Individual heating in schools and kindergartens not connected to district heating networks** | **Individual heating in residential buildings not connected to district heating networks** | **New district heating networks supplying schools and residential buildings** | **Total** |
| **Total generated heat** | **68.598** | **41.406** | **10.136** | **71.570** | **24.285** | **215.995** |
| High-efficiency solutions | **43.004** | **25.666** | **6.431** | **61.021** | **15.390** | **151.511** |
| High-efficiency cogeneration | 43.004 | 25.666 | 6.408 | - | 15.390 | **90.468** |
| Heat pumps | - | - | 23 | 61.021 | - | **61.043** |
| Solar thermal | - | - | - | - | - | **-** |
| | | | | | | |
| Supplementary boilers for cogeneration | 24.857 | 14.836 | 3.704 | - | 8.896 | **52.293** |
| Conventional solutions supplying heat only | 737 | 904 | 1 | 10.549 | - | **12.192** |
| | | | | | | |
| **Socio-economic heat potential – percentage of the total** | | | | | | |
| **Total generated heat** | **31.76%** | **19.17%** | **4.69%** | **33.13%** | **11.24%** | **100.00%** |
| High-efficiency solutions | **19.91%** | **11.88%** | **2.98%** | **28.25%** | **7.13%** | **70.15%** |
| High-efficiency cogeneration | 19.91% | 11.88% | 2.97% | 0.00% | 7.13% | **41.88%** |
| Heat pumps | 0.00% | 0.00% | 0.01% | 28.25% | 0.00% | **28.26%** |
| Solar thermal | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | **0.00%** |
| | | | | | | |
| Supplementary boilers for cogeneration | 11.51% | 6.87% | 1.71% | 0.00% | 4.12% | **24.21%** |
| Conventional solutions supplying heat only | 0.34% | 0.42% | 0.00% | 4.88% | 0.00% | **5.64%** |

Compared to the central scenario, a 20 % decrease in capital costs leads to a slight increase in the percentage of heat, for which district heating supplied from high-efficiency cogeneration are the most cost-efficient solutions (from 40.12 % to 41.88 %), replacing primarily individual heat pumps whose share has decreased (from 30.56 % do 28.26 %). The total share of high-efficiency cogeneration has slightly decreased (from 70.76 % to 70.15 %), since high-efficiency cogeneration provides only 63 % of heat, with the remainder being generated by heat generation plants. Total generated heat has increased slightly (from 215 352 TWh to 215 995 TWh) due to the increased potential of district heating, translating into higher heat losses in transmission via pipes.

### 7.2.5 Higher cost of capital (5 % discount rate, the cost of capital increased by 20 % and the average projected fuel prices)

**Table 7.12 Socio-economic annual heat potential and breakdown for the scenario with higher cost of capital**

| Socio-economic heat potential GWh/year | Contribution by sector and of district heating | | | | | |
|---|---|---|---|---|---|---|
| | Existing district heating networks | Industry | Individual heating in schools and kindergartens not connected to district heating networks | Individual heating in residential buildings not connected to district heating networks | New district heating networks supplying schools and residential buildings | Total |
| **Total generated heat** | **68 598** | **41 406** | **10 147** | **81 468** | **13 275** | **214 894** |
| High-efficiency solutions | **43 000** | **25 662** | **6 438** | **61 811** | **8 412** | **145 323** |
| High-efficiency cogeneration | 43 000 | 25 662 | 6 415 | - | 8 412 | **83 490** |
| Heat pumps | - | - | 23 | 61 811 | - | **61 833** |
| Solar thermal | - | - | - | - | - | **-** |
| | | | | | | |
| Supplementary boilers for cogeneration | 24 855 | 14 833 | 3 708 | - | 4 863 | **48 259** |
| Conventional solutions supplying heat only | 743 | 911 | 1 | 19 657 | - | **21 313** |
| | | | | | | |
| **Socio-economic heat potential – percentage of the total** | | | | | | |
| **Total generated heat** | **31.92%** | **19.27%** | **4.72%** | **37.91%** | **6.18%** | **100.00%** |
| High-efficiency solutions | **20.01%** | **11.94%** | **3.00%** | **28.76%** | **3.91%** | **67.63%** |
| High-efficiency cogeneration | 20.01% | 11.94% | 2.99% | 0.00% | 3.91% | **38.85%** |
| Heat pumps | 0.00% | 0.00% | 0.01% | 28.76% | 0.00% | **28.77%** |
| Solar thermal | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | **0.00%** |
| | | | | | | |
| Supplementary boilers for cogeneration | 11.57% | 6.90% | 1.73% | 0.00% | 2.26% | **22.46%** |
| Conventional solutions supplying heat only | 0.35% | 0.42% | 0.00% | 9.15% | 0.00% | **9.92%** |

Compared to the central scenario, a 20 % increase in the cost of capital leads to a decrease in the percentage of heat, for which high-efficiency cogeneration and heat pumps are the most cost-effective solution in social terms (from 70.67 % to 67.63 % in total; high-efficiency cogeneration: from 40.12 % to 38.85 %, and heat pumps: from 30.56 % to 28.77 %). Total generated heat has slightly decreased (from 215 352 TWh to 214 894 TWh) due to the decreased potential of district heating, translating into lower heat losses in transmission via pipelines.

## 7.2.6 Low fuel prices (5 % discount rate, the average cost of capital and the low projected fuel prices)

**Table 7.13 Socio-economic annual heat potential and breakdown for the scenario with low fuel prices**

| Socio-economic heat potential GWh/year | Contribution by sector and of district heating | | | | | |
|---|---|---|---|---|---|---|
| | Existing district heating networks | Industry | Individual heating in schools and kindergartens not connected to district heating networks | Individual heating in residential buildings not connected to district heating networks | New district heating networks supplying schools and residential buildings | Total |
| **Total generated heat** | **68 598** | **41 406** | **10 141** | **77 327** | **17 883** | **215 355** |
| High-efficiency solutions | **43 004** | **25 666** | **6 434** | **65 741** | **11 333** | **152 178** |
| High-efficiency cogeneration | 43 004 | 25 666 | 6 411 | - | 11 333 | **86 414** |
| Heat pumps | - | - | 23 | 65 741 | - | **65 764** |
| Solar thermal | - | - | - | - | - | **-** |
| | | | | | | |
| Supplementary boilers for cogeneration | 24 857 | 14 836 | 3 706 | - | 6 551 | **49 949** |
| Conventional solutions supplying heat only | 738 | 904 | 1 | 11 585 | - | **13 228** |
| **Socio-economic heat potential – percentage of the total** | | | | | | |
| **Total generated heat** | **31.85%** | **19.23%** | **4.71%** | **35.91%** | **8.30%** | **100.00%** |
| High-efficiency solutions | **19.97%** | **11.92%** | **2.99%** | **30.53%** | **5.26%** | **70.66%** |
| High-efficiency cogeneration | 19.97% | 11.92% | 2.98% | 0.00% | 5.26% | **40.13%** |
| Heat pumps | 0.00% | 0.00% | 0.01% | 30.53% | 0.00% | **30.54%** |
| Solar thermal | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | **0.00%** |
| | | | | | | |
| Supplementary boilers for cogeneration | 11.54% | 6.89% | 1.72% | 0.00% | 3.04% | **23.19%** |
| Conventional solutions supplying heat only | 0.34% | 0.42% | 0.00% | 5.38% | 0.00% | **6.14%** |

Compared to the central scenario, low projected fuel prices lead to a virtually identical mix of socially cost-effective heating options from high-efficiency cogeneration and conventional sources.

### 7.2.7 High fuel prices (5 % discount rate, the average cost of capital and the high projected fuel prices)

**Table 7.14 Socio-economic annual heat potential and breakdown for the scenario with high fuel prices**

| Socio-economic heat potential GWh/year | Contribution by sector and of district heating | | | | | |
|---|---|---|---|---|---|---|
| | Existing district heating networks | Industry | Individual heating in schools and kindergartens not connected to district heating networks | Individual heating in residential buildings not connected to district heating networks | New district heating networks supplying schools and residential buildings | Total |
| **Total generated heat** | **68 598** | **41 406** | **10 142** | **78 191** | **16 921** | **215 259** |
| High-efficiency solutions | **43 002** | **25 663** | **6 435** | **66 948** | **10 723** | **152 770** |
| High-efficiency cogeneration | 43 002 | 25 663 | 6 412 | - | 10 723 | **85 800** |
| Heat pumps | - | - | 23 | 66 948 | - | **66 970** |
| Solar thermal | - | - | - | - | - | **-** |
| | | | | | | |
| Supplementary boilers for cogeneration | 24 856 | 14 834 | 3 706 | - | 6 198 | **49 595** |
| Conventional solutions supplying heat only | 740 | 909 | 1 | 11 244 | - | **12 894** |
| **Socio-economic heat potential – percentage of the total** | | | | | | |
| **Total generated heat** | **31.87%** | **19.24%** | **4.71%** | **36.32%** | **7.86%** | **100.00%** |
| High-efficiency solutions | **19.98%** | **11.92%** | **2.99%** | **31.10%** | **4.98%** | **70.97%** |
| High-efficiency cogeneration | 19.98% | 11.92% | 2.98% | 0.00% | 4.98% | **39.86%** |
| Heat pumps | 0.00% | 0.00% | 0.01% | 31.10% | 0.00% | **31.11%** |
| Solar thermal | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | **0.00%** |
| | | | | | | |
| Supplementary boilers for cogeneration | 11.55% | 6.89% | 1.72% | 0.00% | 2.88% | **23.04%** |
| Conventional solutions supplying heat only | 0.34% | 0.42% | 0.00% | 5.22% | 0.00% | **5.99%** |

Compared to the central scenario, high projected fuel prices lead to a virtually identical mix of socially cost-effective heating options from high-efficiency cogeneration and conventional sources. This is followed by a slight decrease in the percentage of heat, for which high-efficiency cogeneration is the most cost-effective solution (from 40.12 % to 39.86 %), which is almost entirely due to the reduction in the percentage of new district heating networks supplied from high-efficiency cogeneration (from 5.25 % to 4.98 %). In the case of heat pumps, there is a slight increase (from 30.56 % to 31.11 %). The overall result is a very slight increase in the percentage of heat, for which high-efficiency cogeneration is the most socially cost-effective solution (from 70.67 % to 70.97 %).

# 8 Identification of energy efficiency potentials of district heating and cooling infrastructure

The energy efficiency potential of the district heating and cooling infrastructure is defined as the difference between the current total losses in transmission networks (heating and cooling) and the minimum losses that would occur on the same networks, if the best available practices were used.

It is considered that the best available practices entail the use of pre-insulated district heating pipes enabling a reduction in losses to 3 %. Such a level of losses can be achieved for systems with high power density. In the light of national conditions, it is assumed that the average power density of district heating systems will enable a reduction in heat losses to 4 % (if the best available technology is used).

In order to reduce losses to 4 % (current losses are 12.9 %), district heating networks must be upgraded so that the annual losses of 1.6 TJ/km are reduced to 0.45 TJ/km. Since the length of the district heating network is closely correlated with the value of heat lost during transmission, it can be assumed that the requirement for a reduction in losses per km of the network (to 0.45 TJ/km) should apply to all district heating systems in the country.

The potential resulting from the improved energy efficiency of district heating systems is estimated at 23.3 PJ, representing 72 % of the heat currently being lost in transmission.

The total cooling demand that could be met through the use of sorption units supplied by heat from the system is less than 15 PJ. The realisation of that potential will require that the demand for district heat be increased by 18.7 PJ, representing one third of the total demand of service (office) buildings. Such buildings are equipped with central ventilation (cooling distribution) systems, meaning that using a cooling system involving sorption units in them would involve only fitting district heating sub-stations with cooling equipment (the conversion of a district heating sub-station into a district heating and cooling sub-station). Multi-dwelling buildings, which may not be provided with cooling equipment at all, usually do not have a central ventilation system, therefore the authors did not include these buildings in the technical potential of using district heat for cooling purposes.

# 9 Description of strategies, policies and measures

## 9.1 Current situation

### 9.1.1 High-efficiency cogeneration

The development of electricity generation from high-efficiency cogeneration units contributes to better environmental protection, and, above all, to improved efficiency of electricity production, thus leading to a more efficient use of primary energy carriers. Legislative measures taken to achieve these objectives seek to increase the production of energy from high-efficiency cogeneration sources.

The support mechanism for entrepreneurs generating electricity from high-efficiency cogeneration was introduced in Poland in 2007 for a period until the end of 2018. The mechanism involves the mandatory receipt, transmission or distribution of the electricity generated by an appropriate electricity system operator, while maintaining the reliability and security of the national electricity system, and the issue by the President of the Energy Regulatory Office (*Urząd Regulacji Energetyki, URE*) of certificates of origin from cogeneration. Certificates of origin from cogeneration represent the property rights that can be traded on the Polish Power Exchange (TGE S.A.).

In addition, the law requires the electricity system operator to ensure that electricity produced from high-efficiency cogeneration (and renewable energy sources) has priority in the case of transmission and distribution services. Moreover, the electricity system operator is required to receive electricity from high-efficiency cogeneration, if the cogeneration facility is located on the Polish territory and connected directly to the electricity system.
The fact that electricity has been derived from cogeneration is confirmed by the President of URE through the issue of a certificate of origin from cogeneration. The certificates of origin are issued at the request of the generator (licence holder), confirmed by the electricity system operator in terms of the production volume for a given period.

Generators who have obtained certificates of origin from cogeneration may resell them on the Polish Power Exchange to those who are required to purchase these certificates, thus earning additional revenues from electricity generation activities. The cogeneration support scheme is supplemented by the Energy Law Act, which imposes financial penalties on undertakings which have failed to meet the obligation to redeem the appropriate number of certificates of origin from cogeneration or to pay a replacement fee.

The obligation to obtain and submit for redemption certificates of origin from cogeneration or to pay a replacement fee was imposed on the undertakings engaged in the generation of or trade in electricity, as well as the sale of such electricity to final consumers.

In order to comply with the above obligation, the obligated undertakings may:

1) redeem the relevant certificates of origin;
2) pay a replacement fee into the National Fund for Environmental Protection and Water Management (*Narodowy Fundusz Ochrony Środowiska i Gospodarki Wodnej, NFOŚiGW*), which should be allocated to support the renewable energy sources and cogeneration sources located in Poland.

In accordance with the Energy Law Act, it is the responsibility of the President of URE to ensure that energy undertaking complies with the above obligations.
There are three types of certificates of origin in Poland that confirm that electricity has been

produced in high-efficiency cogeneration:

1) the certificates of origin for the electricity generated in units fired with gaseous fuels or with an installed capacity of less than 1 MW;
2) the certificates of origin for the electricity generated in other cogeneration sources;
3) the certificates of origin for the cogeneration units fired with methane, in which methane is released and captured during underground mining works in operating hard coal mines, closed mines or mines under liquidation, or fired with gas derived from biomass processing.

The law defines, in percentage terms, the minimum quantitative share of electricity derived from obtained and redeemed certificates of origin from high-efficiency cogeneration or a substitute fee payable each year, broken down by the three types of high-efficiency cogeneration mentioned above.

The system in question is an operating system; it does not provide excessive fiscal benefits that would promote the development of new high-efficiency cogeneration units and efficient district heating networks.

There are currently no formalised procedures in place in Poland to support the construction of new generation capacities that would promote investment decisions. The exceptions are the above-mentioned preferential terms on which renewable energy sources with an installed electricity capacity of less than 1 MW are connected – a connection fee is charged which is equal to half the amount of fee calculated on the basis of the actual expenditure – involving the payment by a distribution or transmission system operator of 50 % of the costs of connection. Other generators are required to pay the fee calculated on the basis of 100 % of the capital expenditures incurred for the delivery of connections.

Investors may apply for financial support from NFOŚiGW within the Programme for the projects relating to renewable energy sources and high-efficiency cogeneration units, the aim of which is to increase electricity production from renewable energy sources and high-efficiency cogeneration units, as well as financial support from EU funds earmarked for high-efficiency cogeneration or preferential commercial loans for the investments promoting the environmental protection.

### 9.1.2 District heating networks

Property owners are required to connect the newly constructed buildings to district heating, if: the facility does not have its own district heating network based on renewable sources, heat from cogeneration or waste heat from industrial installations, and the expected peak demand for heat is not less than 50 kW, and the facility is located in the area which provides the appropriate technical conditions for supplying heat from district heating, in which at least 75 % of the heat per calendar year is the heat produced from renewable energy sources, useful heat in cogeneration or waste heat from industrial installations. Unless:

- An energy undertaking engaged in the transmission or distribution of electricity has refused to issue grid connection conditions;
- The heat prices applied by the energy undertaking engaged in the generation of heat are equal to or higher than the applicable average selling heat price (defined elsewhere under the applicable law) for the heat source utilising the same type of fuel.
- The supply of heat to that facility from a district heating network or individual renewable heat source, a source of useful heat in cogeneration or waste heat from industrial installations delivers lower energy efficiency than the heat supply from a different individual heat source which can be used to provide heat to that facility.

Heat tariffs are determined by the Energy Regulatory Office (URE). Licensed district heating companies are required to submit requests for heat tariffs to the regional branches of the Energy Regulatory Office for approval. The prices are regulated on the basis of the Tariff Determination Methodology (*Metodologia Kształtowania Taryf*) of the Energy Regulatory Office, which involves the establishment and approval of permitted revenues and tariff rates. The duties of the Energy Regulatory Office include the verification of planned fixed and variable costs (including the cost of modernisation, development and environmental protection) and the evaluation of the financial consequences of new tariffs for specific customer groups.

The operators of district heating networks in Poland are required to develop a plan for the development of a heat supply system within the area of their activities. That plan should be based on the projected development of certain cities and villages, according to the information provided by local authorities. The planning activities related to the development of cogeneration systems are coordinated by regional authorities, because the planning of heat supply lies within the competence of municipalities.

## 9.2 Potential additional policy actions

Article 14(2) of the EED Directive states that:

*Member States shall adopt policies which encourage the due taking into account at local and regional levels of the potential of using efficient heating and cooling systems, in particular those using high-efficiency cogeneration. Account shall be taken of the potential for developing local and regional heat markets.*

The policy should define measures which can be taken by 2020 and 2030 to realise the potential of cogeneration with a view to increasing the share of cogeneration in heating and cooling, as well as electricity production;

The policy and strategy to be developed should cover the following:

- actions to develop the efficient district heating and cooling infrastructure in connection with the development of high-efficiency cogeneration and the use of waste heat and renewable energy sources in heating and cooling;
- incentives for locating new thermal electricity generation installations and industrial plants generating waste heat at the sites where it is possible to recover the maximum amount of available waste heat in order to meet the existing or projected demand for heating and cooling;
- actions to promote the location of new residential zones or new industrial plants which consume heat in their production processes at the sites where the available waste heat identified in a comprehensive assessment can be used to meet part of their demand for heating or cooling. Such actions may include proposals for concentration of a greater number of individual installations in a given location in order to ensure the optimum adjustment of the heat and cooling demand and supply;
- actions to encourage thermal electricity generating installations, industrial plants generating waste heat, waste incineration plants and other facilities producing energy from waste to connect to the local district heating or cooling network;
- actions to support the process by which residential zones and industrial plants which consume heat in their production processes are connected to the local district heating or cooling network.

In Poland, the document setting out the policy and strategy is entitled 'National energy policy until 2030' ('*Polityka energetyczna kraju do roku 2030*'). The document identifies cogeneration as one of the priority technologies aimed at meeting the growing demand for electricity, while reducing emissions of pollutants and carbon dioxide into the air. The document, adopted by the Polish Government, envisages that production from cogeneration will double by 2020. The Ministry of Energy is currently working on a new support scheme for the electricity generators using that technology. The new system, which is consistent with the guidelines on support schemes issued by the European Commission, is designed to:

- encourage the investors to construct new high-efficiency cogeneration units,
- provide operational support to the already existing units so that they can function under the conditions of competitive energy market,
- promote the development of the network heat market which is essential for the development of cogeneration.

The first two actions should be primarily covered by financial mechanisms. The last action should receive significant support from administrative and legal mechanisms.

Support mechanisms can be divided into two basic categories:

- administrative and legal mechanisms (non-financial),
- financial mechanisms designed to increase the economic benefits of cogeneration.

It is difficult to determine which of these mechanisms is more important or effective. To achieve the objective pursued, it is necessary to determine the optimal set of mechanisms in terms of benefits to the national economy. Administrative mechanisms can be implemented at no cost to the State budget, thus replacing the financial mechanisms which require public support.

# 10 Progress achieved in accordance with Directive 2004/8/EC on the promotion of cogeneration

**MONITOR POLSKI**

OFFICIAL JOURNAL OF THE REPUBLIC OF POLAND

Warsaw, 1 March 2012

Item 108

**STATEMENT OF THE MINISTER FOR THE ECONOMY[1)]**

of 16 February 2013

**concerning the report on the progress achieved in increasing the share of electricity produced from high-efficiency cogeneration in the total national electricity production**

Pursuant to Article 9n(2) of the Energy Law Act of 10 April 1997 (*Journal of Laws* 2006, No 89, item 625, as amended[2)]), the publication of the assessment report on the progress achieved in increasing the share of electricity produced from high-efficiency cogeneration in the total national electricity production, attached as an appendix to the statement, is hereby announced.

Minister for the Economy: *W. Pawlak*

1) The Minister for the Economy manages the economy branch of government administration pursuant to Section 1(2) of the Regulation of the Prime Minister of 18 November 2011 on the detailed scope of operation of the Minister for the Economy (*Journal of Laws (Dziennik Ustaw)* No 248, item 1478).

2) Amendments to the consolidated text of the above-mentioned Act were published in *Journal of Laws* 2006, No 104, item 708, No 158, item 1123 and No 170, item 1217; and from 2007 No 21, item 124, No 52, item 343, No 115, item 790 and No 130, item 905; from 2008 No 180, item 1112 and No 227, item 1505; from 2009 No 3, item 11, No 69, item 586, No 165, item 1316 and No 215, item 1664; from 2010 No 21, item 104 and No 81, item 530; and from 2011 No 94, item 551, No 135, item 789, No 205, item 1208, No 233, item 1381 and No 234, item 1392.

The above report is available in both Polish and English versions at: [http://ec.europa.eu/energy/en/topics/energy-efficiency/cogeneration-heat-and-power](http://ec.europa.eu/energy/en/topics/energy-efficiency/cogeneration-heat-and-power)

# 11 Projected primary energy savings

## 11.1. Primary energy savings in high-efficiency cogeneration units

The primary energy savings provided by high-efficiency cogeneration units (PES), expressed as a percentage, calculated in accordance with Annex II to Directive 2012/27/EU of the European Parliament and of the Council was converted into chemical energy of the fuel, expressed in TJ, according to the following formula:

$$\Delta Q_{bq} = \frac{Q_{bq} \cdot PES}{100 - PES}$$

where:
Qbq – the chemical energy of fuel consumed during the cogeneration process [TJ],
PES – primary energy savings provided by cogeneration units [%]
ΔQ_bq – primary energy savings [TJ].

The PES indicators were delivered, on an individual basis, by the energy companies comprising the cogeneration unit concerned.
The amounts of primary energy savings are listed in Table 11.1 and Figures 11.1 and 11.2.

**Table 11.1 Primary energy savings in high-efficiency cogeneration units**

| Breakdown | | Year | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 |
| | | PJ | | | | | | | |
| **National total** | | 93.91 | 94.24 | 98.46 | 102.06 | 97.99 | 100.83 | 93.13 | 89.00 |
| **Condensing Main Activity Producer Electricity Plants** | | 6.89 | 7.98 | 7.00 | 8.05 | 6.98 | 6.93 | 6.21 | 5.36 |
| **Main Activity Producer CHP Plants** | | 60.59 | 60.53 | 60.97 | 61.88 | 58.13 | 59.58 | 57.14 | 50.99 |
| **Autonomous CHP Plants** | | 2.64 | 1.85 | 3.36 | 3.41 | 3.85 | 3.66 | 4.19 | 4.23 |
| **CHP Plants of district heating companies** | | 0.16 | 0.34 | 0.75 | 1.13 | 1.07 | 1.32 | 1.42 | 1.70 |
| **Autoproducer CHP Plants** | | 23.64 | 23.54 | 26.40 | 27.60 | 27.95 | 29.34 | 24.17 | 26.72 |
| **of which: National total** | **units with a capacity <1 MW** | 0.037 | 0.054 | 0.028 | 0.040 | 0.059 | 0.147 | 0.110 | 0.681 |
| | **fired with gas** | 5.44 | 6.06 | 6.53 | 6.98 | 7.11 | 10.99 | 9.85 | 7.81 |
| | **fired with methane or biogas** | - | - | - | 0.76 | 1.64 | 2.70 | 2.52 | 2.92 |
| | **other units** | 88.43 | 88.12 | 91.91 | 94.29 | 89.18 | 87.00 | 80.65 | 77.59 |

*Source: ARE [18]*

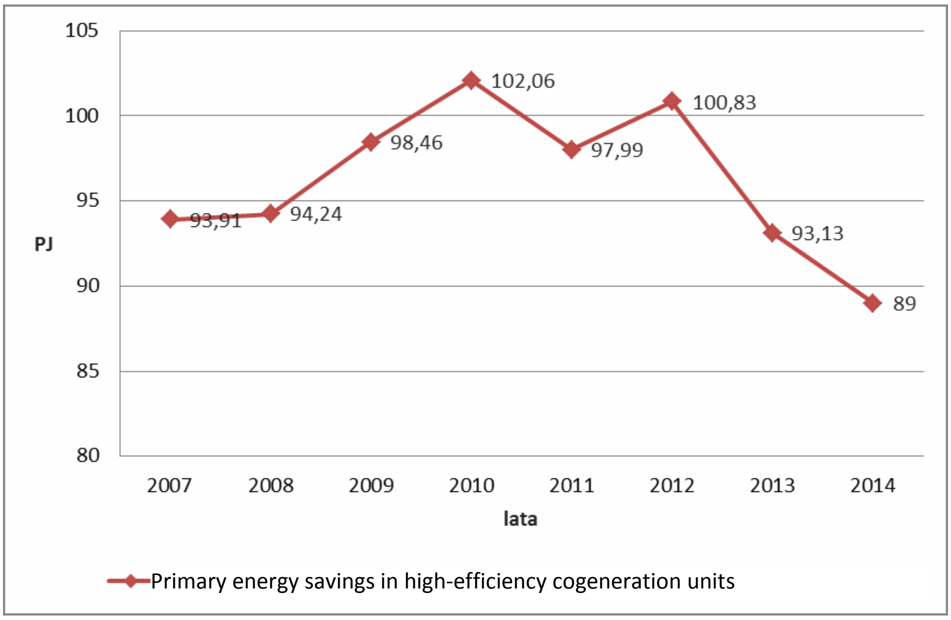



**Figure 11.1 Primary energy savings in high-efficiency cogeneration units**

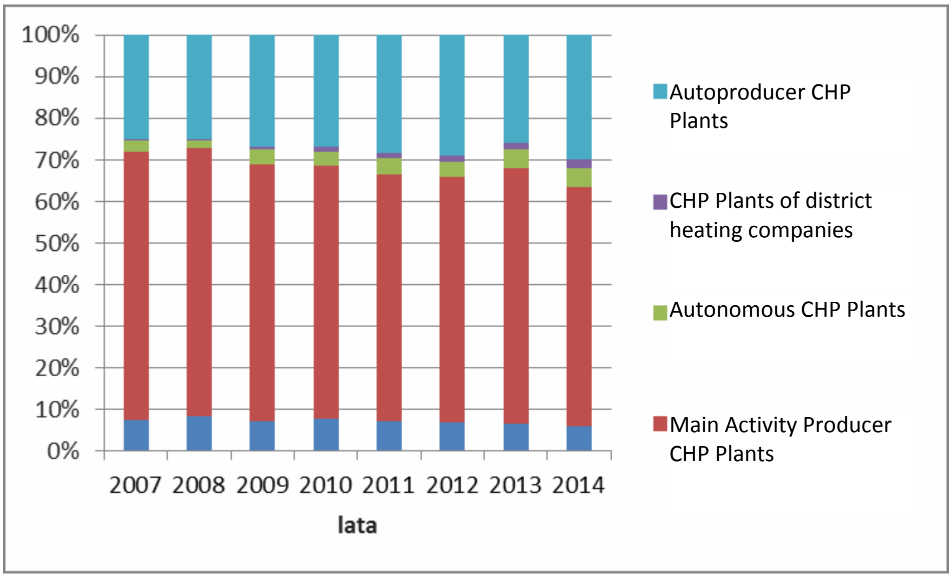



**Figure 11.2 Primary energy savings in high-efficiency cogeneration units, percentages**

Primary energy savings in subsequent years depend on the amount of heat produced. The highest primary energy savings were achieved in 2010 – 102.06 TJ (4.5 million tonnes of coal with a calorific value of about 22 100 kJ/kg) and the lowest – in 2014 – 89 TJ (4.2 million tonnes of coal with a calorific value of about 22 100 kJ/kg). In total, in 2007-2011, primary energy savings amounted to 769.62 PJ, of which nearly 70 % was accounted for by the main activity producer energy sector, and 27 % by the CHP plants operating in industrial plants.

## 11.2. Primary energy savings in high-efficiency cogeneration units expressed as a reduction in $CO_2$ emissions (avoided)

Table 11.2 and Figure 11.3 provide a summary of the annual $CO_2$ emissions avoided in individual cogeneration units. The most significant reduction was observed in 2010 (8.34 million tonnes of $CO_2$) and the lowest in 2014 (6.96 million tonnes of $CO_2$). Total savings in terms of $CO_2$ emissions in 2007-2011 amounted to 62.03 million tonnes of $CO_2$, of which 75 % was accounted for by the main activity producer energy sector, and 21 % by Autoproducer CHP Plants.

**Table 11.2 Primary energy savings in high-efficiency cogeneration units expressed as a reduction in $CO_2$ emissions (avoided)**

| Breakdown | | Year | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 |
| | | million tonnes | | | | | | | |
| **National total** | | 8.08 | 7.98 | 7.73 | 8.34 | 7.73 | 7.69 | 7.52 | 6.96 |
| **Condensing Main Activity Producer Electricity Plants** | | 0.79 | 0.74 | 0.65 | 0.74 | 0.63 | 0.62 | 0.60 | 0.52 |
| **Main Activity Producer CHP Plants** | | 5.54 | 5.44 | 5.33 | 5.41 | 4.93 | 4.94 | 4.90 | 4.42 |
| **Autonomous CHP Plants** | | 0.22 | 0.15 | 0.33 | 0.35 | 0.36 | 0.27 | 0.30 | 0.30 |
| **CHP Plants of district heating companies** | | 0.01 | 0.02 | 0.05 | 0.08 | 0.07 | 0.09 | 0.11 | 0.13 |
| **Autoproducer CHP Plants** | | 1.53 | 1.63 | 1.37 | 1.77 | 1.73 | 1.76 | 1.61 | 1.60 |
| **of which: National total** | **units with a capacity of <1 MW** | 0.001 | 0.003 | 0.001 | 0.002 | 0.003 | 0.009 | 0.005 | 0.033 |
| | **fired with gas** | 0.32 | 0.36 | 0.36 | 0.46 | 0.44 | 0.71 | 0.67 | 0.52 |
| | **fired with methane or biogas** | - | - | - | 0.05 | 0.10 | 0.09 | 0.18 | 0.20 |
| | **other units** | 7.76 | 7.62 | 7.36 | 7.83 | 7.19 | 6.88 | 6.66 | 6.20 |

*Source: ARE [18]*

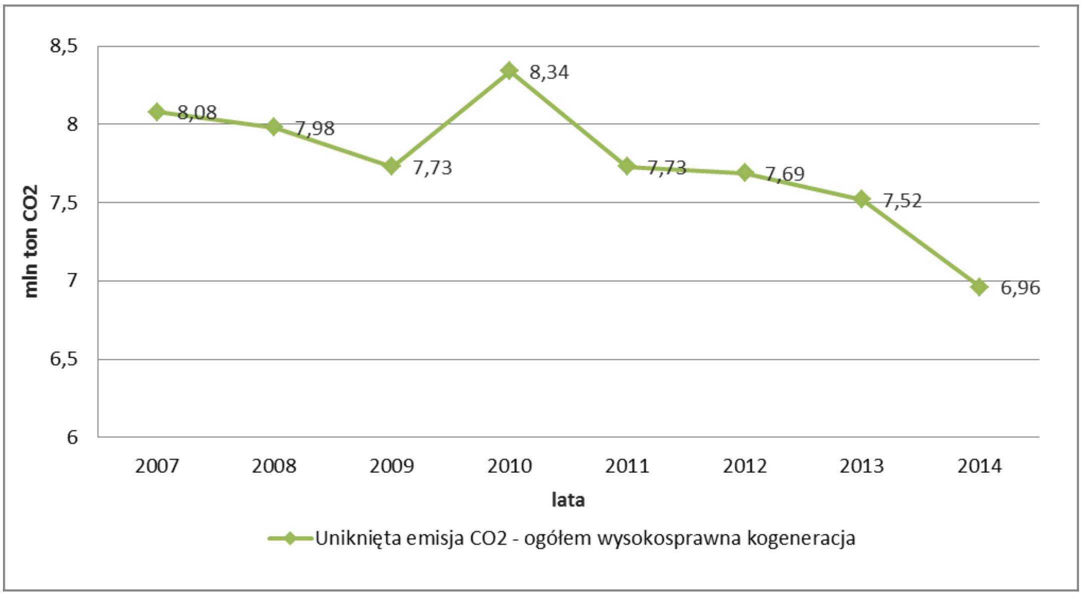



**Figure 11.3 $CO_2$ emissions avoided in high-efficiency cogeneration units** (million tonnes $CO_2$)

## Data sources


1. Data on heat consumption received from the Ministry of the Economy, '*20140516_TABL_ostateczne_do_przekazania_MG_Ricardo.xls'*, sheet'*LOCATION_razem_TS_499PJ'*

2. Data on heat consumption for the power plant and industrial cogeneration, the CHP plant and industrial heat generation plants, schools and kindergartens prepared by KOBiZE and submitted by the Ministry of the Economy 'KOBiZE-arkuszPrzemysł', 'KOBiZE-arkuszPrzemysł_lokalizacja_produkcja_ISP_Uzupelniony' and 'MG -arkusz nr 2 SzkołyiPrzedszkola'

3. KOBiZE's guidance on the national database, 'Guidance on how to prepare and include a report in the National Database for 2013'. https://krajowabaza.kobize.pl/docs/poradnik_KB_2013_wersja_01_2014.pdf

4. The number and floor area of residential buildings and the data on heat sales from the Central Statistical Office (GUS),'*Mieszkania wg sposobu ogrzewania_pl_en.xls', 'Sprzedaż energii cieplnej w ciągu roku wg celu_pl_en.xls'* and *'Budynki_Mieszkania.xls'*

5. Publication by the Ministry of the Economy '*Energy in Poland'* (historical data from 2012)

6. Statistical report for 2011-2012: *'Fuel and energy management in 2011-2012'*prepared by the Central Statistical Office, which provides more details than the publication by the Ministry of the Economy '*Energy in Poland'* (historical data from 2012)

7. National inventory of buildings with a breakdown by sector at the province level and the list of cadastral units (results of cadastral surveys of plots) in each province, including the number and floor area of the buildings from the National Inventory of Buildings submitted by the Ministry of the Economy
   a. *'krajowy_wykaz_budynkow_01_01_2014'*
   b. *'krajowy_wykaz_jednostek_ewidencyjnych_01_01_2014'*
   c. *'krajowy_wykaz_lokali_01_01_2014'*
   d. *'krajowy_wykaz_gruntow_01_01_2014'*

8. Total floor area and storage capacity of wholesale and retail distribution warehouses in 2007 *'Commercial wholesale and retail distribution warehouses according to the Polish Classification of Economic Activities (PKD) 2007'*

9. Poland's Report as an EU Member State from 16 February 2012: *'Assessment of the progress achieved in increasing the share of electricity production from high-efficiency cogeneration in the total electricity production in Poland'*

10. EU-ETS Register: European Union Transaction Log http://ec.europa.eu/environment/ets/

11. Sandbag's website http://www.sandbag.org.uk/maps/emissionsmap/?country=PL

12. Website of the Chief Environmental Protection Inspectorate http://mapy.gios.gov.pl/prtr/

13. European Pollutant Release and Transfer Register (EPTR) http://prtr.ec.europa.eu/Home.aspx

14. World Electric Power Plants Database (Platts)

15. 'Forecast of demand for fuel and energy up to 2050' provided to Ricardo by the Ministry of the Economy

16. Statement of the Minister for the Economy concerning Poland's Report as an EU Member State of 16 February 2012: *'Assessment of the progress achieved in increasing the share of electricity production from high-efficiency cogeneration in the total electricity production in Poland'* http://ec.europa.eu/energy/efficiency/cogeneration/cogeneration_en.htm

17. Cogeneration Observatory and Dissemination Europe (CODE2), D2.3 First draft of final CHP roadmap – Poland http://www.code2-project.eu/wp-content/uploads/CODE2-D2-3-Final-Draft-Roadmap-Poland-Web1.pdf

18. Programme of cogeneration development in Poland http://www.ptez.com.pl/_upload/file/PRwPK_vk7.pdf

19. Sprawozdanie_z_dzialalnosci_Prezesa_Urzedu_Regulacji_Energetyki_w_2013_r_: http://www.ure.gov.pl/pl/urzad/informacje-ogolne/sprawozdania/2916,Sprawozdania.html

20. Information Centre for Energy Market http://cire.pl/item,96214,1 0,0,0,0,0,cieplownicy-pracuja-nad-chlodem-sieciowym.html

21. *125n tbl 02(34).xls* (Total public roads by category of roads and provinces – 2012) http://stat.gov.pl/download/gfx/portalinformacyjny/pl/defaultaktualnosci/5511/9/13/1/tr ansport_wyniki_dzialalnosci_2013_tabele.zip

22. POPULATION STATUS AND STRUCTURE AND VITAL STATISTICS BY TERRITORY IN 2013 As of 31 December, Table 8 Report by Poroky Consulting, 'The Potential and Costs of District Heating Networks', April 2009 http://www.poroky.co.uk/sites/www.poroky.uk/files/A_report_providing_a_technical_analysis_and_costing_of_DH_networks.pdf

23. Report by PB Power Ltd. 'Heating Supply Options for New Development – An Assessment Method for Designers and Developers'. http://www.scotland.gov.uk/resource/doc/217736/0091415.pdf

24. Carbon Trust Biomass Heat Guide CTG012, p. 82 Publication date: January 2009 http://www.carbontrust.com/media/31667/ctg012_biomass_heating.pdf

25. Current availability of natural gas 'Wykaz Gmin.xls' and the natural gas availability planned for 2018 'Gazyfikacjagmin do 2018.xls' – data from the Ministry of the Economy

26. INOGATE Textbook, Regulatory Implications of District Heating, ERRA http://www.erranet.org/index.php?name=OE-eLibrary&file=download&keret=N&showheader=N&id=7931

27. Polish support schemes for renewable energy sources and cogeneration, Energy Regulatory Office http://www.ure.gov.pl/download/2/241/Polish_support_schemes_for_renewable_and__cogeneration_so.pdf

28. Additional guidance on the Green Paper: valuation of energy use and greenhouse gas emissions for assessment purposes, Additional guidance on the Green Book of the Ministry of Treasury setting out rules for the valuation of energy use and greenhouse gas emissions for government analysts, Valuation of energy use and greenhouse gas emissions – Additional information, Chapter 5 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/360044/2014_Background_Documentation_to_DECC_HMT_Supplementary_Appraisal_Guidance.pdf

29. Additional guidance on the Green Paper: valuation of energy use and greenhouse gas emissions for assessment purposes, Additional guidance on the Green Book of the Ministry of Treasury setting out rules for the valuation of energy use and greenhouse gas emissions for government analysts, Data tables 1-20: guidance concerning a set of tools and guidelines, tables 1, 3, 9-13, 15-20. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/360323/20141001_Supporting_Tabelas_for_DECC-HMT_Supplementary_Appraisal_Guidance.xlsx