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Solutions maximizing environmental, social and economic effects governing the combustion of solid fuels in individual energy source used by households in Poland

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Abstract. The effect of smog is one of the most important environmental problems in Poland today. According to a research [1], the main source of this situation is low-stack emissions. It is primarily responsible for the appearance of suspended dust and benzo(a)pyrene in the air. In the last few years, a broad social campaign was launched in Poland, followed by a legislative action to significantly reduce the problem of low-stack emissions and, in consequence, smog. These measures are based mainly on the CAFE Directive [2], the Environmental Protection Act [3] and the National Air Protection Program [4]. As a result, there are now so-called mass-produced in Poland: anti-smog resolutions and Low-Stack Emission Reduction Programs (PONE). In this article, author presented the results of simulating the impact of these decisions on environmental (level of reduction of suspended particulate matter and benzo(a)pyrene), but also social aspects (decrease in employment in mining and related industries) and their economic consequences (related general economic). Selected documents concerning the limitations and changes in the range of used furnaces and types of fuels by the households, analytical data from Polish Central Statistical Office (GUS) (including Local Data Bank (BDL) of the Polish Central Statistical Office) [5] and own calculations are the base for this analysis. On the basis of the obtained results, in the final part of the work, author proposed the method of elimination of low-stack emission, which will take into account the environmental, social and, consequently, economic aspects.

1. Introduction

Recent years are the time of dynamic growth of ecological awareness in Poland. It is moving into the implementation of many legislative acts that tighten environmental standards. This situation is also observed in the air quality aspect, in which the smog and low-stack emission are one of the most frequently discussed problems. It seeks to create and implement legislation that will help to reduce this pollution. The above aspects are relevant, to protect the health, and even the life of the inhabitants of the affected area. On the other hand, the fact of a skilful, comprehensive look at environmental issues is extremely important. It should, on the one hand, allow to reduce smog effect. On the other hand, however, the social danger in the mining industry shall be kept at lowest possible level. The industry is often incorrectly judged as main responsible for combustion emission. This work is an attempt for an objective view on at these aspects.



2. Role of the consistent fuels in the process of air pollution

As Sadlok and others point out [6], low-stack emission is an emission on a low amount of noxious dusts PM10 and PM2.5 and gases. It classifies emitters (chimneys and other emission sources) that are of a height no more than 40 m. Because of this process these dusts and gases create the smog effect that is created from these elements.

The most negative aspect of smog is its bad influence on a human's organism [6].

For the subject matter taken at the work findings of pollutants conducted by the Ministry of the Environment in the national program of the environmental protection, but concerning the reduction of air are very important from emitters of so-called low emission in Poland in 1988-2014 years. They are shown on figure 1.

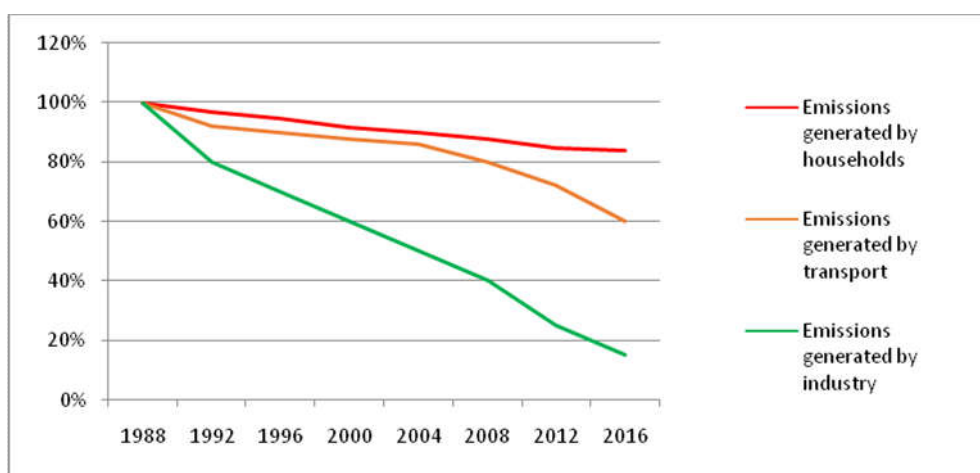


Figure 1. Reduction of air pollution from the range of so-called low emission in Poland in 1988-2014 divided into industry, transport and communal sector (1988 occurs as a base = 100%) [1].

Analysis of the data in figure 1 indicates that, in the case of industrial and transport emissions, over 80% of pollution reductions in the case of low emissions from industrial emitters and 40% in transport have occurred in the last 25 years. In the case of low-stack emissions from communal sector are still at a similar level. It is not surprising that this challenge has emerged as the main objective, strategy and action plan, both national and regional and even local.

One of the sources of low-stack emission in its part related to the communal sector is hard coal. It points to this issue, for example, a report published in March 2015 by the Ministry of the Environment within the framework of the National Program for Environmental Protection [7], the most interesting opinion of the author concerning solid fuels used for individual heating of buildings is shown on figures 2 and 3. From these data it is clear, that responsible for the generation of low-stack emission in Polish cities are the individual heating of buildings. If this fact is to be combined even in a simple, direct manner with the generalized structure of the sources of heating of buildings in the gas, liquid and solid sources, it is clear that the main responsible for the low-stack emission are solid fuels in which coal is undoubtedly found.

3. Legal norms in Poland that aim to limit smog

In Poland, the European Parliament Directive and Council 2008/50/WE from 21th May 2008 is the legal basis for actions aimed at reducing low-stack emissions and regarding to air quality and cleaner air for Europe (CAFE) [2] and earlier law from 27th of April 2001 r. Environmental Law with changes [3]. According to §91 of this law, it is required to elaborate an air protection program for zones, where the acceptable or target level of any substance has been transgressed, among specified in the ordinance the Ministry of Environment from the 3rd of May 2008, regarding to the case of the levels of certain

substances in the air [4]. Among them, we can find indicated above dusts PM₁₀ i PM_{2.5} and benzo(a)pyrene.

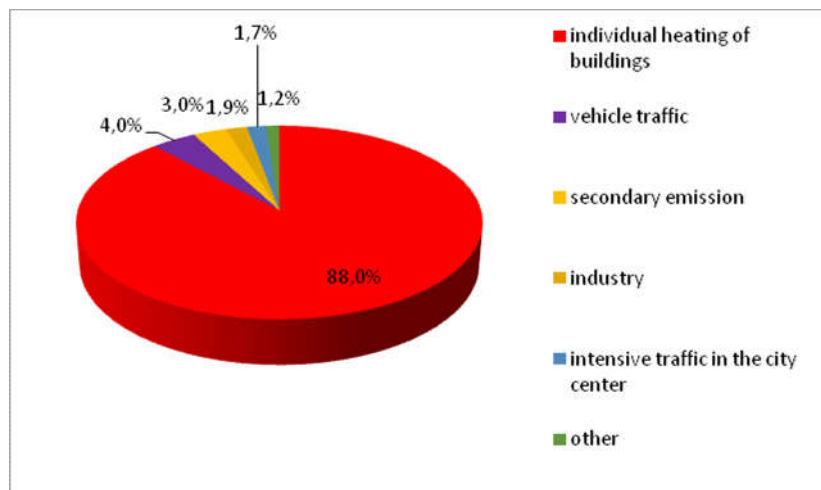


Figure 2. The participation of sources responsible for transgression of acceptable level of the PM₁₀ dust in Poland.

Source: Own development, based on [4].

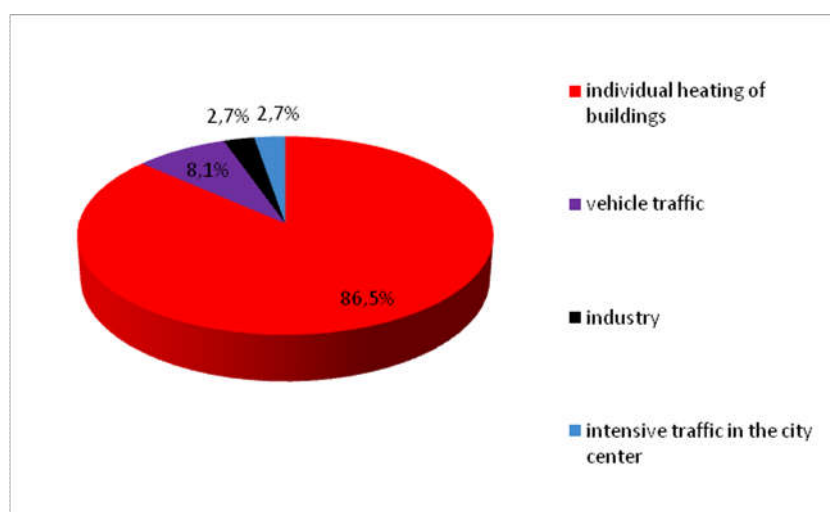


Figure 3. The participation of sources responsible for transgression of acceptable level of the PM_{2.5} dust in Poland.

Source: Own development, based on [4].

EU directive shown constitutes, that plans of such air protection, in case of transgressing the acceptable amounts, have to specify the suitable actions to make the period when they are not being met as short as possible.

The air quality controls in a zone are being done by the Provincial Inspector for Environmental Protection, based on the air quality monitoring. For example, being qualified to class C (in the classification from A to D2, where class A means no permissible contamination exceedances, class B no exceedances of the permissible level with an added margin of tolerance and in classes C, D1 and D2 significant exceedances of these limits [4]) means that is necessary to elaborate an air protection program for this terrain. The air protection program aims for pointing out

the direction of corrective actions that will make it easier to achieve the target or acceptable level. In addition to the CAFE Directive and the Environmental Protection Law, the air protection programs have to include the fulfillment of obligations arising from the [6]:

- Kyoto Protocol from 15th July 1998,
- 2002/91/EC Directive from the 16th of December 2002 on the energy performance of buildings,
- European Parliament Directive and Council 004/107/WE from 15th of December 2014 in case of arsenic, cadmium, mercury, nickel and polycyclic aromatic carbohydrates in ambient air.

The Low-Stack Emission Reduction Program (LERR) is one of the most important, obligatory corrective actions within the air protection program related to the cities and communities, where the low-stack emission problem exists. The Low-Stack Emission Reduction Program aims mostly for air quality correction, the inhabitants' health and life quality correction, especially children and sick people, the most vulnerable to impure air. In turn, the basis of creating the Low-Stack Emission Reduction Programs are both air protection programs and environmental programs. Practically, the voivodeship management develops air protection programs for zones, where the transgression of target and acceptable levels has been surpassed. Next, the provincial council accepts the program as a resolution that constitutes an act of local law.

The basic document for the essential construction PONE is the "Energy, Safety and Environment' Strategy - perspective until 2020" [7]. In its detail target number 3.3 designated in the area of the communal-based sector (so individual customers) activities that serve to limit the role of constant fuels in heating the flats, doing this in this document for example by:

- eliminating the coal fuel as a furnace power source in terms of so-called ecoprojects for energy-related products (conditions of Directive of the European Parliament and of the Council 2009/125/EC of 21th of October 2009, establishing a general framework for the setting of ecodesign requirements for energy related products),
- legislative changes enabling the promotion, control and enforcement of low-stack emission reduction measures, in particular the possibility of the voivodeships adoption of resolutions on the acceptable mode and type of fuels used,-
- prohibition of the sale to individual consumers of waste generated by mining coal, which are often building fired by.

The indications above have been elaborated in terms of actions in the "National Air Protection Program" until 2020 [4].

How the portal „Dziękuję, nie truję" points out, there are currently 87 PONE air protection programs in Poland, in which the corrective action has been predicted for the years 2015-2020 [8]. All of them contain the shown above records about significant limitation of hard coal combustion to heat homes to 2020. In the most peculiar situations, PONE was planned to eliminate coal as a heating fuel in the municipality. The most well-known and representative thing is that at September 2019, the coal burning in the municipality of Kraków is going to be banned.

4. Influence of initiated legal norms of limiting smog per sector of coal

4.1. Present role of individual customers for mining companies

Situation pointed out in chapters 2 and 3 has got fundamental meaning for mining company. The main determinant for this argument is the big weight of individual customers in its wallet. This issue is shown on figures 4 and 5.

On the figure 4 we can see, that the category of households has been located on the second place in respect of the volume of sales in the comparison of mining companies' client groups from the Polish mining sector, consuming 17% of its production. Treating this issue with value, what has been shown on figure 5, the participation of the individual customers' segment on the Polish coal market is even bigger, increasing to 23%. The difference between the amounts from figures 4 and 5 is due to the fact, that there are bigger sale prices in this segment, than in remaining segments, that causes a possibility for the mining companies to generate a higher profit margin than in the other market parts.

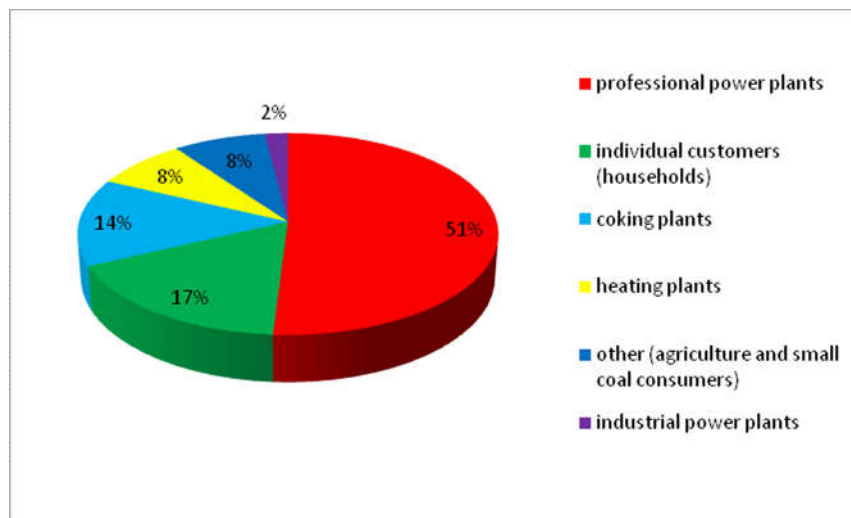


Figure 4. Quantitative structure of Polish coal consumers in the year 2015 [%].
Source: Own development, based on [9].

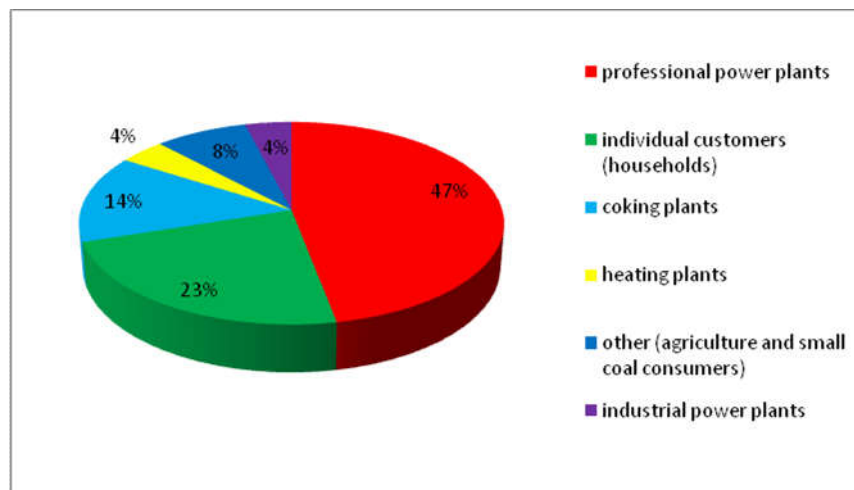


Figure 5. Qualitative structure of Polish coal consumers in the year 2015 [%].
Source: Own development, based on [9].

4.2. Simulations of the impact of legal changes on the hard coal mining sector

By combining the importance of the individual customer segment for a mining company presented in section 4.1., with the low-stack emission legal norms set forth in chapter 3, and the issues referred to the role of solid fuels in the formation of smog, showed in chapter 2, it is easy to come to the author's view, to an interesting conclusion about the fundamental economic and social character. It is a matter of future changes in the level of sales of individual coal types to the consumer segment. This will have a major impact on the level of production, and even the financial situation of mining companies. To demonstrate below, the impact of possible modifications to legislation on low-stack emissions reduction and consumption of solid fuels has been simulated.

Firstly the level of smog pollutants in Poland was checked, indicating where the levels of permissible levels were exceeded. The results of research conducted by the Chief Inspectorate for Environmental Protection, made available on air portal gios.gov.pl [10], were used for this purpose.

On the basis of the collected data concerning average value in 2015, the sites of PM_{2.5}, PM₁₀ and benzo(a)pyrene breakdowns were found in particular parts of Poland in this time. This allowed us to pinpoint the most likely places for PONE introduction in the near future. These areas show the map shown on figure 6. They were presented there as red and brown spots. Visible is their accumulation mainly in the Śląskie, Małopolskie, Łódzkie and Mazowieckie voivodeships (figure 6). These voivodeships were determined to indicate potential forbidding the use of solid fuels in the near future. It is worth pointing out that in some of these regions, such as in Krakow, these bans have already been announced and are currently under preparation for their implementation and enforcement.

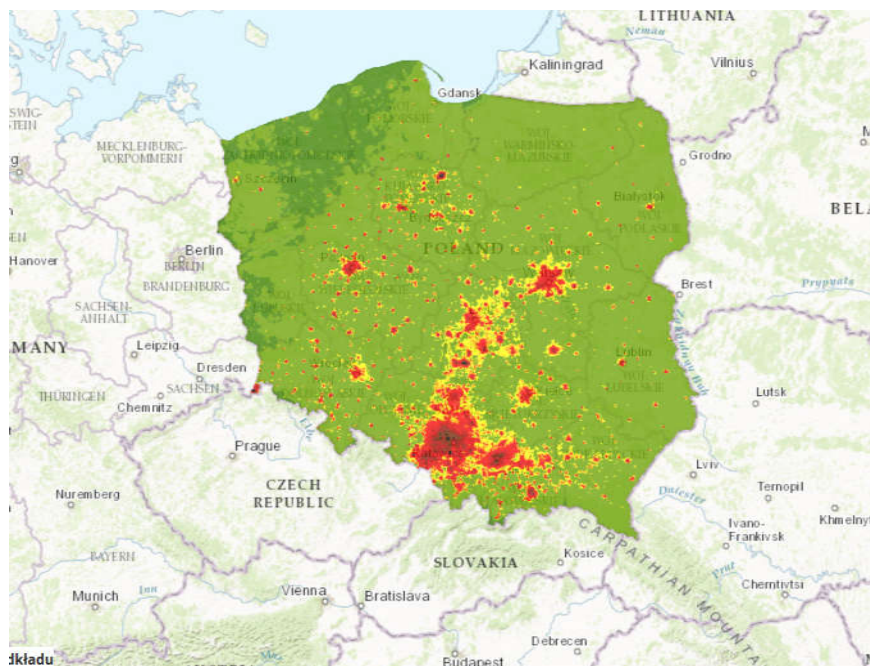


Figure 6. Concentration levels of PM_{2.5} and PM₁₀ and benzo(a)pyrene in Poland in 2015.

Source: Own development, based on [10].

The next stage of work was to compile for these areas the levels of solid fuel consumption. In this case the author used his calculations of market capacities, based on the calculation of the number of solid fuel furnaces in a given area, multiplied by the annual hard coal consumption index of such equipment in that area. The number of furnaces was determined using the data collected by the Polish Central Statistical Office (GUS) in the Local Data Bank (BDL). Secondary sources were taken into account. The levels of annual hard coal consumption were determined in the course of a nationwide survey conducted by the author on a group of 1500 households in the autumn of 2016. The limited volume of this work does not allow to present the details of assumptions as well as the methodology of the above calculations. For this purpose the author invites others to his work, primarily to [11] and [12]. Due to the key aspect for the results shown below, the qualitative and quantitative aspects of fuels contained in solid fuels are the important elements of the above-mentioned work (the most important are coal with 41,16% and wood with 40,51%). Secondly, it was an algorithm to find the equivalent of wood expressed in hard coal.

The calculations allowed to determine the annual hard coal quantitative levels consumed in these regions. They are shown in table 1. It follows that the above four voivodeships with the highest emissions indicated above represent a total of 43,4% of the capacity of the Polish market. They are crucial for the market. These values are associated with 9,1 million Mg equivalent of coal consumed annually. In the event of a possible ban on the burning of solid fuels, this amount will be diminished in direct sales and mining production. It represents an annual production of four mines in Upper Silesia,

or exceeds the annual production of LW Bogdanka mine. Even if you treat 41,16% more of this amount directly with hard coal, then the result is 3,75 million Mg of hard coal. This is the annual production of two hard coal mines in Upper Silesia.

Table 1. Values of the market capacity ratio in selected voivodeships [Mg / year], with their share in Poland [%].

Voivodeship	Market capacity ratio	Percent of Poland capacity
Łódzkie	1 481 177.69	7.06
Małopolskie	1 703 590.96	8.12
Mazowieckie	3 254 814.20	15.51
Śląskie	2 666 168.23	12.71
Sum	9 105 751.08	43.4

Source: Own development

If you transfer the above values to the social aspect, then by combining it with the question of the number of workers employed in the hard coal mines, even the quick estimates go to the first question about the loss of employment of about 8-9 thousand people, and in the second type of calculation for about 3- 4 thousand employees less.

To summarize the results of the above calculations, it should be noted that they point to the multifacetedness and within them the high importance of the analyzed issues. On the one hand there is a undeniable positive ecological effect, and on the other, its possible achievement will be associated with a negative large scale social effect. In trying to find the best solution, author decided to propose solutions whose implementation would achieve a satisfactory low-stack emission reduction, but not lead to a negative result related to the reduction of employment in mining plants. The last chapter of this article concerns this issue.

5. Proposition for significant in low-stack emissions simultaneously reducing negative changes in the hard coal mining sector

As shown above, the PONE proposals tend to completely eliminate the use of solid fuels as a source of heating for the households or to significantly tighten their eligibility. According to the author, there are no good solutions and on this basis he decided to give his proposals for changes.

On the social dangers associated with the potential for possible liquidation of solid fuels, author discussed in the previous chapter. Next to them, one must also not forget about the impact these decisions would have on the demand for other types of fuel. Undoubtedly, the first of the fuels for which consumption would increase would be natural gas. The first obstacle to such a free growth would undoubtedly be the fact that there are considerable shortcomings in the final delivery part of the transmission grid. Technically, this issue is a major problem in expanding the sales of natural gas in Poland on an even larger scale. Bringing a gas network into many places is completely unjustified economically. The second danger lies in the import character of this product. Only in 1/3 Poland provides itself with the supply of this fuel from its own sources. There is therefore a risk of increased dependency on the external producers of this product

Apart from natural gas, author does not see the current state of the art and the raw materials of another, which could compete in Poland on a large scale with solid fuels. Today, there is no such possibility of renewable energy sources, although here it seems that in the future it will be possible.

Some approved PONE do not prohibit the full use of solid fuels, as shown by the author's observations the possibility of firing in the 5th generation furnace, so in retort furnaces. These are actually very modern furnaces with screw feeders. However, their assumption in the scope of the

charge is, however, that the fuel is of the type of peas or has, with appropriate quality parameters, with a calorific value of about 25000kJ/kg and low TSP and OGC dusts and NO_x contents. The main problem of this type of fuel is the limited supply capacity, mainly related to the small capacity and the level of exploitation of the corresponding hard coal. Author estimates the production capacity of this fuel in Poland at a maximum of 1 million Mg per year. In relation to the numbers referred to in the previous chapter, this is an amount 9 times too small.

In the light of the above facts, there are doubts as to the possibility of addressing the challenges of rational combat with low-stack emissions. According to the author, the following proposals may allow for sustainable operation in the aforementioned issues:

- enough in terms of effectiveness in the fight against low-stack emissions should include prohibition to use fuels outside the classification (flotoconcentrates, muds and lignite) into the PONE, while exacerbating the control and penalties for the using of these fuels, as well as "fuels" already banned, for example rubbish. As the research of the Institute of Chemical Processing of Coal [13] shows, the combustion of this type of fuel results in high particulate emissions, mainly due to the very low quality of these fuels and the largest share of carbonaceous particles in them. Coal, even if it is in fine form, has these particles even several times less than mud, flotoconcentrate and lignite,
- implement into the PONE prohibition of using the lower category furnaces than 3rd category. The implementation of this type of proposal will eliminate the weakest and oldest 1 and 2 generation furnaces operating in the feeder technology, but above all the badly-suited for the construction of the combustion chamber. Leaving the 3 and higher furnace market on the market will allow us to benefit from a wide range of hard coal and therefore will not lead to the above-mentioned lack of fuel on the market,
- implement into the PONE, followed by a comprehensive promotional campaign, the technology of high emitting in the furnaces "from the top". This technology, which consists in firing the furnace from the top, gives the possibility of burning solid particles in the furnace chamber, which, when burned from the bottom, first releases more in the coal heating process (the first subprocess in the furnace combustion) and then emit into the atmosphere, not being burned up due to the lack of sufficiently high temperature in the upper part of the combustion chamber. The experience presented on czysteogrzewanie.pl [14] shows that coal fired in burner boilers, but in from the top technology generates dust levels and benzo(a)pyrene in the exhaust, fully within the environmental norms.

According to the author, these three solutions implemented in PONE and implemented by these programs provide the opportunity to achieve the essential goal of significant, expected reduction of air pollution by PM_{2,5}, PM₁₀ and benzo (a) pyrene. The second, however, not less effect of these actions will be maintaining a good balance in the hard coal production in Poland, along with the maintenance of jobs in Polish hard coal mines.

In addition to the efforts to optimize the use of solid fuels in local ovens, as developed countries, it is necessary to strive to further develop the network infrastructure associated with the development of small municipal or municipal heating plants.

6. Conclusions

Among many aspects of improving the quality of life in Poland, attention is increasingly paid to the quality of the environment. One of its essential elements is air, and in its scope improves its purity. As shown in the first part of the article, smog is one of the most important issues in maintaining its proper level. Its main cause is the low-stack emission, which in 85% is achieved by heating the buildings using local furnaces and ovens. In their case, the responsibility is largely to be attributed to solid fuels.

Due to the above observations, it is not surprising that the main way of fighting smog became the basis of air protection programs called Low-Stack Emission Reduction Programs (PONE). In their framework most often came restrictions or prohibition of solid fuels use.

If link the above-mentioned directions to the development of the legislation with the situation of the hard coal producer, it may be noted that the implementation of further PONE can affect its production very negatively, reducing it. Of course, this will have a negative impact on the employment of such establishments. Taking into account only the introduction of rigorous PONE records in the four voivodeships with the highest levels of smog, this could reduce the production and sales of hard coal from 3,75 to over 9 million Mg per year. This is the production of several mines, and above all the work for several thousand people.

Accordingly, in the opinion of the author, Poland cannot allow to completely eliminate the smog in its part connected with the burning of solid fuels using only the existing instruments. Therefore, it was proposed to introduce three types of changes to the PONE, the implementation of which would, on the one hand, significantly reduce the smog, but on the other it would protect the hard coal mining sector from a significant reduction, which would give the enterprises the greatest economic benefits. These are the first to prohibit smoking with fuels outside the classification, secondly to prohibit the use of lower category furnaces than 3 category and thirdly to introduce the principle of smoking "from the top".

Author is aware that this article does not constitute a sufficient set of actions in the fight against smog. It is certain, however, that in this fight it can help, by doing so with a sense of responsibility in hard coal producers. These issues will continue in subsequent works.

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