Energy efficiency in the context of low-stack emissions reduction on the example of the city of Czestochowa

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Abstract

Energy efficiency is the base of the European energy policy and it is also one of the main “Europe 2020” strategy objectives. It includes a target of reducing primary energy consumption by 20% by 2020. Due to the fact that emissions related to energy account for nearly 80% of total greenhouse gas emissions, efficient use of energy can significantly contribute to achieving the goal of a low emission economy and fighting the climate changes.

According to the European Environment Agency report from 2013, Poland was among the European countries with the most polluted air, with the largest share of low-stack emissions in polluted air, mostly with toxic dust.

The city of Czestochowa undertakes a number of activities in the field of energy efficiency and reduction of energy use to counteract negative impacts on the environment. Implications of the actions taken contribute to reducing greenhouse gas emissions with the aim to protect the climate as well as to support the national commitments implementation to reduce greenhouse gas emissions, improve energy efficiency and increase the share of renewable energy sources in the national energy balance.

The purpose of this article is to characterise the actions taken by the city of Czestochowa to increase energy efficiency and reduce greenhouse gas emissions in the period of 2008-2014, and also to evaluate tangible benefits of these actions.

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1. Introduction

According to the European Environmental Agency report of 2013 (Report, 2013), Poland was among the European countries with the most polluted air. The list of the top 10 metropolises included as many as six Polish cities such as: Gliwice, Katowice, Krakow, Nowy Sacz, Sosnowiec and Zabrze. In these cities the largest share of air pollution is caused by low-stack emissions, and above all toxic dust.

Low-stack emissions concept is conventionally defined as emission of pollutants released into the air by emitters (chimneys) up to 40 meters high. Thus, responsibility for low-stack emissions is attributed to transportation, local boilers burning solid fuels and heavy fuel oil, supplying heat to municipal buildings, utilities, service companies, small businesses and individual house hearths burning fossil fuels, especially coal and biomass (Kubica 2013).

Considering the domestic structure of sources of gaseous and particulate pollutants while developing collective air quality assessments, in Poland pollutants are generally divided into the following groups:

- basic pollution: sulphur dioxide, nitrogen dioxide and dust, formed mainly during combustion of fuels in energy production processes and widespread throughout the country;
- specific pollution from various processes used in industrial plants;
- pollutants emitted from mobile sources, mainly from motor vehicles;
- secondary pollution often arising at a considerable distance from emission sources as a result of the reaction and the changes taking place in a polluted atmosphere, for example: oxidizing agents (photochemical oxidants), such as ozone, or leading to acidification of the environment, such as sulphates and nitrates.

Individual households are the most responsible for the air poisoning and smog formation. The reason lies mainly in inefficient house heating, using outdated technologies, poor quality fuel combustion and waste that emit particularly toxic compounds into the air (Voytenko et al., 2015). Pollution emitted from house chimneys can be divided into two types - toxic gases and toxic dust. Toxic gases originate primarily from combustion of coal and poor quality gas. These gases have a very irritating effect on the respiratory system. In contrast, dust is made up by tiny particles which comprise, inter alia, heavy metals such as mercury, cadmium or lead. They cause mechanical irritation of the upper and lower respiratory tract, facilitating the process of infecting organism by bacteria and viruses (Holman et al. 2015).

Plans of low emission economy being introduced in many municipalities have, among the others, to contribute to achieving objectives set out in the EU climate-energy package by 2020, i.e.:

- reducing the greenhouse gas emissions;
- increasing the share of energy from renewable sources;
- reduction of final energy consumption, which should be achieved by improving energy efficiency,
- and improving air quality within the municipalities.

2. The state of air pollution

Every country, including Poland, is obliged under the EMEP (European Monitoring Environmental Program) to take an annual inventory of emissions such as CO, SO2, TSP, PM2.5 and PM10, heavy metals (As, Cd, Cr, Cu, Hg, Ni, Pb, Se, Zn), dioxins (PCDDs / PCDFs) and a total of 4 PAH (benzo (a) pyrene, benzo (b) fluoranthene, benzo (b) fluoranthene, indeno (1,2 3-cd) pyrene). Poland is in the group of the EU countries with the largest emissions of these pollutants (Table 1).

From 1990 to 2013, the EU-28 recorded reductions in emissions of all air pollutants considered in this article. The biggest fall was reported for sulphur oxides (SOx) which between 1990 and 2013 decreased by 86.7 %, followed by non-methane volatile organic compounds (NMVOCs) which declined by nearly 60 %. Nitrous oxides (NOx) stood at 53.5 % of their 1990 levels (a decrease of roughly 46.5 %); while the smallest decrease was reported for ammonia (NH3), emissions which fell only by 27 % by 2013 (Air Pollution 2015).

In 2013, the emissions of ammonia (NH3) in the EU-28 stood at 3 847 870 tonnes, NMVOCs at 7 004 930 tonnes, nitrogen oxides (NOx) at 8 176 454 tonnes and sulphur oxides (SOx) at 3 429 764 tonnes (see Table 1). The biggest emitters of ammonia in 2013 in the EU-28 were France with 18.7 % of the EU total, followed by Germany with 17.4 %
and Italy with 10.5%. The NMVOC emissions were the highest in Germany, Italy, France and the United Kingdom - each with double-digit shares of the EU total. Nitrogen oxides (NOx) were emitted mostly in Germany (15.5% of the EU total), the United Kingdom (12.5%), and France (12.1%). Regarding sulphur oxides (SOx), unlike the other pollutants, the biggest emitter was a country from Eastern Europe: Poland with 24.7% of the EU total, followed by Germany with 12.1% and the United Kingdom with 11.5% (Shrubsole et al., 2015).

Table 1. Emissions of air pollutants by country, in tonnes, 2013 (Eurostat, 2015).

| Country          | NH3 Ammonia | NOx Nitrogen oxides | NMVOC Non-methane volatile organic compounds | SOx Sulphur oxides |
|------------------|-------------|---------------------|----------------------------------------------|-------------------|
| EU – 28          | 3 847 870   | 8 176 454           | 7 004 930                                     | 3 429 764         |
| Belgium          | 62 233      | 207 680             | 137 430                                       | 45 558            |
| Bulgaria         | 30 497      | 122 573             | 88 832                                        | 193 966           |
| Czech Republic   | 68 500      | 181 094             | 136 397                                       | 137 915           |
| Denmark          | 74 320      | 123 865             | 114 431                                       | 13 643            |
| Germany          | 670 849     | 1 269 182           | 1 138 241                                     | 416 214           |
| Estonia          | 11 303      | 29 721              | 32 931                                        | 36 500            |
| Ireland          | 107 758     | 79 064              | 90 001                                        | 25 393            |
| Greece           | 60 570      | 238 621             | 144 765                                       | 152 327           |
| Spain            | 379 308     | 812 152             | 550 801                                       | 287 128           |
| France           | 718 133     | 989 521             | 758 380                                       | 218 785           |
| Croatia          | 33 729      | 55 749              | 46 072                                        | 16 378            |
| Italy            | 402 230     | 20 574              | 905 539                                       | 145 054           |
| Cyprus           | 4 756       | 16 164              | 6 681                                         | 13 766            |
| Latvia           | 14 707      | 34 044              | 87 448                                        | 1 502             |
| Lithuania        | 40 410      | 46 166              | 63 394                                        | 18 928            |
| Luxembourg       | 4 573       | 31 434              | 7 650                                         | 1 580             |
| Hungary          | 81 243      | 120 567             | 120 400                                       | 29 309            |
| Malta            | 1 586       | 4 872               | 3 318                                         | 5 028             |
| Netherlands      | 133 801     | 239 619             | 149 682                                       | 29 926            |
| Austria          | 66 249      | 162 317             | 126 341                                       | 17 245            |
| Poland           | 263 402     | 798 233             | 635 776                                       | 846 845           |
| Portugal         | 49 111      | 16 147              | 169 630                                       | 42 276            |
| Romania          | 165 147     | 218 823             | 322 953                                       | 202 676           |
| Slovenia         | 17 451      | 42 893              | 33 324                                        | 11 294            |
| Slovakia         | 25 245      | 79 582              | 63 204                                        | 53 208            |
| Finland          | 37 283      | 144 877             | 94 558                                        | 47 377            |
| Sweden           | 52 168      | 125 915             | 173 756                                       | 26 785            |
| United Kingdom   | 271 309     | 1 019 674           | 802 997                                       | 393 158           |
| Iceland          | 5 337       | 20 775              | 5 402                                         | 72 563            |
| Liechtenstein    | 174         | 704                 | 417                                           | 28                |
| Norway           | 27 239      | 154 437             | 133 737                                       | 17 038            |
| Switzerland      | 61 690      | 72 304              | 84 139                                        | 10 207            |
| Turkey           | 1 089 748   | 1 047 000           | 868 184                                       | 1 939 104         |

The source sectors responsible for emissions differed across the specific air pollutants. Ammonia (NH$_3$) emissions came overwhelmingly from agriculture (93.3% of the EU total in 2013). NMVOCs, such as for example, benzene, ethanol, formaldehyde and acetone were mostly emitted from industrial processes and product use (49.8%), activities
in the commercial, institutional and households sector (16.4 %) and road transport (11.8 %). The biggest source of nitrous oxides (NOx) emissions was road transport with 39.4 % of the total in 2013, followed by energy production and distribution with 21 %, while the commercial and institutional sectors and households had a share of 15.1 %, and energy use in industry - 12.2 %. Finally, sulphur oxides (SOx) resulted mainly from activities in energy production and distribution (56.1 %), energy use in industry (19.1 %) and commercial, institutional and households (16 %) (Air Pollution 2015).

| Pollutant | 2012 | 2013 | 2013/2012 |
|-----------|------|------|-----------|
| SO2       | 858 625.9 | 846 845.5 | 98.63 |
| NOx       | 819 211.2 | 798 233.4 | 97.44 |
| NH3       | 262 525.0 | 263 401.5 | 100.33 |
| CO        | 2 791 083.4 | 2 876 382.2 | 103.06 |
| NMLZO     | 630 290.2 | 635 775.5 | 100.87 |
| TSP       | 406 429.4 | 407 362.9 | 100.02 |
| PM10      | 245 256.7 | 246 201.0 | 100.14 |
| PM2.5     | 144 771.3 | 144 510.1 | 99.47 |
| Lead (Pb) | 553.5 | 561.2 | 101.39 |
| Cadmium (Cd) | 15.6 | 15.3 | 98.22 |
| Mercury (Hg) | 10.4 | 10.4 | 100.18 |
| Arsenic (As) | 43.7 | 44.8 | 102.38 |
| Chrome (Cr) | 45.7 | 46.5 | 101.81 |
| Copper (Cu) | 347.8 | 350.9 | 100.89 |
| Nickel (Ni) | 148.1 | 147.6 | 99.71 |
| Zinc (Zn) | 1545.2 | 1588.2 | 102.78 |

Collective results of emissions in years 2012-2013 in Poland are presented in Table 2. Compared to 2012, in 2013 the emissions of major pollutants decreased, mostly the oxides of nitrogen (approx. 4%). The highest increase regarded the emissions of carbon monoxide (approx. 3%).

The heavy metal emissions changed slightly; emissions of arsenic and zinc increased by approx. 2-3% and emissions of cadmium decreased by approx. 1.8%. The most persistent organic pollutants with increased emissions included dioxins and furans and PAHs - approx. 7% (Meijering et al., 2014).

The analysis conducted to date with regard to air quality assessments for the years 2003-2013 points out the fact that the air quality in Poland has been systematically improving. The share of individual sources affecting air quality has also changed. Initially, the biggest impact was made by the energy and industry sector, and much less the transport sector and household/ municipal sector (Cárdenas et al., 2016). However, in the application of legal, technical and technological solutions, the impact of the industrial sector has decreased significantly. Despite the significant reductions in emissions in the industrial sector, the air quality standards are still not met. The results of the annual assessments carried out by the Inspection of Environmental Protection clearly indicate that the inadequate state of air quality in Poland is in the first place due to low-stack emissions originating from household/ municipal sector and transportation sector (Krajowy Program…, 2015).

In 2013 the participation of sources responsible for exceeding the permissible level of PM10 dust in Poland was as follows:

- 88.21% - individual house heating,
- 5.77% - traffic (including heavy vehicle traffic in city centres),
- 2.98% - secondary emissions of particulate pollutants from the surface of exposed roads and streets,
- 1.84% - industry,
- 1.17% - the cross-border influx,
- 0.03% - non-anthropogenic sources.

Emissions from the household/ municipal sector are dependent on the length of the heating season. For many years, the amount of coal burnt in individual households has been about 8-9 million tonnes per year, and the amount of firewood - around 7.0-7.5 million tonnes. Unfortunately, in the household/ municipal sector a new kind of fuel appeared on the market: dried coal sludge (culm), in the amount of about 800,000 tonnes in 2012, as a result of the lack of coal quality standardization for the household/ municipal sector. The effect of such energy sources structure in the household/ municipal sector is high emissions of pollutants, with peaks during the heating season, resulting in temporary exceedances of PM10 emissions in 28 areas of Poland (for 48 total zones: 12 in agglomerations, 18 in cities with more than 100,000 inhabitants, 16 in areas that are not part of agglomerations, and cities with over 100,000 inhabitants), and in 16 zones permanently.

It is worth noting that the air quality has been improving steadily. In Table 3 the downward trend in average values of the average annual concentration of PM10 is presented in relation to 2010.

Table 3. The value of average annual concentration of PM10 in selected zones of Poland in the years 2001-2013 (Krajowy Program…, 2015).

| Zone code | Zone                        | 2010  | 2011  | 2012  | 2013  |
|-----------|-----------------------------|-------|-------|-------|-------|
| PL0204    | Lower Silesia               | 32.3  | 32.3  | 31.7  | 27.6  |
| PL1001    | Lodz agglomeration          | 42.7  | 40.5  | 38.9  | 38.1  |
| PL1002    | Lodz                        | 42.8  | 45.9  | 42.7  | 40.1  |
| PL1201    | Krakow agglomeration        | 56.9  | 64.6  | 56.7  | 51.1  |
| PL1203    | Lesser                      | 51.3  | 48.4  | 45.0  | 43.6  |
| PL1202    | Tarnow                      | 44.9  | 40.7  | 43.1  | 33.9  |
| PL1802    | Subcarpathian               | 42.6  | 41.4  | 39.9  | 35.1  |
| PL2401    | Upper Silesia agglomeration | 51.4  | 51.8  | 48.4  | 44.9  |
| PL2402    | Rybnicko-Jastrzebska agglomeration | 57.7 | 50.9  | 51.2  | 49.1  |
| PL2405    | Silesia                     | 53.0  | 47.4  | 43.3  | 44.4  |

The RIEP (Regional Inspectorate of Environmental Protection) branch office in Czestochowa runs the air testing measurement program in compliance with the EU directives applicable in this respect. The stations continuously measure the levels of such substances as particulate matter PM10, sulphur dioxide, nitrogen oxides, carbon monoxide. The results of both stations are available in the internet at the website of the Regional Inspectorate of Environmental Protection in Katowice, and the results of the first station since 2004 are also displayed on the board located in the vicinity.

The measurement results from 2013-2015 for the station located at Armii Krajowej Avenue are presented in Table 4.

Table 4. The measurement results of air pollution in the period 2013-2015 for the station at Armii Krajowej Avenue in Czestochowa (own elaboration based on: http://monitoring.katowice.wios.gov.pl/).

| Parameter                      | Unit | Year | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 | 11 | 12 |
|--------------------------------|------|------|----|----|----|----|----|----|----|----|----|----|----|----|
| Sulphur dioxide (SO₂)          | µg/m³| 2013 | 30 | 21 | 22 | 15 | 5  | 4  | 5  | 5  | 4  | 12 | 15 | 25 |
|                               |      | 2014 | 20 | 35 | 22 | 10 | 5  | 5  | 5  | 4  | 9  | 9  | 12 | 18 |
| Nitric oxide (NO)             | µg/m³| 2013 | 27 | 32 | 31 | 31 | 32 | 20 | 19 | 17 | 31 | 59 | 38 | 44 |
|                               |      | 2014 | 36 | 84 | 52 | 38 | 79 | 22 | 17 | 18 | 33 | 65 | 57 | 46 |
| Nitrogen dioxide (NO₂)        | µg/m³| 2013 | 39 | 40 | 42 | 44 | 40 | 32 | 32 | 37 | 33 | 46 | 41 | 32 |
|                               |      | 2014 | 34 | 52 | 45 | 40 | 30 | 31 | 35 | 32 | 40 | 38 | 32 | 32 |
| Carbon monoxide (CO) (average 8h) | mg/m³ | 2013 | 1.98 | 3.46 | 2.87 | 2.97 | 1.44 | 1.16 | 0.95 | 1.22 | 2.53 | 2.49 | 2.65 | 4.88 |
|                               |      | 2014 | 1.81 | 3.92 | 3.41 | 2.11 | 1.60 | 0.86 | 0.84 | 0.87 | 1.09 | 2.29 | 1.41 | 2.83 |
| Nitrogen oxides (NOₓ)         | µg/m³| 2013 | 80 | 89 | 89 | 91 | 89 | 62 | 62 | 63 | 76 | 132 | 90 | 99 |
|                               |      | 2014 | 89 | 181 | 125 | 99 | 150 | 65 | 61 | 58 | 87 | 140 | 125 | 101 |
Deterioration of air quality in the area of large urban areas – including Czestochowa city – primarily is due to the contamination from the transport sector. A significant share of road transport in the air pollution has several causes: a dynamic growth in the number of vehicles, poor technical condition and age of vehicles, lack of road infrastructure. At the end of 2012 there were up to 453 cars per 1000 inhabitants of Czestochowa, in 2013 – 467, and at the end of 2014 - already 479 (Statystyczne, 2015). Czestochowa is the largest city in Poland, which has no ring road. The transit takes place primarily by Wojska Polskiego Avenue (National Road No. 1), followed by the sequence of Jana Pawla II – Szajnowicza - Iwanowa – Okulickiego streets (transit towards Opole and Wielun).

In terms of linear emissions reduction in Czestochowa, the following ideas are postulated (Strategia Rozw. Wojew.):

- Directing the transit traffic in the north – south axis to the ring road (A1). According to the assessments, it will limit the intensity of transit traffic through the city centre by approximately 60% of heavy trucks, and by approximately 30% of passenger cars;
- Improving transit through the city in the east – west axis, in the perspective the construction of the southern ring road in the framework of the Staropolski Route;
- Development of public transport, including construction of new tram lines;
- Replacement of public buses with vehicles meeting the Euro IV standards;
- Introduction of intelligent traffic management systems;
- Promoting the use of electric cars (1,000 charging points planned in 2012-2020).

In the analysed period, only particulate matter exceeded the norm established at 40 mg/m³, and nitrogen dioxide was close to exceeding the standards, for which the standard concentration in the air is also 40 ug/m³. The station at Armii Krajowej Avenue is located at the junction of the main transit routes, hence the high concentration of these chemicals.

### 3. Program of low-stack emissions reduction for Czestochowa city

A coherent energy policy is one of the priorities in the proper economic development of Czestochowa. Environmental objectives of Czestochowa city regarding air quality improvement are consistent with the long-term objectives of the Silesia Region (“Program for Silesia Region Environmental Protection to 2004 and long-term targets to 2015”, “Development Strategy of Silesia Region in the years 2000-2015”) and assumptions of the European Union energy policy determined at a glance as 3x20 by 2020 year.

A coordinated, multifaceted plan of activities for effective use of energy and popularization of this subject generates significant savings to the municipality, shapes the ecological awareness of residents and gains the recognition of specialists.

The methodology used in this paper is the case study method. It characterizes the successive stages of the investment project carried out in 2008-2010 on the basis of the “Program of low-stack emissions reduction for the Dzbow district in Czestochowa”. On its basis, 39 multi-apartment buildings have been modernized, including a total of 610 apartments and the municipal kindergarten building. The paper also characterizes the program “Grant from Czestochowa city for the tasks under the program to limit the low-stack emissions for Czestochowa city, based on modernization of the heating systems in buildings and apartments throughout Czestochowa city, implemented by individuals”. The characteristics are taking into account the number and amount of grants for the heating systems modernization and solar collectors installation in buildings and residential premises in Czestochowa city, carried out by individuals.

Czestochowa is taking actions to improve energy efficiency by implementing thermo-modernization and replacement of equipment with modern one equipped with energy saving functions, improving the energy efficiency...
by increasing the efficiency of electricity generation, increasing the share of electricity produced in the cogeneration process, development and modernization of transmission and distribution systems with the basic premise to reduce losses, and increasing the use of renewable energy sources.

Replacing low-efficient heat sources is the most energy-efficient activity in the municipal economy at a relatively low cost. The use of more efficient equipment helps to reduce the consumption of energy contained in the fuel, but often this decrease can be compensated (or even exceed) the increase in heating costs during the transition from coal to more environmentally friendly, but more expensive sources of energy (gas or electricity).

One of the examples of activities taken in Czestochowa in this area is the low-stack emissions reduction program for the Dzbow district. This investment task was executed in 2008-2010 based on the “Program of low-stack emissions reduction for the Dzbow district in Czestochowa” adopted by the City Council of Czestochowa. They have upgraded the 39 apartment houses with a total of 610 housing units and the building of the municipal kindergarten. These buildings were erected in the years 1950 - 1958, and almost 90% of them in 1950-55, which means that they are occupied by older people for whom using coal was a big nuisance, so this investment also had a big social and sociological effect.

Heating the buildings involved in the “Program” was connected with the issue of air pollution: dust, sulphur dioxide, carbon dioxide and carbon monoxide, nitrogen oxides and benzo-α-pyrene. In order to determine the emissions of pollutants, the current structure of the existing heating and quantities of fuels used for heating purposes for individual houses could be set. Apartments were heated with coal-fuelled tile stoves, boilers, coal and liquefied petroleum gas (LPG) fuelled central heating systems and other methods involving different energy source used at home (mostly electric storage heaters).

Collectively, according to the calculations made for standard conditions, in homes heated with coal (coal-fuelled stoves and central heating systems) approx. 2,453 tonnes of coal were used annually, in houses equipped with gas (LPG) central heating systems - approx. 50,000 litres of gas, and in homes with electric storage heaters - approx. 234 MWh of electricity. In addition to the construction technology and the efficiency of the heat sources, energy consumption in buildings was influenced by many other factors, including the type of fuel used, the efficiency of the internal systems, and different heating needs of users as well as skilful energy management. The highest energy consumption was characteristic to objects powered with solid fuels, which resulted primarily from the limited ability to continually adjust the amount of fuel burnt and the relatively low price compared to natural gas and liquid fuels. Emissions associated with the combustion of solid fuels mainly in stoves in the Dzbow district accounted for a high share of total emissions of carbon fuels (individual heating and stoves from 1 to 10%) and total emissions (renewable energy) for the whole district (0.2%-3 7%).

For all 39 buildings included in the “Program”, the energy costs analyses were made i.e. the demand for power and heat was calculated. The real demand for heat in the fuel and economic indicators calculated taking into account the efficiency of individual heating systems in the existing and targeted states, adopting the following assumptions:

- discount rate of 5%;
- investment lifetime of 20 years;
- design temperature in the apartments: 20°C.

Calculations of energy costs - analysis included the introduction of the following measures:

- insulation of external walls - 14 cm layer of Styrofoam;
- replacement of windows in the apartments and stairwells with energy-efficient windows $U = 1.6 \text{ W} / \text{ m}^2 \text{K}$ ($U_{\text{glass for windows}} = 1.1 \text{ W} / \text{ m}^2 \text{K}$);
- replacement of external door of staircases with door $U = 1.6 \text{ W} / \text{ m}^2 \text{K}$;
- insulating basement ceilings with 10 cm layer of Styrofoam;
- insulation of attic roof slants with 20 cm of mineral wool;
- providing the internal heating systems with thermostatic valves (in the case of coal-fired stoves and electric heating);
- installation of the chimney system.
Central heating system variant has been selected based on the concept of economic and technical modernization of residential heating system at Dzbow in Częstochowa according to its cost competitiveness. With a view to achieving the objectives of 3x20 by 2020, Częstochowa city has measured and achieved the following environmental effects in buildings covered by the program:

- reduction of SO₂ by 81%;
- reduction of NO₂ by 80%;
- reduction of CO by 85%;
- reduction of CO₂ by 82.5%;
- reduction of dust by 85.5%.

As a result of actions taken in Dzbow district, there was a 2.2% decrease of CO₂ emitted into the atmosphere in the whole city.

The whole task was implemented in 3 stages.

1st stage
The first stage was implemented between October 2008 - June 2009. The cost of the first stage was PLN 5,476,465.17 including: a loan from WFOŚiGW PLN 2,716,041 and own resources PLN 2,760,424.17.

In the first stage, 13 residential buildings were modernized, i.e. Drzymaly Street 1, 3, 5, 6, 8, 10; Rydla Street 1, 2, 3; Czajkowskiego Street 1, 2, 4, 6; all with a total of 274 housing units.

2nd stage
The second stage was implemented between August 2009 - April 2010. The cost of the second stage was PLN 4,911,893.45 including: a loan from WFOŚiGW PLN 2,179,787.77 and own resources PLN 2,732,105.63.

In the second stage, 12 residential buildings were modernized, i.e. Drzymaly Street 2, 4; Rydla Street 4, 5, 6, 7, 8; Wopistow Street 8, 10, 13, 15; Plac Walecznych 1; all with a total of 247 housing units.

3rd stage
The third stage was implemented between August 2010 – November 2010. The cost of the third stage was PLN 2,826,858.01 including: a loan from WFOŚiGW PLN 1,896,918.98, own resources PLN 744,462.96, and a cost of the municipal kindergarten PLN 185,476.07.

In the third stage, 14 residential buildings were modernized, i.e. Wopistow Street 1, 2, 3, 4, 5, 6, 7, 9, 11; Rydla Street 9, 11; Kopaliniana Street 14, 16, 18; all with a total of 100 housing units, and Czajkowskiego Street 3 with the municipal kindergarten.

The total cost of this task was: PLN 13,215,216.63.

The implementation of the project reduced emissions of harmful compounds into the atmosphere while reducing solid waste i.e. the ashes. This resulted in a significant reduction of environmental degradation, improved the quality of life of Dzbow residents, and consequently raised its attractiveness.

Subsequent actions taken by Częstochowa city to reduce low-stack emissions included the program “Grant from Częstochowa city for the tasks under the program to limit the low-stack emissions for Częstochowa city, based on modernization of the heating systems in buildings and apartments throughout Częstochowa city, implemented by individuals”. Additional resources are subject to upgrades involving installation and elimination of the heat sources (boilers) that are old-style, coal or coke fuelled, and replacing them by:

- connecting to the central heating network,
- electric heating,
gas boiler, oil boiler,
the retort boiler (with auto sampler) with an efficiency of at least 80% , with certification (valid certificate certifying the environmental conditions of combustion in the boiler type). The certificate must be issued by an institution having the certificate of the Polish Centre for Testing and Certification.

and upgrades involving dismantling and removal of coal-fuelled heat sources (boilers) and replacing them by:

- connecting to the central heating network,
- the electric heating,
- gas boiler,
- oil boiler.

The grant amount is 50% of the costs incurred by the applicant for the connection to the district heating system or buying a new energy source - a boiler (excluding the cost of the design and installation), but not more than PLN 1000.00. The number of grants awarded and their total amount are presented in Table 5.

Table 5. Number and amount of grants for the modernization of heating systems in buildings and housing units in Czestochowa city carried out by individuals (own elaboration based on data shared by Czestochowa city).

| Year | Kind of grant | Number of grants | Amount of grants in PLN |
|------|---------------|------------------|-------------------------|
| 2004 | GFOŚiGW       | 63               | 62 775.00               |
| 2005 | PFOŚiGW       | 157              | 146 144.00              |
| 2006 | PFOŚiGW       | 245              | 239 636.00              |
| 2007 | PFOŚiGW       | 158              | 156 264.00              |
| 2008 | GFOŚiGW       | 129              | 128 517.00              |
| 2009 | GFOŚiGW       | 104              | 103 581.00              |
| 2010 | -             | -                | -                       |
| 2011 | Budget        | 43               | 42 994.00               |
| 2012 | Budget        | 49               | 48 934.00               |
| 2013 | Budget        | 61               | 60 865.50               |
| 2014 | Budget        | 57               | 56 790.50               |
| 2015 | Budget        | 46               | 70 000.00               |
| Total|               | 1112             | 1 116 501.00            |

Subsequent tasks resulting from the Program of reducing low-stack emissions in Czestochowa city rely on the installation of solar collectors supporting the heating systems or used for the production of hot water in buildings and apartments. The amount of the subsidy amounts to 50% of the costs incurred by the applicant for the purchase and installation of solar panels (excluding the cost of the design), but not more than PLN 2000. In the years 2009-2015 100 such grants were awarded totalling PLN 176,586 (Table 6).

Table 6. Number and amount of grants for installation of solar collectors on buildings and housing units in Czestochowa city, carried out by individuals (own elaboration based on data shared by Czestochowa city).

| Year | Kind of grant | Number of grants | Amount of grants in PLN |
|------|---------------|------------------|-------------------------|
| 2009 | GFOŚiGW       | 25               | 49 342.00               |
| 2010 | -             | -                | -                       |
| 2011 | Budget        | 9                | 17 244.00               |
| 2012 | Budget        | 6                | 6 000.00                |
| 2013 | Budget        | 28               | 56 000.00               |
| 2014 | Budget        | 24               | 48 000.00               |
| 2015 | Budget        | 8                | 16 000.00               |
| Total|               | 100              | 176 586.00              |
Warsaw and Czestochowa stand out compared to other Polish cities in terms of efforts taken to improve air quality - that is concluded in the prestigious report by international NGO CDP (Carbon Disclosure Project).

The report “Businesses and cities for low-carbon economy in the region of Central and Eastern Europe” (Companies, 2015), collected data from more than 300 cities. It shows that local governments can have a significant impact on the construction of a low carbon economy in two ways - by reducing carbon dioxide emissions and investment in energy-efficient solutions. In this regard, CDP appreciated two Polish cities - Warsaw and Czestochowa. These are the local leaders that excel in comparison to other cities in the country in a bid to reduce emissions.

It is the result of 10 years of Czestochowa’s local government’s efforts to promote energy efficiency and low emission economy. So, among others, thermos-modernisation, putting savings in the consumption of utilities in public and subsidiaries of the municipality, a new connection to the district heating network, development of the natural gas supply network in the city, the purchase of hybrid buses and replacement by residents of 1109 old coal-fired boilers for ecological heat sources and installation of 100 sets of solar collectors - and that with the help of municipal grants.

Environmental policy of the City also brings benefits to the budget. Since 2009, Czestochowa has been benefiting from the free electricity market. And that translates into its finances, as a result of changing the energy supplier the City saved up to PLN 21.3 million in 2009 - 2015. In 2016 the estimated savings in this respect will amount to approx. PLN 5.8 million.

Concrete profits have also brought the so-called white certificates. Czestochowa, in cooperation with Tauron, provided energy-saving lighting fixtures and reduced the power consumption. As a result of the tender announced by the President of the Energy Regulatory Office, it received a certificate of energy efficiency, the white certificate. In August 2015 as the first local government, Czestochowa finalized the sale at the Power Exchange yielding an income of PLN 660 000 respectively.

The report underlined the merits of Czestochowa in the field of cooperation with business within the area of low emission economy. As an example shown in co-operation with Fortum, five years ago the company launched a modern and environmentally friendly power plant that uses biomass.

Over these five years, the emissions were limited by over 625,000 tonnes of carbon dioxide. Also, emissions of other pollutants were reduced, dust - more than ten times, and sulphur dioxide - over seven times. In 2015 Fortum, which is also the owner of Czestochowa’s heating network, invested approx. PLN 6.5 million in its expansion and modernization, including in the heating network the area of the Old Town with Katedralna, Krakowska and Strazacka Streets, which is a densely built area and the largest source of low-stack emissions in the city.

4. Conclusions

The possibility of reducing low-stack emissions depend on local, social and economic conditions. Reducing the amount of pollutants emitted from the municipal sector, resulting in improved air quality, cleaner environment and reduced risks to human health requires multi-directional technical and non-technical activities. The technical methods include:

- reduction of heat demand of residential buildings by thermo-modernization and thermo- regeneration;
- use of existing district central heating networks;
- construction of local boilers for houses and blocks of flats;
- fuel substitution - replacing coal with gas, use of renewable energy sources (RES), development of distributed energy;
- replacement of old, inefficient heating appliances burning solid fuels - coal, biomass combustion installations to meet the requirements of BAT (Best Available Technology), high-performance energy-efficient and environmentally-powered, qualified solid fuels;
- use of smokeless, low-carbon fuels.

At the same time it is necessary to initiate and implement some non-technical methods, including introduction of:

- mandatory standards for emissions from solid fuel combustion facilities with a capacity of less than 1MW;
- quality requirements for qualified solid fuels for the municipal sector, to control and monitor their quality;
uniform nationwide system of state control of low-power combustion facilities in the municipal and household sector, using the service currently chimney, city guards;

- nationwide financial incentive scheme, providing grants for replacement of traditional, outdated heating appliances with high-performance boilers that meet the appropriate criteria for voluntary commitments by energy and emission areas preventing connection to district heating and natural gas networks;

- continuous widely understood education in the application of good practices in the production of useful heat in individual households.

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