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Original Research

Assessing Efforts to Mitigate Particulate Matter Air Pollution in the Moravian-Silesian Region

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Abstract

The Moravian-Silesian Region suffers from bad air quality, and air pollution levels even exceeding health limits. The national and local authorities are striving to solve this adverse situation in cooperation with the responsible bodies. Significant amounts of resources have been allocated to various interventions in the region. This article provides the results of a multi-criteria analysis that evaluates sets of various measures to mitigate air pollution in the region. Multiple criteria, including cost-effectiveness evaluation, uncertainty about both the information on the contribution of the respective sub-sectors to local pollution, and the actual long-term effects of the measures were applied in the analysis. The results suggest that implementation of best available technologies, energy-efficiency improvements, and road transportation management are to be the best measures in terms of efficient air quality improvement. Smog mitigation and fuel change represents medium-efficiency solutions. Closing of plants, end-of-pipe solutions, and imports of intermediate products are among the least-efficient measures.

Keywords: environmental policy, air pollution, policy assessment, particulate matter (PM)

Introduction

Significant progress has been achieved in solving the air pollution problem in the Czech Republic (CR) since the 1980s. However, the Moravian-Silesian Region (5.427 km^2, 1.25 million inhabitants, home of the third largest city in the country), still suffers – particularly due to its geographical conditions (location in a large basin bordered by mountains in the west, east, and partially south), climatic conditions (frequent temperature inversions in winter), the structure of its economic sector (coal mining, metallurgy), population density, and related intensive vehicular transport – from air pollutant concentrations that frequently reach high levels, and even exceed health limits.

In cooperation with the major pollution sources (both private and public) and other stakeholders, the national and local authorities have sought ways to solve this adverse situation. Currently, the most stressing problem related to air pollution in the region is excessive pollution with particulate matter (PM). This problem has both national and international dimensions, as the Moravian-Silesian Region (the MSR) is located at the Czech-Polish border area. According to Blažek et al. [1] the levels of air pollution by particulate matter are similar in the MSR and the Silesian Voivodeship (Poland).

A major goal of this paper is to identify, organize, analyze, and sort in terms of effectiveness the various types of measures being used to mitigate particulate matter air pollution in the MSR. To reach this goal, a survey and multi-criteria and comparative analysis based on the survey results were applied as the main research methods; a vast array of criteria, including economic aspects, uncertainties about both the information on the contribution of the respective sub-sectors to local air pollution and the actual

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long-term effects of the particular measures were introduced into the analysis. A review of literature dealing with the studied object, ranging from theoretically oriented works to feasibility and implementation studies (of sets) of measures to deal with the negative situation in the region, was conducted as an initial step to ground this approach both in the current knowledge and the real conditions within the region.

Our paper is structured as follows: first, air pollution development/trends in the MSR, their negative consequences, and major sources are described. Then, air pollution mitigation measures relevant for the region were suggested. The results of the multi-criteria analysis applied to learn about studied mitigation measures and the consequences of their implementation, are presented and discussed in the next part; finally, recommendations for environmental policy strategy in the region are formulated.

Air Pollution and its Negative Impacts in the MSR

Monitoring of PM, SO_2, CO, and NO_x was established as early as the 1980s in the Czech Republic. Results of the monitoring show a slight decrease of pollution already in this time period [2]. This initial success was followed with significant air pollution reduction in the 1990s, which is usually understood as a result of the new Czech Air Protection Act adopted in 1991 [3], and also as a result of structural changes in the Czech economy being transformed from a centrally planned one to a market one [4]. The emission trends of the major air pollutants have rather stagnated since 2000.

Concerning the emission reduction, similar trends as in the whole Czech Republic also have been observable in the Moravian-Silesian Region. However, despite the emission stagnation, air quality has been worsening in the MSR since the beginning of the 21st century. Concentrations of PM_{10} and $PM_{2.5}$ are higher than EU Standards and they cause serious health problems. There is the problem that even if the emissions of PM are reduced, the desirable air quality is not achieved due to the specific dispersion and meteorological conditions and geomorphologic characteristic in the region. The current situation of the current PM pollution in the Czech Republic is illustrated by Fig. 1.

Epidemiological studies in the Czech Republic pay attention to those parts of the Moravian-Silesian Region (especially the Ostrava area) with heavily polluted air and this kind of health impact of pollution. Several studies conducted in recent years have proven various negative impacts of air pollution, especially carcinogenic polycyclic aromatic hydrocarbons (c-PAHs) such as the proven human carcinogen benzo[a]pyrene (B[a]P), on respiratory morbidity – specifically bronchial asthma – in children, and the significant increase in genetic damage (using biomarkers such as DNA adducts, chromosomal aberrations, gene expression, DNA oxidative damage, and lipid peroxidation) in children and adults. For more details see Rossner et al. [5], Rossnerova et al. [6, 7], and Svecova et al. [8]. The negative impacts of air pollution on children are shown in Nikolič et al. [9]. Topinka et al. [10] concluded that the concentrations of $PM_{2.5}$ are more dangerous in the Ostrava area than in other parts of the Czech Republic, because of higher genotoxicity of the pollution due to higher concentrations of B[a]P adsorbed on $PM_{2.5}$. Other extensive information about the issue can be found in the Air Protection Journal

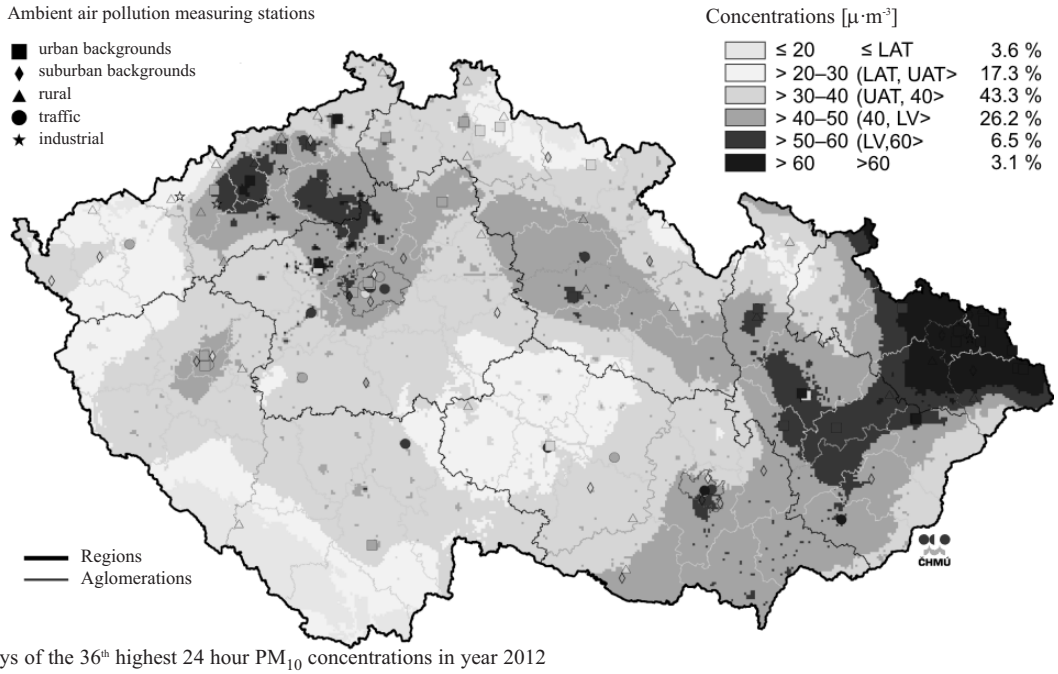

Fig. 1. Particulate matter concentrations in the Czech Republic, 2012.
Source: Czech Hydrometeorological Institute
The map shows areas where the daily limit value for PM_{10} concentration (50 µg·m^3) was exceeded more than 35 times per year. The grey tones reflect the magnitude of the exceedance.

(Ochrana ovzduší; ISSN 1211-0337), where more than 20 articles devoted to air pollution in the MSR and its impacts on health were published in 2008-12 (in Czech language only).

Kowalska et al. [11] present persistent negative impacts of PM_{10} air pollution on mortality in the Katowice region (Poland, Upper Silesia) near the border with the Czech Republic. Grzegorz et al. [12] suggest that despite a better air pollution situation, Upper Silesia witnessed in 1993-2007 a statistically significant increase in the prevalence of all physician-diagnosed allergic disorders: asthma, allergic rhinitis, atopic dermatitis, allergic conjunctivitis, allergy to pollen, and allergy to food. Badyda et al. [13] stress the negative impacts, and thus the importance of air pollution from transport; the study indicates that the risk of bronchial obstruction is significantly higher for people living near busy urban roads than for other people. On the other hand, air pollution is not listed among important environmental problems in Karbownik et al. [14], who analyze the urbanized part of Upper Silesia in Poland.

Air Pollution Trends and Sources in the MSR

The trend analysis shows that the total emissions in the MSR have been reduced more intensively than in the Czech Republic as a whole (Figs. 2 and 3). However, the MSR still contributes to total Czech emissions significantly (alongside the Ústí and Labem Region and the Central Bohemian Region).

The data also show that the total emission trend is declining both in the Moravian-Silesian Region and in the Czech Republic, whereas the decline was significantly stronger in the MSR compared to the country as a whole. However, there are negative trends in the household and self-employed sector. The total emissions from this sector are rising again both in the region and in the country.

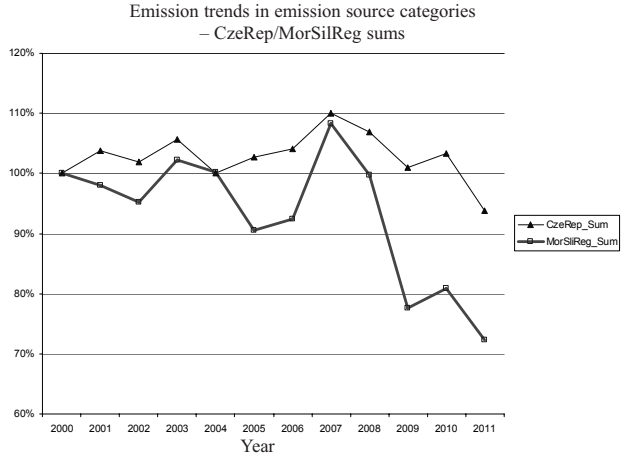

Fig. 2. Particulate matter emission trends in the Czech Republic and Moravian-Silesian Region – totals.
Source: Czech Hydrometeorological Institute, National Emission Balances
(http://portal.chmi.cz/files/portal/docs/uoco/oez/emisnibilance_CZ.html)

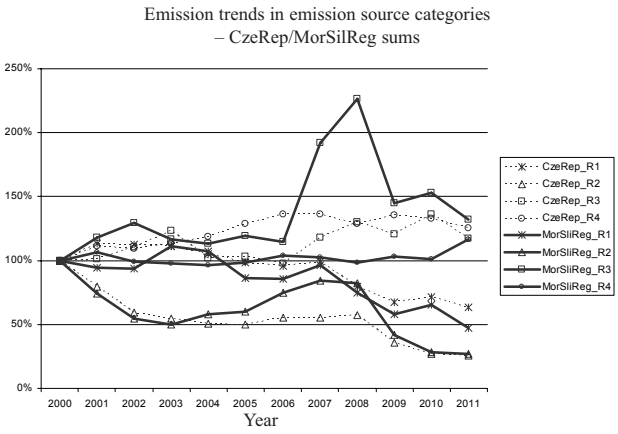

Fig. 3. Particulate matter emission trends in the Czech Republic and Moravian-Silesian Region – emission source categories.
Source: Czech Hydrometeorological Institute, National Emission Balances
(http://portal.chmi.cz/files/portal/docs/uoco/oez/emisnibilance_CZ.html)
R1 – registry of large sources (mostly industrial) – emissions monitored, measured, and reported
R2 – registry of medium and small sources – emissions monitored, measured, and reported
R3 – registry of emissions from household and self-employers – emissions modelled and estimated
R4 – registry of mobile sources (mostly transport) – emissions modelled and estimated, data not available before 2000.

The regional emissions from small stationary sources tend to grow more rapidly than in the country. An overview of the air pollution sources in the region is shown in Fig. 4.

Industrial activities, especially coke-oven plants, steel works, ironworks, sintering, and power and heating plants are the most important source of air pollution in the Moravian-Silesian Region, followed by transportation and small combustion sources. The transportation and small combustion sources are of about the same importance.

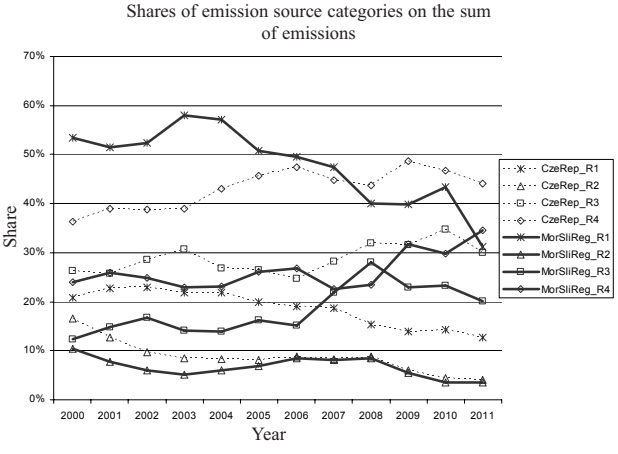

Fig. 4. Sources of particulate matter emissions in the Czech Republic and Moravian-Silesian Region.
Source: Czech Hydrometeorological Institute, National Emission Balances
(http://portal.chmi.cz/files/portal/docs/uoco/oez/emisnibilance_CZ.html)

Recent studies (e.g. the Health Institute in Ostrava [15]; Jančík [16]; Gębicki and Szymańska, [17]) show that the above sources are the most important ones concerning not only emissions but also the ambient quality/concentrations which the inhabitants and other environmental elements are exposed to. The Health Institute in Ostrava [15] employed the HYSPLIT model (hybrid single particle lagrangian integrated trajectory model developed in a joint effort by the US National Oceanic and Atmospheric Administration and Australia's Bureau of Meteorology). The results indicate that individual heating in households can make a much more significant contribution to the pollution burden and also that long-range emission sources (e.g., in Poland) cannot be regarded as insignificant.

Air Pollution Mitigation Type Measures Relevant for the Region

There are various technological measures available that can contribute to solving the air pollution problem in the MSR. The solution could be found both in production and consumption activities. Relevant literature sources (especially various studies and official governmental documents) contain more detailed specifications of these measures [18-21].

Based on studies and relevant literature, it is possible to formulate the following types of pollution mitigation type measures: smog situation mitigation, end-of-pipe solutions, energy efficiency improvements, fuel change for more environmental friendly ones, pro-environmental management measures in road transportation, imports of intermediate products, best available/environmentally friendly technologies, closing of plants, and management of green areas.

Smog Situation Mitigation

Stationary and mobile sources can be (temporarily) regulated during periods of pollution concentrations above set limits.

In the Czech Republic, and thus also in the MSR, based on the Air Protection Act [22] and related legal provisions, in case a relevant regional authority declares a smog situation as a result of air quality monitoring and in compliance with an announcement of the Ministry of the Environment/ Hydrometeorological Institute, the information is immediately released to the public. Operators of all major plants significantly contributing to air pollution (coke-oven plants, sintering, roasting, power generation) are, in correspondence with their individual operating permits (negotiated with and issued by a relevant regional authority), obliged to reduce the operation of air-polluting equipment. However, the smog situation regulation can be a rather weak measure, because the production plants often succeed in negotiating operating permits that enable them to reduce their operations by only a few percentage points and the air pollution effects are delayed in time.

In addition, the MSR applies voluntary agreements concluded between the Czech Ministry of the Environment and ArcelorMittal (the major air polluter in the MSR; see [23]), and BorsodChem (concluded in 2011). In these agreements, the parties declare – among other things – their willingness to reduce operation during smog situations. Other voluntary agreements are in the process of preparation and/or negotiation (with Biocel Paskov, a.s., Třinecké železárny, a.s., Evraz Vítkovice Steel, a.s., OKK Koksovny, a.s., and Dalkia Česká republika, a.s.).

Based on the Air Protection Act, municipalities can issue rules to reduce road traffic, if such a reduction makes sense in terms of emission reduction. These rules are issued in the form of an order. The Ministry of the Environment must be informed about it.

End-of Pipe Solutions

This type of measure consists in (additional) construction equipment to capture pollution which would otherwise be emitted to an environmental component. End-of-pipe solutions may have quite a high environmental efficiency. This measure usually does not bring any other (integrated) effect. Experts can assess the costs relatively easily.

In the case of the MSR they especially install high-efficiency particulate filters (which has a long tradition in the Czech Republic), electrostatic precipitators and others. However, the current orientation on very small particulates (PM_{10}, $PM_{2.5}$) brings new technological challenges. All the large and medium plants in the region operate some kind of end-of-pipe equipment. Moreover, there are other projects to install additional devices, especially in metallurgical works. For instance, in a voluntary agreement with the Ministry of the Environment, ArcelorMittal declares its willingness to run only shops with textile filters from 2013 at the very latest, and to use more intensive separation processes in some shops.

Energy and Material Efficiency Improvement, and Use of Renewable Sources

Energy and material efficiency improvement has the potential to achieve pollution reduction quite efficiently. Use of renewable sources, especially biomass, does not necessarily reduce emissions. Burning of straw can have that opposite effect, i.e., it can increase dust emissions.

Concerning this type of measure (energy and material efficiency and use of renewable energy sources), the region does not have significant specifics compared to the other areas of the Czech Republic.

Fuel Change

This has been one of the most typical measures to improve air quality in towns and cities. Formerly, it meant switching from high-sulphur content lignite to low-sulphur lignite and from solid fuels to gaseous ones. For solving the particulates, a switch from coal to gas or electric power is

the issue. There is a cost problem because the more environmentally friendly energy sources are becoming more expensive, which some households and firms cannot afford. It is reported that some households have turned back from gas to coal or wood, which brings to light the problem of un-controlled burning of solid waste by households.

Based on Decree No. 13/2009 Coll., municipal authorities can implement control procedures on quality of fuels used by small sources of air pollution (households and small and medium businesses). The power lies within the Czech Trade Inspection Authority.

Moreover, the renovation of public transport fleets is considered in many cities in the region. The city of Havířov is actually the city with the highest quantity of public transport buses fuelled by compressed natural gas (CNG). In other cities of the region, CNG buses are either being tested or operated in small numbers. The reason for switching from liquid to gaseous fuels in mass transport is also economic, since oil prices have risen in the last decade. Public transport companies can save up to 40% of their fuel costs by switching from liquid fuels to CNG.

Road Transportation Management

Restrictions in traffic and an increase of fluidity and traffic congestion reduction can take the shape of traffic prohibition of entry of cars with emissions above standards into so-called low-pollution zones. Reducing speed brings both pollution reduction and noise reduction. This prohibition could have a permanent character or it can be a part of the smog situation mitigation mentioned above. Delivery services, security and health services, but also residents' cars can have exceptions. For the efficient functioning of this measure, it is important to develop an adequate infrastructure: bypass roads, parking places connected to public transport (P+R), and public transportation development, including integrated transportation systems. Protecting against secondary dust emissions (street cleaning and sprinkling) is part of this sort of measure.

A feasibility study for low emission zones has been performed for all cities with over 10,000 inhabitants in the region (namely Ostrava, Havířov, Karviná, Frýdek-Místek, Opava, Třinec, Orlová, Nový Jičín, Český Těšín, Krnov, Kopřivnice, Bohumín, Bruntál, Hlučín, Frenštát pod Radhoštěm, and Studénka), as the health limits are exceeded repeatedly in all of them.

Imports of Intermediate Products

This means importing products, the production of which is connected with high pollution from outside the region instead of production inside the region.

Coke production, metal ore roasting and sintering, and production of pig iron and steel are considered to be stopped in the MSR. Downstream industrial processes such as rolling, pickling, and coating would need to change their supply chains completely or cease operation as well.

Best Available Environmentally Friendly Technologies

Compared to the end-of-pipe solutions, environmentally friendly technologies usually bring multiple, integrated effects. The costs linked with the pro-environmental effects of the projects can be best quantified by units (household, firms) that decide to implement these projects (which also bring other socio-economic effects, which should be taken into account), while for anybody from the "outside" it may be rather difficult. As there is an information asymmetry between the firms/households on the one hand and other stakeholders, especially the government, on the other hand, only the firm/household itself has a chance to quantify these costs when deciding about relevant capital investment. For more about this issue, see Sauer et al. [24] and Sauer et al. [25].

Heat recovery is a typical example of this sort of measure. Insulation of buildings and replacement of windows can also serve as examples of this type of measure implemented by both firms and households. Fuel change, mentioned in a separate paragraph, can also have the character of this kind of project with multiple integrated effects. However, it can be said that the measures of this sort undertaken in the MSR are not very specific compared to other regions.

Closing Down of High-Polluting Units

Although this measure brings 100% environmental efficiency, is it applicable only rarely, since it is connected with quite high social costs, typically in the form of resulting loss of jobs. Moreover, it is difficult to apply it to private firms.

As an example of this type of measure in the MSR, we can quote the promise of AcelorMittal, included in a voluntary agreement with the Ministry of the Environment, to close down tandem furnaces (and to start to use different production methods).

Management of Green Areas

This measure concerns especially the green areas in cities and villages – planting of protective greenery, minimization of felling, and compensation of felled trees with new planting. Although these measures do not bring very high environmental effects, they bring other social positive effects and are not very costly.

Concerning the MSR, there are no specifics compared to the other regions.

Let us also mention compensatory measures. They do not contribute to pollution reduction, but they do contribute to reducing various risks from current pollution until it is reduced. Curative stays in clean nature for children, support to employees' healthy life patterns, etc., are typical examples here. Compensatory measures can also serve as a balancing factor to keep pollution at the same/lower level in case new sources of pollution are to be constructed and operated in an area.

An increase in knowledge and information campaigns has the potential to increase the effectiveness of the measure selection process. There are still many open questions concerning assessment of emission dispersion in specific areas, the share of primary and secondary sources of pollution on ambient quality, and the impacts of certain kinds of pollution on health of people, including small children. Also, providing the public with true information contributes to better decisions about pollution management. People's voluntary pro-environmental behavior could bring positive effects with relatively low costs (see, for instance, the effects of information campaigns on household behavior in the area of waste management in Sauer et al. [26]).

Assessment Methodology

The literature analyzing single mitigation approaches and projects in the region in detail is generally available and is exploited in various parts of this paper. Our goal is to contribute to the rather limited literature dealing with complex analysis comparing various types of measures. Multicriteria analysis is the method applied in our paper. For more details on the use of multicriteria analysis see Fiala [27]. The criteria cover all the three pillars of sustainable development. The following criteria were introduced to the analysis of the above-discussed measures:

- Expensiveness (direct and indirect social costs, including private ones)
- Major positive environmental effect(s), including the time horizon and probability that the effects are achieved
- Other environmental effects in the analyzed environmental component and the other environmental components (i.e., both positive and negative cross-media effects)
- Other social effects (other than environmental ones)
- Political aspects and legal feasibility

The following point scales (scores) were used in the analysis. Both plus and minus points were applied in the assessment:

3 points– very positive
2 points– medium positive
1 point – slightly positive
0 points– neutral or the parameter is not relevant for assessing the measure
(-)1 point – slightly negative
(-)2 points – medium negative
(-)3 points – very negative.

Six Czech experts in the fields of environmental protection, policy analysis, public administration and environmental economics, who are very familiar with the situation in the MSR, were asked to complete three forms:

a) Point evaluation of the measures according to the individual criteria
b) Pair comparison of the criteria (to get weights)
c) Direct pair comparison of the measures

A third method of analysis (questionnaire "c") was designed to find out whether there is consistency between the single score assessment (weighted or not) and the pairwise comparison of the measures.

Table 1. Criteria pair comparison.

Pair comparison of the criteria	Weights
Other social effects	0.1
Political and legal aspects	0.14
Other environmental effects	0.17
Major environmental effects	0.29
Expensive	0.3

Table 2. Total and weighted scores of the measures.

Measure	Score	Weighted score
Imports of intermediate products	13	2.39
End-of-pipe solutions	19	2.95
Closing of plants	13	3.09
Fuel change	24	4.29
Smog mitigation	24	4.97
Road transportation management	29	5.96
Energy efficiency improvements	31	5.99
Best available technologies	35	6.53
Management of green areas	36	6.82

The experts were asked, among other things, to consider various uncertainties when working on the assessment. The main uncertainties suggested are the dominant source of the pollution, the true costs of both the measures and the pollution, and the attitude of the residents, public decision-makers, and private companies.

The Analysis Results

The results of the pair comparisons are presented first. Regarding the criteria, the expense and major environmental effects were assessed as the most important criteria, each gaining almost a third of the total. The remaining third is unevenly distributed among other environmental effects, political aspects, and other social aspects (Table 1).

The results suggest that there is a strong trade-off between two major criteria. The costs of a measure are even slightly more important than the major environmental effects of the measure. The overall results show that the benefit-to-costs ratio (or simply the main economic principle) is implicitly present in this particular assessment.

Table 2 shows the results of the score assessment and weighted score assessment. The measures are sorted ascending from the worst to the best according to the weighted score. The simple score shows the total score obtained by each measure from the scale (+3 to -3) men-

tioned above for all the criteria. The weighted score comprises the value of each score multiplied by the relative weight of each criterion.

There is only one absolute difference in the ranking of the measures. The "closing of plants" measure is ranked slightly better when the weights are included. Also, the relative distance of the measures changed slightly, but without any obvious significance.

The measures were also assessed by the experts in a pair-wise comparison. The results are shown in Table 3. Again, the measures are sorted ascending from the worst to the best. The marks correspond to the total points gained by the measure against every other measure in a pair-wise comparison.

Here, one can see two significant differences in comparison to the table of scores. The measure "management of green areas" gained the first (best) score; however, it performed poorly in the pair-wise comparison exercise. Similarly, yet in the opposite way, the "end-of-pipe solutions" measure did not act well in the score assessment, but reached the third best position when compared to every other measure.

Measures that perform well and steadily in both the score assessment and the pair-wise comparison are "best available technologies," "energy efficiency improvements," and "road transportation management." The lowest overall ranks are steadily occupied by the measures "imports of intermediate products," "closing of plants," and "smog mitigation."

The bouncing of the "management of green area" measure can be easily explained. Within the score assessment method, the measure gained steadily positive scores. No matter that these scores were only slightly positive, the total score was the highest among the other measures. Other measures, such as "best available technologies" or "end-of-pipe solutions" performed better under, e.g., the "main environmental effect" criterion, but they were assessed as neutral, or very negative under the "expensive" criterion. This was not the case of "management of green areas" – it gained not the best but still a positive score under every criterion.

Table 3. Measures by (direct) pair-wise comparisons.

Measures	Marks
Imports of intermediate products	10.5
Management of green areas	15.5
Closing of plants	17
Smog mitigation	18
Road transportation management	19.5
Fuel change	21
End-of-pipe solutions	23
Energy efficiency improvements	25.5
Best available technologies	30

Discussion

The results of the performed analysis can be discussed from various perspectives. The legal and political feasibility as well as support for implementing the air pollution mitigation measures represent key areas of this discussion. The following discussion of these aspects – even though it focuses on the Czech Republic/the MSR – thus also brings into focus more general issues.

In the particular case of the Czech Republic, the new Air Protection Act adopted in 2012 (valid from September 1, 2012) [22], which supersedes the previous act adopted in 2002, and which includes the European Directive on Ambient Air and Cleaner Air for Europe, might have a mixed impact on air quality in terms of effects resulting from the implementation of the analyzed measures.

In addition to the new Act, the Ministry of the Environment of the Czech Republic has prepared three key documents that establish a base for solving the air pollution problem. These include the "National Emission Reduction Program" [28], "Emission Reduction Potential in the Czech Republic up to 2020" [29], and "State Environmental Policy for the Period 2012-2020" [30]. These documents, among other things, reflect the fact that particulate matter is currently one of key issues for air quality in the Czech Republic.

The provisions of the Act [22] with the potential for discussion concerning the impact on the analyzed measures are as follows: First, fees will not be collected if the pollution source reaches an emission level lower than 50% of the top emission level achieved by best available technologies. The best available technologies associated with emission levels are supposed to be repeatedly stringent within a defined time period (approximately eight years). This means that relief from emissions fees will be, as time goes on, more difficult to reach, and it will significantly motivate polluters only after 2021, when the maximum rates will kick in, as a result of fees increase for those sources which do not reach the standards defined by the act. Second, while the act takes, because of EU legislation implementation, into account 12 pollutants (instead of 20 as did the previous act), it states fees only for four of them that are supposed to cause about 90% of the adverse effects on the environment, and while in terms of emission sources, regulation is effective for all of them, in terms of emissions limits statement and summation of capacities, it is effective only for the stationary sources listed in its appendix 2 of the Act [22] (in comparison with a broader scope of small, medium, large, and extra-large sources as defined by the previous act).

Thus the scope of sources susceptible to adopt the most effective measures to mitigate air pollution as a direct result of the act provisions is limited. Again, this can be at least partially compensated for by support of other ways to improve air quality, like voluntary agreements (polluters can receive subsidies from EU operational programs, not available in the case when the same measures are imposed by the authorities).

The act also introduces compensation measures, of both investment and operational nature, to ensure that new pollution sources do not operate in areas characterized by low air quality until compensatory measures balancing the state of air pollution are implemented. This provision can serve as a stimuli to introduce some efficient measures to mitigate air pollution (best available technologies, energy efficiency improvement) but can also work in favor of less effective ones (import of intermediate products) or those close to the middle of the efficiency scale (fuel change).

Concerning road transportation management, the act introduces low-emission zones into the Czech legal environment. This creates an opportunity for municipalities to regulate transport in relation to set emissions limits.

The efficiency of mitigation measures within the local and regional scope will be influenced also by the following changes within the act: current regulatory plans for smog episodes have been cancelled (with the exception of transport regulation plans issued by municipalities and the right of regional authorities to define special conditions for stationary sources); regional and local programs to reduce emissions will no longer be developed and implemented (as they were weak, and thus ineffective), thus only national programs will be run; control of local sources of pollution passes from municipal authorities to municipalities with extended powers or to the Czech Environmental Inspectorate; the maximum amount of emissions produced by residential boilers is stated. However, as the Act has been in force for only one year, the real impact of these provisions on the measure's efficiency will be possible to study within some time horizon when the relevant data are available.

The air quality problem also can be interpreted as a broader issue of a greening (regional) economy [31]; presented conclusions about mitigation measures can contribute to the relevant discussion both at the theoretical and methodological levels, and/or as an input into the process of identifying contradictions, directions, key factors and tools of greening the regional economy [32]; the conclusions can thus also contribute to the ongoing effort to formulate relevant "green tasks" and strategies to optimize environmental and economic efficiency [33]; policy targeted to reduce PM pollution can drive innovative processes at the regional and national levels [34].

The conclusions from the presented analysis also can be exploited within the ongoing discussion of climate change [35]. While a primary goal of the air pollution mitigation measures research is to define and implement in the most possible efficient way measures with a positive impact on the health of the local population, there are also other important environmental effects present. The other way around, measures with primary effects in lowering risks resulting from climate change, implemented by local authorities, can have – as the above-mentioned correlations of effects resulting from particular measure implementation show – positive impacts on PM reduction (air quality improvement) [36].

Conclusions

As the discussion shows, there is more or less an agreement among the addressed experts concerning the effectiveness of the measures to mitigate pollution in the MSR. When criteria weights are included in the overall assessment of the measures, "the energy efficiency improvement," "best available technologies," and "management of green areas" should be prioritized when formulating environmental policy strategies. However, the last measure is considered to be significantly weak in terms of environmental effectiveness, as the pair wise comparison of the measures has shown. For the decision about implementation of concrete projects in a concrete territory and at a concrete time, it is important to take into consideration the concrete conditions and synergies of concrete innovation cycles.

Measuring the real shares of particular sources of pollution, especially big and local ones, represents a key step to resolving the air quality problem. This knowledge would enable the political sphere to make appropriate decisions and adopt effective measures in terms of environmental gains and a related cost ratio at the national, regional and local levels. Evaluating the economic impact of polluted air on people's health (in terms of treatment costs, economic losses induced by illness, etc.) would be of the same importance. While responsibility for this stays with the relevant ministries (environment, health), neither of them has handled it yet.

While big (stationary) sources (R1) play the most important role in terms of air pollution in the MSR, small/medium local sources (households) and/or transport primarily contribute to the bad air quality in some other areas of the Czech Republic. However, the effort aimed at air quality improvement in the region has focused primarily on big (stationary) sources (R1) not only because of their share in the total air pollution but also because of the fact that it is easier to apply regulatory measures to this kind of air pollution source than to small sources and transport.

A concept of economic and industrial development of the region, spatial planning activities, and people's living conditions in the most polluted locations within the region represent key parameters of the region's future development in terms of the air pollution problem. This strategic discussion should happen at all levels (national, regional, local) with the same insistence, but this strategic discussion should not be questioned (as it currently often is) by the argument that measures applied within the region will not improve air quality, as pollution will get there from areas outside the region.

Concerning relations with Poland, although the methodologies and the information as such are only being generated and not having enough information about the transfer of the pollution across the border, we believe that the policy strategy here is not too difficult. As both countries get richer, they will be solving the air pollution problems in their territories and thus contribute to pollution reduction in the other countries as well. Yet it still makes sense to investigate whether an "extra cake" could be cre-

ated in some cases of specific collaboration. Alternatively, it is useful to discuss whether there is a danger of moving to a so-called Nash equilibrium if the two countries do not collaborate, where such situations would not be efficient for both countries.

Asymmetry of information which is typical for situations like those presented in this paper, can be solved either by ways resulting into sub-optimal solutions (authoritative decisions), or to close-optimal solutions (reached by negotiation, within the framework of voluntary approaches, etc.). Further development of these procedures represents an important direction of research in this area.

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