DRIVERS AND HEALTH IMPACTS OF AMBIENT AIR POLLUTION IN SLOVAKIA

Final Report

February 2021

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ACRONYMS

BCR	Benefit to Cost Ratio
EU CAFÉ	Clean Air For Europe
CI	Confidence Interval
CO_2	Carbone dioxide
EC	European Commission
EEA	European Environment Agency
EU	European Union
GDP	Gross Domestic Produtc
GHGs	Greenhouse Gases
HAD	Hospital Admission
HRAPIE	Health Risks of Air Pollution in Europe
MoE SR	Ministry of Environment of the Slovak Republic
NAPCP	National Air Pollution Control Programme
NH_3	Ammonia
NMVOV	Non-Methane Volatile Organic Compound
NO_2	Nitrogen dioxide
NOx	Nitrogen oxides
NPV	Net Present Value
OECD	Organisation for Economic Co-operation and Development
$PM_{2.5}$	Particulate matter with diameter of less than 2.5 μm
PM_{10}	Particulate matter with diameter of less than 10 μm
RAD	Restricted Activity Days
PVB	Present Value of Benefits
PVC	Present Value of Costs
RR	Relative Risk
SO_2	Sulphur dioxide
VAT	Value-Added Tax
VLYL	Value of Life Years Lost
VSL	Value of Statistical Life
WHO	World Health Organization
WTP	Willingness To Pay
$\mu g/m^3$	Microgram per cubic meter

EXECUTIVE SUMMARY

Background and purpose

This report, created with the support of the Structural Reform Support Programme of the European Commission (EC), provides an estimate of the health impacts of current concentrations of air pollutants in the Republic of Slovakia across its 72 districts (the two biggest cities are counted as one each) and evaluates the benefits of measures to reduce concentrations of pollutants relative to the costs of such measures. At the same time, a toolkit is prepared so that similar analyses can be conducted in the future. The study is motivated by the need to better understand the extent of the health consequences of the levels of ambient air pollution in Slovakia (which is among the highest in Europe) and to evaluate different actions to improve air quality in terms of their benefits relative to their costs. In this way policy actions to address air pollution can be more cost effective.

Methodology

The health impacts are measured in terms of increases in premature mortality and increases in the incidence of different morbidities. It is the first time that an analysis of such impacts has been carried out at a granular level for Slovakia. The study goes on to project concentrations in 2030 if the government´s National Air Pollution Control Programme (NAPCP) is implemented. The benefits of the Programme are measured through reduction in the physical health impacts (premature mortality and morbidity), as well as the monetary benefits of such reductions. The benefits are compared to the costs of the Programme, relative to the full economic costs as well as the fiscal costs.

Results

Current concentrations of $PM_{2.5}$, PM_{10} (particulate matter with diameter of less than 2.5 μm and 10 μm respectively) and nitrogen oxide (NO_2) are estimated to result in around 1,592 premature deaths every year. What this figure says is that if concentrations were reduced to the guideline value of 10 microgram per cubic meter (μg/m^3) for $PM_{2.5}$ and 20 μg/m^3 for PM_{10}, then the number of avoidable premature deaths would fall by this amount. The main source of premature deaths is $PM_{2.5}$. The uncertainty in the estimate suggests that the figure could lie between 1,143 and 2,013 premature deaths – a range of about +/-27%. Regarding morbidity, main impacts take the form of restricted activity days and workdays lost, with some additional cases of chronic bronchitis and asthma. The modelling estimates 2.7 million restricted activity days and 138,000 workdays lost, along with 431 cases of chronic bronchitis and 99 cases of asthma.

The monetary cost of these impacts depends significantly on whether a value of statistical life (VSL) approach is taken to evaluate a premature death or a value of life years lost (VLYL). Both approaches have been adopted in European Union (EU) policy discussions. If the VSL method is adopted, the estimated cost of premature mortality is in the range €2.7 and €8.0 billion, with a mean value of €5.3 billion. The VLYL method gives a lower estimate: the median-based figure is €1.1 billion and the mean figure is €2.4 billion. The morbidity costs across all endpoints are around €549 million, or less than half the premature mortality costs based on VLYL (median value) and about 10% of the costs based on VSL (mean value). Taken together, the mortality and morbidity costs amount to €3.0 billion (VLYL) and €5.8 billion (VSL), making them equal to 3.6% to 6.9% respectively of the gross domestic product (GDP) in 2017.

The NAPCP has been formulated to meet the air quality and emissions reductions targets for Slovakia by 2030. It consists of several measures to reduce emissions of $PM_{2.5}$, nitrogen oxides (NOx), sulphur dioxide (SO_2) and ammonia (NH_3) across transport, residential heating and agriculture sectors. The measures will have health benefits over the total implementation period 2021-2030. By 2030, the NAPCP saves about 116 lives, and reduces restricted activity days by 195,000, workdays lost by 92,000 and the number of chronic bronchitis cases by about 81. The value of these health benefits by 2030 are: €397-€1,192 million via VSL and €107-€363 million via VLYL for reduced mortality and €97-€124 million for reduced morbidity. The value of the benefits over the period 2021-2030 is higher as they include gains in the intervening years. The estimated present value of the benefits is €2,363 million (VSL) with a range €1,218-€3,280; and €663 million (VLYL) with a range of €504-€1,240.

There are two concepts of cost against which the benefit to cost ratio (BCR) can be estimated. One is the economic cost and the other is the fiscal cost. The economic cost measures in monetary terms the value of scarce resources used to implement the project. The fiscal cost is the cost measured in terms of net expenditures required by the government to implement the NAPCP. The analysis has been conducted with respect to both the economic cost as well as the fiscal cost. The estimated figures for the present value of the costs for the 13 components of the NAPCP at a 5% discount rate are: €1,124 million (economic) and €398 million (fiscal).

The results indicate the following for the economic costs:

a. Under a VSL valuation of premature mortality the NAPCP has a BCR greater than one for the whole range of VSL values.
b. Under a VLYL valuation the BCR exceeds one only if the upper end of the range is taken. Under the value that is set by the Slovak legislation to estimate the cost effectiveness of new medications, the ratio is only 0.44 and under a median value it is 0.57. This means that the benefits of the period 2021 to 2030 only represent 44% and 57% of the costs, respectively.
c. There is the question of what benefits might remain after 2030. It is reasonable to assume there will be some, as the base case without NAPCP cannot be expected to converge automatically to the NAPCP level of concentration. However, it is difficult to estimate the gap precisely. As an approximation, a sensitivity calculation has been made in the case of economic costs, assuming the gap in 2030 between concentrations under the base case and the NAPCP remains for another ten years. In this case the annual costs of the NAPCP for the period 2031-2040 are estimated as being the same as the maintenance costs for 2030 for each of the programs where such costs are incurred. Extending the analysis to 2040 raises the BCR by about 18%, which is not sufficient to increase the BCR above one in the VLYL analysis.

Further sensitivity analysis was carried out using the range of physical health impacts. As stated in Section III, the 95% confidence interval (CI) for the range of impacts is approximately +/-27%. Applying this range to the BCRs keeps the BCR above one for all cases with the VSL except for the combination of the low VSL value and the lower bound physical impacts. Under the VLYL, however, the BCR only exceeds one with the high VLYL value and under physical impacts at or above the mean. These figures are for benefits until 2030 only.

The fiscal costs are €398 billion while the economic costs are €1,124 billion, or 2.8 times as high. Since the benefits are the same, the NAPCP has a higher BCR when judged under these costs. The BCR is now above one and the NPV is positive in all cases. Under VSL, the BCR ranges from over 3 to over 8 and under VLYL the range is over 1 to over 3. Allowing for the +/-27% physical impacts CI, the BCR remains above unity in all cases.

There are additional implications when the findings from the study are viewed in the context of the COVID-19 pandemic. Although the impacts of the pandemic have not been modelled explicitly here, recent research has shown that particulate matter could create a suitable environment for transporting the virus at greater distances. Furthermore, the health impacts of atmospheric air pollution and associated chronic diseases/NCDs increases the vulnerability to COVID-19.

Both these linkages give greater impetus to immediate action to reduce PM concentrations. To some extent the lockdown measures have reduced PM concentrations in some countries, but the evidence for Slovakia is limited. Some decrease in air pollutant concentrations was seen in March and April 2020[1], but the long-term impact is not known. Strategies for 'Building Back Better' aim to sustain improvements in air quality through measures that combine a reduction in greenhouse gases (GHGs) as well as local air pollutants. Implementation of this strategy in Slovakia could involve accelerating and even strengthening the measures proposed in the NAP-CP and assessed in this study.

There are three main recommendations to the Ministry of Environment of the Slovak Republic (MoE SR) of the as a follow-up to this analysis:

- Evaluate the health impact of individual air quality interventions within the NAPCP;
- Use the models developed within this analysis to assess the impacts of regional policies;
- Further improve and regularly update the data used in the toolbox.

1 SHMU: Impact of the first month of COVID-19 related measures on air quality in Slovakia. http://www.shmu.sk/sk/?page=2049&id=1054

I. Introduction

The population of Slovakia faces high concentrations of air pollutants. The levels of pollution in the ambient air cause negative impacts on public health and the environment, with Slovakia having one of the highest mean levels of exposure to $PM_{2.5}$ (particulate matter less than 2.5 microns in diameter) among the EU member states. These particles contribute to the incidence of asthma, cardiovascular problems, lung disease and consequently to premature death[2]. Despite some improvements over the past years, the situation in the country remains unsatisfactory, not least because of the insufficient transposition of the EU regulatory framework regarding air quality.

This report, created with the support of the Structural Reform Support Programme of the European Commission (EC), aims to support Slovakia improving its ambient air quality by strengthening the understanding of health impacts attributable to air pollution and related economic costs, and, in cooperation with the Ministry of Environment of the Slovak Republic (MoE SR), to increase the public ability to perform cost-efficient interventions and address ambient air pollution.

The estimates of policy costs are compared against their benefits in terms of reduced health damages. The net benefits are reported using benefit cost indicators. The results and analytical tools developed can support and facilitate the implementation of the National Air Pollution Control Programme (NAPCP). The project would therefore broaden the knowledge base for future decision making on issues dealing with transition towards sustainable energy resources as well as policy considerations for major polluting sources.

[2] World Bank/IHME (2018). The Cost of Air Pollution: Strengthening the Economic Case for Action. World Bank, Washington DC.

II. Data description and methodology

The data on concentrations of ambient air pollutants were assembled at the district level for the most recent period based on the models of the Slovak Hydrometeorological Institute. This was done for the 71 districts in the country and weighted by the affected population for the following concentrations that are linked to possible health impacts:

i. $PM_{2.5}$, Annual Mean
ii. $PM_{2.5,}$ Daily Mean
iii. $PM_{10,}$ Annual Mean
iv. $PM_{10,}$ Daily Mean
v. $NO_{2,}$ Annual Mean
vi. $NO_{2,}$ Maximum 1-Hour

A list of the districts and their location is given in Annex I. The baseline year for concentration data was 2017, while the two reduction scenarios modelled the pollution concentrations for the year 2020 and the year 2030 (scenario used to model the full implementation of the NAPCP). All health-related input data were provided by the National Health Information Center. Figures were given as a range for each district, reflecting the uncertainties in measurement. The data are stored in an interactive file that forms the basis of the toolkit that will be used by the MoE SR to perform future calculations after the completion of this study. A manual for the toolkit has been created and will be published alongside this report.

The dose response functions were selected to reflect the main health impacts. These functions give the expected increase in a given health impact per unit increase in concentration to which a baseline population is exposed. They were taken from the World Health Organization (WHO) Health Risks of Air Pollution in Europe (HRAPIE)[3] project. The same source, which is the most up-to-date available, was also used to estimate air pollution impacts across Europe by the European Environment Agency (EEA)[4]. Table 1 summarizes the functions used, giving relative risk (RR) estimates for the main health impacts. Coverage in the study was limited to PM and $NO_{2.}$ The data on atmospheric ozone were not available in sufficient quality to estimate the impacts on the district level. Therefore, the estimates of health impacts of ozone on the regional level were not included in this study.

The RR is a measure of the relative risk. It is the ratio of risks, i.e. of probabilities, of an adverse health event among the exposed and non-exposed group[5]. The relative risk in the table

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3 WHO, 2013b, *Health risks of air pollution in Europe — HRAPIE project: New emerging risks to health from air pollution — Results from the survey of experts*, World Health Organization, Regional Office for Europe, Copenhagen

4 EEA (2019). Air Quality in Europe – 2019 Report. EEA: Copenhagen.

5 In the epidemiological literature the relative risk is sometimes related to a concept called the Population Attributable Fraction (PAF). PAF is the proportional increase in population disease or mortality that would occur if exposure to a risk factor were increased from an alternative ideal exposure scenario: Mathematically it is expressed as: $PAF = \frac{(P_i - P_i^{'})RR}{P_i RR}$ where Pi=proportion of population at exposure level i, current exposure and = proportion of population at exposure level i, counterfactual or ideal level of exposure. See: **WHO | Metrics: Population Attributable Fraction (PAF)**

describes how much the morbidity or mortality would increase if the pollution level increased by 10 μg/m^3. The 95% confidence interval (CI) shows the range of RR and our estimates that lie within a 95% CI. The guideline value for estimation is the pollutant concentration a country like Slovakia should aim to achieve. It does not mean that no health effects exist below this value, but that the defined value is a desirable target. The values used here are those recommended by the WHO[6]. Since some other studies, particularly the EEA, do not use the same guideline values but measure impacts relative to a zero concentration or a threshold level below which a zero impact is expected (whichever is the highest), we provide estimates both relative to the guideline values as well as similar values to the EEA. Different pollutants are linked to different health outcomes based on information from a wide range of epidemiological studies.

Table 1: Dose Response Functions Used in Making Estimates of Health Impacts

Pollutant Metric	Health Outcome	RR (95% CI) per 10μg/m^3	Guideline Value for Estimation
$PM_{2.5}$ Annual Average	All-Cause Mortality. Age 30+	1.062 (1.040 – 1.083)	10 μg/m^3
$PM_{2.5}$ Annual Average	Restricted Activity Days. All Ages	1.047 (1.042 – 1.053)	10 μg/m^3
$PM_{2.5}$ Annual Average	Workdays Lost. Ages 20-65	1.046 (1.039 – 1.053)	10 μg/m^3
PM_{10} Annual Average	All-Cause Post Neonatal Mortality 1-12 Months	1.04 (1.02 – 1.07)	20 μg/m^3
PM_{10} Annual Average	Incidence of Chronic Bronchitis Age 18+	1.117 (1.040 – 1.189)	20 μg/m^3
PM_{10} Daily Mean	Asthma Events. Ages 5-19	1.028 (1.006 – 1.051)	20 μg/m^3

Source: WHO (2013).

In order to estimate the health effects given the dose response functions the following formula has been used:

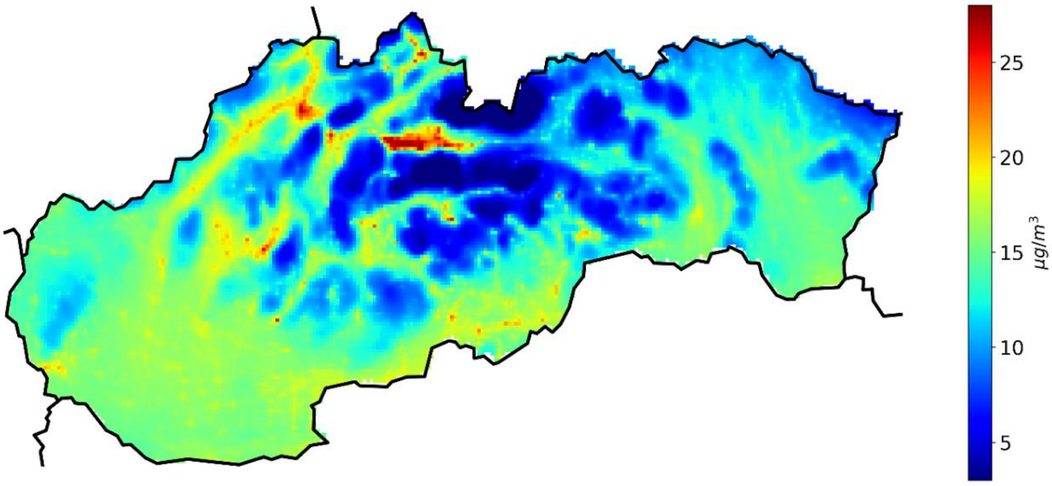
$$CASES = \frac{(RR-1)}{RR} * \frac{(C-C_0)}{10} * B$$

Where C is the concentration in micrograms per cubic meter $(\frac{\mu g}{M^3})$ and C_0 is the guideline concentration. B is the exposed population. The baseline number of cases has been derived from local data in most cases. Where this was not possible, estimates of the RR of a particular health effect were taken from the WHO (2013) study for Eastern Europe. In the future these could be substituted with local information and re-estimated to produce a local RR function for Slovakia. The Ministry of Health could help with the design of a survey to collect this epidemiological information. The model was also used to calculate other indicators of pollution effects on the population's health. However, the available data on average concentrations by district did not show any significant results. These include cardiovascular and respiratory hospital admissions, asthma events in children and all indicators estimating the effects of the NO_2 pollution.

[6] EEA (2017). Air Quality Standards. EEA: Copenhagen.

III. Description of the current state

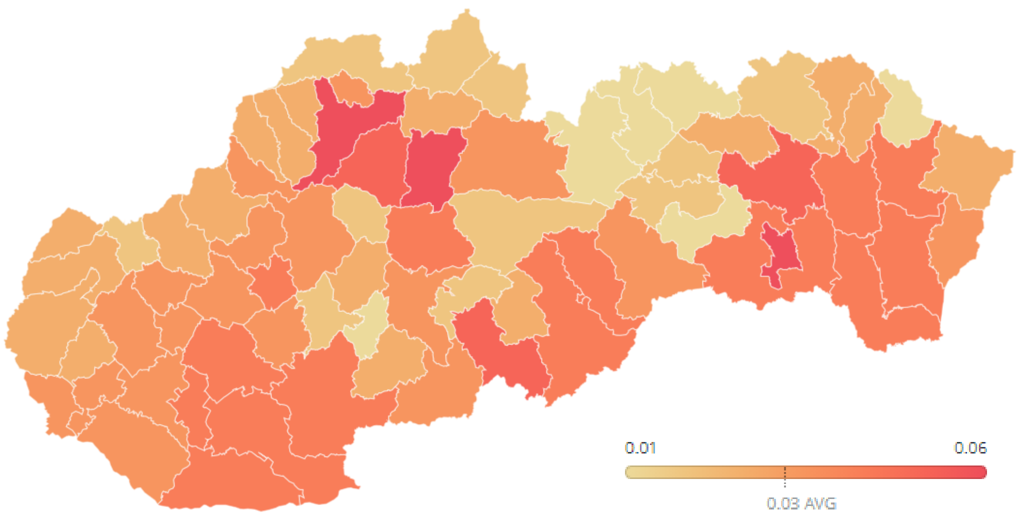
The estimate of premature deaths is calculated from data on average pollution in the district weighted by the population and the total all-cause mortality in each district. This method gives a rough estimate of air pollution impacts but needs to be interpreted carefully. Below is a map of the pollution distribution within the country as well as the average $PM_{2.5}$ concentration levels in each region.



Map 1: Yearly average of $PM_{2.5}$ concentrations in Slovakia in 2017 (CMAQ)

Source: SHMU

Averaging air pollution data diminishes effects of regional pollution hot spots. While some areas show average concentrations similar to the ones on Map 1, the population weighted average creates a unified pollution level for the whole district, which cannot by definition be as detailed as the map above. While for some application the detailed concentrations distribution might be more suitable, for the purpose of this study the population weighted averages of pollutants are sufficient.



Map 2: Attributable fraction of $PM_{2.5}$ pollution

Source: own elaboration

Map 2 shows attributable fraction of all-cause mortality related to $PM_{2.5}$. This can be explained as the percentage of all premature deaths in the district that can be attributed to PM2.5 concentrations. In the most afflicted areas of Žilina, Košice, and Ružomberok, more than 5% of all mortality can be attributed to air pollution. Reduced air pollution in these areas will therefore have the biggest impact on the improvement of public health.

Physical estimates of health impacts

Estimates of the physical Impacts are given in Table 2 (Premature Mortality) and Table 3 (Morbidity). These impacts are, besides air pollution concentrations, dependent on the overall mortality in each of the regions. The mortality data of the population over 30 years is shown in the map below. For the purposes of this study the total number of all deaths in the region is considered, since they are used to calculate the total number of premature deaths. The National Health Information Centre also creates standardized data that better reflect the population distribution within the region but would not be appropriate for this type of study.

Map 3: All-cause mortality for ages over 30 in each of the districts (average 2015-2017)

Source: National Health Information Centre

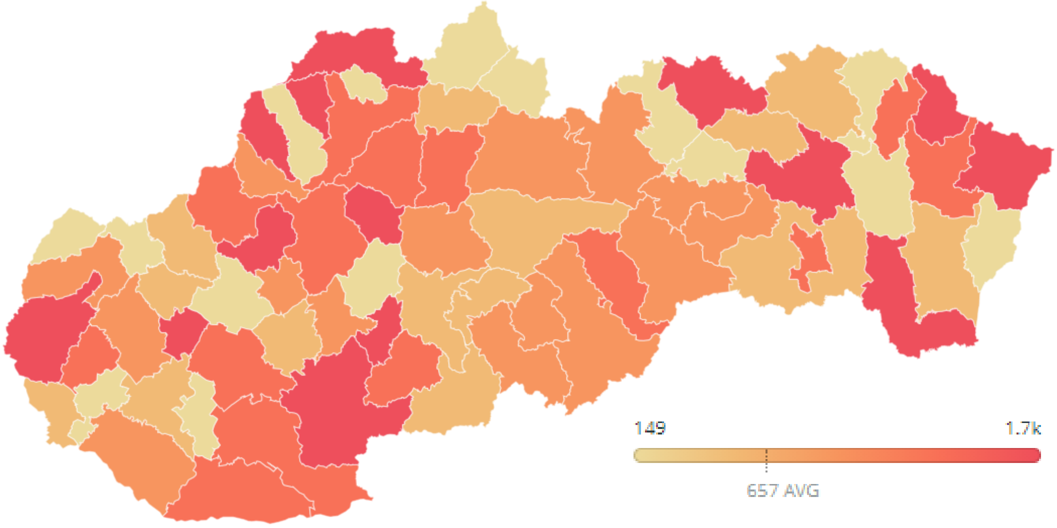


Table 2 gives the estimated number of premature deaths due to ambient air pollution (PM and NO_2) for each district[7]. The main source of premature deaths is the $PM_{2.5}$ all-cause dose response function. There are also an estimated 2-3 neonatal deaths due to PM_{10} concentrations. The total number sums to around 1,592 annual premature deaths. This means if concentrations were reduced to the guideline value of 10 μg/m³ for $PM_{2.5}$ and 20 μg/m³ for PM_{10}, annual mortality would fall by this amount. A more detailed explanation is included in the box below. The NO_2 all-cause mortality estimate is found to be zero in all districts for the reference scenario, as concentrations of this pollutant, when averaged for the whole district area, appear to be below the WHO guideline in all districts[8].

The uncertainty of estimates is shown for the total mortality by combining two sources: the 95% CI for the dose response functions, and the lower and upper bounds for estimates of concentrations stemming from differences in the models for pollutant concentrations. The latter gives rise to much bigger variations than the former. Together they suggest that the figure could lie between 1,143 and 2,013 premature deaths – a range of about +/-27%. As for the regional distribution, premature deaths related to air pollution show the highest impacts in

[7] These data are mapped to show the variations by district

[8] The concentration data are averaged for the total area of the district, which distorts the concentrations close to main NOx pollution sources. This is not avoidable within our methodology, which tends to underestimate the total impacts of NOx pollution.

regions that either have a high figure of total mortality, mostly in the south of the country (which might be caused by factors other than air pollution) and in the regions with a high level of population-weighted concentration levels of the $PM_{2.5}$ (mostly in the north of the country).

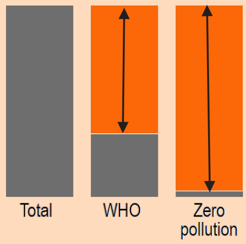
Why do we use two different guideline values in the study?

Physical and economic impacts are estimated using two guideline values. The first refers to a set of recommended maximal values established by the WHO while the second one refers to zero pollution levels that are used by the EEA in the 'Air Quality in Europe' reports. The following values are used (in μg/m^3):

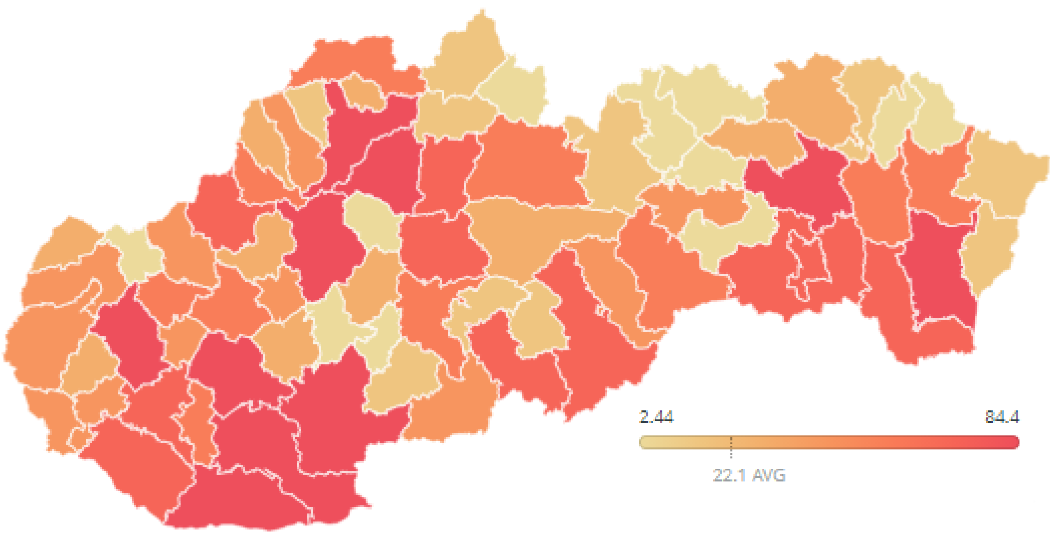
	$PM_{2.5}$ - yearly	$PM_{2.5}$ - daily	PM_{10} - yearly	PM_{10} - daily	NO_2 - yearly	NO_2 - max/hour
Zero pollution (EEA)	0	0	0	0	20	0
WHO	10	25	20	50	40	200

The impacts of air pollution are estimated as the difference between modelled air pollution level and baseline level. The chart on the right shows the total calculated air pollution impacts in orange.

We consider the WHO guidelines to be a better indicator of the total impacts given the fact that it is unlikely to achieve a zero-concentration based on the presence of natural emission sources that are beyond our control.



A comparison of the obtained estimates can be made with the EEA (2019) study. The EEA study estimates premature deaths attributable to PM at 5,426 and to NO_2 at 13. The main difference between the EEA estimate of PM and the baseline estimate of this study can be explained by the guideline value used. The EEA 2019 study published in the Air Quality in Europe 2019 Report took a zero value for PM as the guideline value and 20 μg/m^3 for NO_2. In the second scenario (zero value) when a guideline value of zero is used for PM in our calculations the resulting premature deaths are 4,375, about 80% of the EEA estimate. The EEA estimate focuses on the year 2016 while we look at 2017, which may explain some part of the difference. The remaining difference can be explained by the EEA used model which tends to overestimate pollution concentrations while concentrations provided by the Slovak Hydrometeorological Institute are generally underestimated. Using the zero-guideline value for NO2 concentrations leads to overall results similar to the EEA study.



Map 4: Baseline premature mortality related to the $PM_{2.5}$ pollution

Source: own elaboration

Table 2: Estimates of Premature Mortality Due to Ambient Air Pollution in Slovakia

	WHO guideline			Zero pollution guideline		
District	All-cause mortality ($PM_{2,5}$)	Neonatal mortality (PM_{10})	Mortality (NO_2)	All-cause mortality ($PM_{2,5}$)	Neonatal mortality (PM_{10})	Mortality (NO_2)
Total	**1 589.60**	**2.51**	**0**	**4 350.99**	**24.17**	**0**
Bánovce nad Bebravou	12.78	0.01	-	35.03	0.09	-
Banská Bystrica	40.32	0.02	-	98.35	0.15	-
Banská Štiavnica	2.44	0	-	12.73	0.02	-
Bardejov	13.84	0	-	51.96	0.47	-
Bratislava	17.08	0.11	-	46.03	0.96	-
Brezno	14.5	0	-	55.62	0.15	-
Bytča	8.62	0	-	26.48	0	-
Čadca	21.71	0	-	73.88	0.18	-
Detva	6.8	0	-	27.43	0	-
Dolný Kubín	8.4	0	-	27.23	0.15	-
Dunajská Streda	40.48	0.03	-	109.06	0.23	-
Galanta	35.56	0.03	-	92.89	0.29	-
Gelnica	3.84	0	-	22.39	0.31	-
Hlohovec	15.75	0.01	-	42.36	0.11	-
Humenné	22.3	0.03	-	56.86	0.29	-
Ilava	19.39	0.02	-	54.79	0.12	-
Kežmarok	5.8	0	-	33.65	0.81	-
Komárno	45.4	0.04	-	116.88	0.32	-
Košice	30.8	0.32	-	65.46	1.5	-
Košice - okolie	40.37	0.22	-	101.46	1.68	-
Krupina	7.2	0	-	22.5	0	-
Kysucké Nové Mesto	11.36	0	-	31.64	0.13	-
Levice	48.12	0.07	-	124.46	0.56	-
Levoča	5.48	0	-	21.19	0.2	-
Liptovský Mikuláš	25.19	0	-	67.56	0.03	-
Lučenec	34.83	0.04	-	82.06	0.24	-
Malacky	17.75	0.01	-	57.41	0.24	-
Martin	43.57	0.04	-	97.34	0.22	-
Medzilaborce	2.44	0	-	11.14	0.12	-
Michalovce	42.47	0.12	-	104.68	0.86	-
Myjava	5.86	0	-	24.48	0.03	-
Námestovo	8.37	0	-	32.23	0.19	-
Nitra	58.29	0.08	-	150.86	0.54	-
Nové Mesto nad Váhom	18.32	0.02	-	58.98	0.2	-
Nové Zámky	64.95	0.05	-	165.41	0.41	-
Partizánske	17.37	0.01	-	44.27	0.12	-
Pezinok	15.34	0.01	-	45.15	0.14	-
Piešťany	24	0.02	-	64.26	0.14	-
Poltár	7.63	0	-	22.79	0.03	-
Poprad	9.98	0	-	58.75	0.61	-
Považská Bystrica	16.01	0.01	-	52.05	0.14	-
Prešov	59.56	0.27	-	138.8	1.5	-
Prievidza	44.38	0.05	-	122.47	0.46	-
Púchov	13.56	0.01	-	40.16	0.14	-
Revúca	16.65	0.06	-	41.95	0.44	-
Rimavská Sobota	35.49	0.08	-	87.78	0.62	-

	WHO guideline			Zero pollution guideline		
District	**All-cause mortality ($PM_{2,5}$)**	**Neonatal mortality (PM_{10})**	**Mortality (NO_2)**	**All-cause mortality ($PM_{2,5}$)**	**Neonatal mortality (PM_{10})**	**Mortality (NO_2)**
Total	**1 589.60**	**2.51**	**0**	**4 350.99**	**24.17**	**0**
Rožňava	21.79	0.03	-	60.79	0.36	-
Ružomberok	32.27	0.02	-	68.78	0.12	-
Sabinov	11.3	0.03	-	36.91	0.79	-
Senec	19.24	0.01	-	52.21	0.14	-
Senica	17.85	0.03	-	53.48	0.34	-
Skalica	13.95	0.02	-	40.92	0.17	-
Snina	11.13	0.01	-	34.42	0.22	-
Sobrance	8.69	0.01	-	23.78	0.11	-
Spišská Nová Ves	17.35	0.01	-	60.39	0.78	-
Stará Ľubovňa	5.39	0	-	26.72	0.52	-
Stropkov	5.68	0	-	16.79	0.03	-
Svidník	8	0.01	-	25.1	0.19	-
Šaľa	20.24	0	-	52.25	0.03	-
Topoľčany	27.17	0.04	-	71.34	0.27	-
Trebišov	42.18	0.17	-	106.11	1.24	-
Trenčín	29.53	0.03	-	93.28	0.24	-
Trnava	42.84	0.04	-	114.1	0.32	-
Turčianske Teplice	4.51	0	-	16.34	0.03	-
Tvrdošín	4.86	0	-	20	0.09	-
Veľký Krtíš	17.51	0.01	-	46.84	0.09	-
Vranov nad Topľou	27.08	0.13	-	67.05	1	-
Zlaté Mora-vce	14.6	0.02	-	41.34	0.2	-
Zvolen	22.71	0.02	-	61.12	0.23	-
Žarnovica	6.52	0	-	24.85	0	-
Žiar nad Hronom	12.42	0	-	41.57	0.08	-
Žilina	84.39	0.08	-	173.58	0.47	-

Table 3 provides estimates of morbidity effects of ambient air pollution in physical units. The main findings at this stage are the following:

a. No effects are found for hospital admissions (HADs) for $PM_{2.5}$ (daily mean) or NO_2 (Max. 1-hour) as concentrations of these pollutants are below threshold or guideline values.
b. No effects are found for chronic bronchitis for children due to NO_2 (annual mean) as the concentration of this pollutant is below the threshold or guideline value.
c. A total of 7.3 million restricted activity days RADs per year are recorded, with Bratislava accounting for about 8%.
d. About 431 cases of chronic bronchitis among adults arise annually from PM_{10}, with Košice having the largest number.
e. There are 99 cases of asthma among 5–19-year-olds with Košice having the largest number.
f. Estimation of the number of workdays lost has been problematic as no baseline figure was available. Absenteeism from work in Slovakia in 2018 was reported at 14.22 days/employee/year[9] based on the Social Insurance Agency of Slovakia data. However, this

[9] https://gateway.euro.who.int/en/indicators/hfa_411-2700-absenteeism-from-work-due-to-illness-days-per-employee-per-year/.

data does not differentiate between causes of absenteeism. To obtain a figure of workdays lost due to respiratory illnesses it was necessary to draw on information from other countries. Estimates from the UK suggest that only about 45% of workdays lost are due to illness – the rest being accounted for by other factors[10]. However, the percentage of those accounted for by illness that are due to air pollution factors is difficult to determine. A US study on reasons for visits to the doctor finds upper respiratory conditions accounting for 22.6% of all factors[11]. These two sources have been combined to obtain some preliminary estimate of loss of workdays due to air pollution (1.45 days/ employee/ year in Slovakia). As this estimate is based on broad assumptions, it is recommended to the government to collect data on cause of absenteeism in Slovakia. Provisionally the figures from the above sources suggest a loss of about 138,000 workdays attributable to air pollution, with Bratislava having the highest loss of workdays, at nearly 11,000.

Table 3: Estimates of Morbidity Effects Due to Ambient Air Pollution in Slovakia

	WHO guideline value			Zero pollution guideline value		
District	**Restricted activity days ($PM_{2,5}$)**	**Workdays lost ($PM_{2,5}$)**	**Chronic bronchitis cases in adults (PM_{10})**	**Restricted activity days ($PM_{2,5}$)**	**Workdays lost ($PM_{2,5}$)**	**Chronic bronchitis cases in adults (PM_{10})**
Total	**2 700 222.98**	**1 273 049.65**	**430.77**	**7 342 731.26**	**3 457 389.91**	**4 025.05**
Bánovce nad Bebravou	17 898.66	8 491.64	3.73	49 040.23	23 266.08	28.44
Banská Bystrica	65 735.61	31 766.95	11.67	160 350.11	77 489.72	87.99
Banská Štiavnica	3 265.21	1 563.07	0	17 052.55	8 163.15	10.18
Bardejov	24 063.00	11 107.05	0.41	90 337.76	41 698.28	50.85
Bratislava	216 080.53	101 365.54	37.9	582 461.29	273 238.43	327.03
Brezno	18 640.86	8 763.69	0	71 486.50	33 608.17	40.32
Bytča	12 684.97	5 944.80	0.84	38 984.54	18 270.07	21.12
Čadca	32 122.69	15 556.82	0.42	109 310.48	52 938.37	60.77
Detva	9 076.02	4 303.89	0	36 599.52	17 355.67	21.81
Dolný Kubín	15 010.27	7 092.93	0.1	48 681.57	23 003.91	26.17
Dunajská Streda	60 938.60	29 727.71	10.57	164 164.96	80 084.70	92.67
Galanta	49 705.67	24 168.90	8.22	129 838.56	63 132.75	72.42
Gelnica	5 609.02	2 454.91	0	32 696.69	14 310.42	18.1
Hlohovec	22 845.24	10 820.88	3.61	61 421.64	29 093.00	34.29
Humenné	34 432.04	16 636.55	5.17	87 791.13	42 418.10	47.77
Ilava	27 818.16	13 542.45	6.56	78 605.72	38 266.88	47.34
Kežmarok	13 222.24	5 729.18	0	76 685.80	33 227.86	37.34
Komárno	55 420.91	26 717.60	10.16	142 669.65	68 778.93	80.73
Košice	181 239.79	85 891.84	43.69	385 167.05	182 535.55	205.57
Košice - okolie	71 800.51	32 469.07	11.88	180 431.79	81 593.47	91.38
Krupina	8 954.95	4 197.26	1.08	27 974.06	13 111.67	15.96
Kysucké Nové Mesto	15 755.14	7 531.80	0.76	43 869.71	20 972.06	22.77
Levice	60 085.57	28 799.56	11.1	155 407.99	74 488.47	87.56
Levoča	10 026.73	4 614.69	0	38 742.61	17 830.85	20.79
Liptovský Mikuláš	36 686.51	17 328.32	0.58	98 385.39	46 470.86	49.85
Lučenec	46 455.83	21 788.75	9.2	109 442.61	51 330.87	58.35
Malacky	27 864.69	13 036.96	2.54	90 126.49	42 167.19	50.31
Martin	66 784.76	31 712.50	13.35	149 200.90	70 847.51	78.94
Medzilaborce	2 875.66	1 310.43	0	13 114.03	5 976.05	7.77

10 https://www.timeware.co.uk/download/document/timeware-report-June-2015-absenteeism.pdf

11 https://www.fool.com/investing/general/2013/08/11/the-10-most-common-reasons-people-visit-their-doct.aspx.

District	WHO guideline value			Zero pollution guideline value		
	Restricted activity days ($PM_{2,5}$)	Workdays lost ($PM_{2,5}$)	Chronic bronchitis cases in adults (PM_{10})	Restricted activity days ($PM_{2,5}$)	Workdays lost ($PM_{2,5}$)	Chronic bronchitis cases in adults (PM_{10})
Total	**2 700 222.98**	**1 273 049.65**	**430.77**	**7 342 731.26**	**3 457 389.91**	**4 025.05**
Michalovce	64 455.81	29 976.37	11.4	158 884.37	73 892.12	83.44
Myjava	7 154.76	3 381.09	0.31	29 901.10	14 130.23	18.87
Námestovo	18 591.64	8 382.43	0	71 586.54	32 276.31	34.24
Nitra	86 478.50	40 988.54	18.82	223 818.82	106 084.26	127.85
Nové Mesto nad Váhom	24 028.24	11 227.84	4.03	77 337.86	36 138.21	46.69
Nové Zámky	77 304.30	37 044.23	14.48	196 857.98	94 334.37	111.23
Partizánske	25 241.12	12 009.34	4.61	64 318.19	30 601.61	36.27
Pezinok	27 927.74	13 043.43	3.74	82 205.42	38 393.39	45.31
Piešťany	31 957.52	15 051.45	5.52	85 581.02	40 307.21	48.78
Poltár	9 293.06	4 383.72	1.08	27 753.51	13 091.88	15.85
Poprad	18 281.72	8 511.44	0	107 591.11	50 091.31	58.22
Považská Bystrica	23 757.53	11 604.50	2.37	77 227.50	37 722.21	45.11
Prešov	111 722.88	51 480.73	24.33	260 373.69	119 977.45	136.79
Prievidza	65 362.12	31 564.58	10.59	180 380.86	87 109.28	103.85
Púchov	19 297.57	9 289.30	3.09	57 160.09	27 515.24	33.2
Revúca	22 440.45	10 285.15	3.96	56 532.24	25 910.46	29.75
Rimavská Sobota	48 817.35	22 352.04	8.46	120 744.37	55 285.31	62.79
Rožňava	29 702.82	13 824.33	3.38	82 869.16	38 569.07	44.12
Ružomberok	42 821.38	20 143.64	6.53	91 259.17	42 929.29	44.77
Sabinov	22 583.80	9 785.67	1.18	73 754.32	31 958.11	37.36
Senec	42 131.90	19 407.71	6.1	114 319.90	52 660.52	59.25
Senica	25 868.82	12 402.34	3.73	77 518.68	37 164.94	44.69
Skalica	20 770.28	9 878.56	3.53	60 934.81	28 981.23	35.2
Snina	14 920.96	7 247.68	1.33	46 146.11	22 414.93	26.33
Sobrance	11 232.73	5 236.29	1.66	30 717.53	14 319.40	16.87
Spišská Nová Ves	34 201.55	15 267.93	0.51	119 066.40	53 152.49	62.31
Stará Ľubovňa	11 615.48	5 203.89	0	57 544.00	25 780.50	30.9
Stropkov	8 987.15	4 293.90	0.95	26 576.78	12 697.92	14.72
Svidník	13 079.84	6 270.98	1.25	41 055.39	19 683.54	23.18
Šaľa	28 128.15	13 498.91	4.75	72 614.39	34 848.19	40.17
Topoľčany	37 043.87	17 799.96	8.05	97 274.03	46 741.17	56.51
Trebišov	59 430.13	27 494.43	10.55	149 502.01	69 164.80	78.68
Trenčín	45 189.34	21 221.42	12.43	142 746.39	67 035.31	90.14
Trnava	67 497.60	32 215.55	11.53	179 778.49	85 805.46	100.48
Turčianske Teplice	5 193.98	2 459.23	0.15	18 815.01	8 908.46	11.16
Tvrdošín	9 891.11	4 610.98	0	40 684.68	18 966.15	21.5
Veľký Krtíš	22 405.43	10 808.40	3.66	59 926.78	28 908.74	33.77
Vranov nad Topľou	46 576.64	21 128.01	7.52	115 327.41	52 314.60	58.22
Zlaté Moravce	18 940.60	8 991.84	3.19	53 624.31	25 457.56	31.14
Zvolen	34 746.68	16 596.53	5.13	93 533.71	44 675.80	52.25
Žarnovica	7 978.78	3 785.13	0.16	30 403.57	14 423.44	18.16
Žiar nad Hronom	17 138.66	8 122.34	0	57 362.04	27 184.99	32.21
Žilina	126 933.12	60 342.02	23.15	261 080.15	124 113.41	128.16

Monetary value of health impacts

The valuation of health impacts is divided into the valuation of premature mortality and the valuation of different morbidity endpoints. For premature mortality the literature values such cases using either the "Value of a Statistical Life" (VSL) or the "Value of Life Years Lost" (VLYL or also called VOLY). The value of statistical life is a measure based on how many individuals would be willing to pay to reduce their risk of death. For example, if a group of 100,000 individuals is willing to pay €10 each for a measure that reduces their risk of death by 1:100,000, the group would pay a total amount of €1 million (i.e. 10x100,000) to save one life. The total amount of one million is called the VSL because it represents the amount people are willing to pay to save one non-specific (i.e. statistical) life. The VLYL is based on a similar argument but now the valuation is for a measure that reduces the risk of losing one year of life.[12]

Recent research on the value of life in the EU28 estimates the VSL at €3,370,891 (mean), with a range of €1,685,446 (low) and €5,056,337 (high)[13]. These values are in 2011 prices. Adjusting for inflation to convert them into 2019 prices gives the following values: €3,668,844 (mean), €1,834,423 (low) and €5,503,267 (high)[14]. These values apply for the whole of the EU28. As the GDP per capita in Slovakia is below the EU28 average (about 82%) a further adjustment has been made based on recommendations in the Organisation for Economic Co-operation and Development (OECD, 2012) review[15] using the following formula:

$$VSL_{Slovakia} = \left(\frac{GDPPC_{Slovakia}}{GDPPC_{EU28}}\right)^{0.8} VSL_{EU28}$$

The formula is based on the reasoning that the VSL increases with per capita GDP, reflecting a higher willingness to pay (WTP) to reduce the risk of death in richer countries. The percent increase in WTP per one percent increase in per capita income is estimated in the literature as not being unity but slightly below that – a value of 0.8 is the most appropriate according to the OECD. Applying the above formula provides VSL values for Slovakia of €3,138,572 (mean), €1,569,287 (low) and €4,707,859 (high).

The VLYL estimates in the literature are €52,000 (median) and €120,000 (mean) for the EU28[16]. Adjusting these values, which are in 2000 prices, for inflation gives €71,425 (median) and €164,827 (mean). Adjusting further for the fact that GDP per capita in Slovakia is 82% of the EU28 average gives VLYL values of €61,101 (median) and €141,002 (mean). An alternative way to estimate VLYL is the figure used for policy purposes in the country. A value for a life year is set in the Slovak legislation to determine how much a new medicine can cost per added life year. This benchmark is set at max. 41-times the monthly average wage in Slovakia. As the average monthly wage in 2018 was €1,013, the valuation of an additional year according to the legislation is €41,533, somewhat lower than the numbers obtained from the literature.

In order to apply the VLYL to the premature death estimates the number of life years associated with a premature death are required and depend on whether the health impact is acute or chronic. Acute impacts have fewer years of life lost than chronic ones. The EEA (2019) uses an estimate of 10.2 years for $PM_{2.5}$ all-cause deaths. The same figure has been used here.

The resulting value of losses from premature mortality are shown in Table 4. Total losses for estimates of premature deaths according to the VSL method lie between €2.7 and €8.0 billion,

12 https://strata.org/pdf/2017/vsl-full-report.pdf

13 http://old.heatwalkingcycling.org/index.php?pg=requirements&act=vsl&b=1.

14 A further adjustment could be made to account for growth in per capita GDP between 2011 and 2019 in the EU28. This is something that can be considered in the revisions to the estimates.

15 OECD (2012), Mortality Risk Valuation in Environment, Health and Transport Policies. OECD: Paris.

16 http://en.opasnet.org/w/Value_of_a_life_year_(VOLY)#cite_note-2

with a mean value of €5.3 billion. The VLYL method gives a lower estimate: the median-based figure is €1.1 billion and the mean figure is €2.4 billion. All estimates are annual losses due to premature mortality caused by air pollution in the form of PM and NO_2.

In the case of morbidity, a range of valuations are needed, one for each endpoint. The ones that matter for Slovakia are RADs, cases of chronic bronchitis and workdays lost. For RADs and cases of chronic bronchitis the Clean Air for Europe (EU CAFÉ) study[17] is used. The values for morbidity endpoints in that study have been used extensively in EU National Air Pollution Control Programme documents and the study and figures have not been significantly updated in methodological terms. The estimate for a RAD was €130, and for a case of chronic bronchitis €190,000 (with a range of €120,000 to €250,000). Figures are per day for the EU and in 2000 prices.

Adjusting these figures for inflation and the difference in GDP per capita between the EU28 and Slovakia gives the following estimates: RAD: €172.75; case of chronic bronchitis: €223,255 (lower bound: €141,003, upper bound: €293,756). For workdays lost the average wage in Slovakia has been used giving a cost of €28.36/day[18].

The morbidity costs are presented in Table 5. Total costs across all endpoints are around €549 million, or less than half the premature mortality costs based on VLYL (median value) and about 10% of the costs based on VSL (mean value). RADs account for 75% of the total, followed by chronic bronchitis cases (17%) and asthma in children (6%). Workdays lost make up 2%; these figures, however, may be revised when better data are available.

Table 4:
Value of Losses from Premature Mortality (Euros Million)

	WHO guideline value						Zero pollution guideline value					
	Valuations Via VSL			Valuations Via VLYL			Valuations Via VSL			Valuations Via VLYL		
District	**Lower Bound**	**Mean**	**Upper Bound**	**Slovak Law**	**Median**	**Mean**	**Lower Bound**	**Mean**	**Upper Bound**	**Slovak Law**	**Median**	**Mean**
Total	**2,498**	**4,997**	**7,495**	**672**	**989**	**2,283**	**6,866**	**13,732**	**20,598**	**1,848**	**2,719**	**6,274**
Bánovce nad Bebravou	20.07	40.14	60.21	5.40	7.95	18.34	55.11	110.23	165.34	14.83	21.82	50.36
Banská Bystrica	63.31	126.61	189.92	17.04	25.07	57.85	154.57	309.15	463.72	41.61	61.21	141.25
Banská Štiavnica	3.83	7.66	11.49	1.03	1.52	3.50	20.01	40.02	60.03	5.39	7.92	18.28
Bardejov	21.72	43.44	65.16	5.85	8.60	19.85	82.28	164.56	246.83	22.15	32.58	75.18
Bratislava	26.98	53.95	80.93	7.26	10.68	24.65	73.74	147.48	221.22	19.85	29.20	67.38
Brezno	22.75	45.51	68.26	6.12	9.01	20.79	87.52	175.04	262.56	23.56	34.66	79.97
Bytča	13.53	27.05	40.58	3.64	5.36	12.36	41.55	83.11	124.66	11.18	16.45	37.97
Čadca	34.07	68.14	102.21	9.17	13.49	31.13	116.22	232.44	348.66	31.28	46.02	106.20
Detva	10.67	21.34	32.01	2.87	4.23	9.75	43.05	86.09	129.14	11.59	17.04	39.33
Dolný Kubín	13.18	26.36	39.55	3.55	5.22	12.05	42.97	85.93	128.90	11.57	17.01	39.26
Dunajská Streda	63.57	127.14	190.72	17.11	25.17	58.09	171.51	343.01	514.52	46.16	67.91	156.72
Galanta	55.85	111.70	167.55	15.03	22.12	51.04	146.23	292.45	438.68	39.36	57.90	133.62
Gelnica	6.03	12.05	18.08	1.62	2.39	5.51	35.62	71.25	106.87	9.59	14.11	32.55
Hlohovec	24.73	49.46	74.20	6.66	9.79	22.60	66.65	133.30	199.94	17.94	26.39	60.90
Humenné	35.04	70.08	105.13	9.43	13.88	32.02	89.68	179.37	269.05	24.14	35.51	81.95
Ilava	30.46	60.92	91.38	8.20	12.06	27.83	86.17	172.34	258.51	23.19	34.12	78.74
Kežmarok	9.10	18.20	27.31	2.45	3.60	8.32	54.08	108.16	162.23	14.56	21.41	49.42
Komárno	71.31	142.62	213.93	19.19	28.24	65.16	183.92	367.84	551.76	49.50	72.83	168.06
Košice	48.84	97.67	146.51	13.14	19.34	44.63	105.08	210.16	315.24	28.28	41.61	96.02

[17] AEA (2005) Service Contract for carrying out cost-benefit analysis of air quality related issues, in particular in the clean air for Europe (CAFE) programme. Methodology for the Cost-Benefit analysis for CAFE: Volume 2: Health Impact Assessment

[18] https://countryeconomy.com/national-minimum-wage/slovakia. The data gives a minimum annual wage of €6,240. It is assumed that 220 days are worked per year.

	WHO guideline value						Zero pollution guideline value					
	Valuations Via VSL			Valuations Via VLYL			Valuations Via VSL			Valuations Via VLYL		
District	**Lower Bound**	**Mean**	**Upper Bound**	**Slovak Law**	**Median**	**Mean**	**Lower Bound**	**Mean**	**Upper Bound**	**Slovak Law**	**Median**	**Mean**
Total	**2,498**	**4,997**	**7,495**	**672**	**989**	**2,283**	**6,866**	**13,732**	**20,598**	**1,848**	**2,719**	**6,274**
Košice - okolie	63.70	127.39	191.09	17.14	25.22	58.21	161.86	323.71	485.57	43.57	64.09	147.90
Krupina	11.30	22.60	33.90	3.04	4.47	10.32	35.31	70.62	105.93	9.50	13.98	32.27
Kysucké Nové Mesto	17.83	35.65	53.48	4.80	7.06	16.29	49.86	99.71	149.57	13.42	19.74	45.56
Levice	75.62	151.25	226.87	20.36	29.95	69.10	196.19	392.38	588.58	52.81	77.69	179.28
Levoča	8.60	17.20	25.80	2.31	3.41	7.86	33.57	67.13	100.70	9.03	13.29	30.67
Liptovský Mikuláš	39.53	79.06	118.59	10.64	15.65	36.12	106.07	212.14	318.20	28.55	42.00	96.92
Lučenec	54.72	109.44	164.16	14.73	21.67	50.00	129.15	258.30	387.46	34.76	51.14	118.02
Malacky	27.87	55.74	83.61	7.50	11.04	25.47	90.47	180.94	271.41	24.35	35.82	82.67
Martin	68.44	136.87	205.31	18.42	27.10	62.54	153.10	306.20	459.30	41.21	60.62	139.90
Medzilaborce	3.83	7.66	11.49	1.03	1.52	3.50	17.67	35.34	53.01	4.76	7.00	16.15
Michalovce	66.84	133.67	200.51	17.99	26.47	61.07	165.62	331.24	496.87	44.58	65.58	151.34
Myjava	9.20	18.39	27.59	2.48	3.64	8.40	38.46	76.93	115.39	10.35	15.23	35.15
Námestovo	13.13	26.27	39.40	3.54	5.20	12.00	50.88	101.75	152.63	13.69	20.15	46.49
Nitra	91.60	183.20	274.80	24.65	36.27	83.70	237.59	475.18	712.77	63.95	94.08	217.11
Nové Mesto nad Váhom	28.78	57.56	86.34	7.75	11.40	26.30	92.87	185.74	278.61	25.00	36.77	84.86
Nové Zámky	102.00	204.01	306.01	27.46	40.39	93.21	260.22	520.44	780.66	70.04	103.04	237.79
Partizánske	27.27	54.55	81.82	7.34	10.80	24.92	69.66	139.32	208.98	18.75	27.58	63.66
Pezinok	24.09	48.18	72.27	6.48	9.54	22.01	71.07	142.15	213.22	19.13	28.14	64.95
Piešťany	37.69	75.39	113.08	10.15	14.93	34.44	101.06	202.12	303.19	27.20	40.02	92.35
Poltár	11.97	23.95	35.92	3.22	4.74	10.94	35.81	71.62	107.43	9.64	14.18	32.72
Poprad	15.66	31.32	46.98	4.22	6.20	14.31	93.15	186.31	279.46	25.07	36.89	85.12
Považská Bystrica	25.14	50.28	75.42	6.77	9.95	22.97	81.90	163.80	245.70	22.04	32.43	74.84
Prešov	93.89	187.78	281.67	25.27	37.18	85.80	220.17	440.34	660.51	59.26	87.18	201.19
Prievidza	69.72	139.45	209.17	18.77	27.61	63.71	192.91	385.82	578.74	51.92	76.39	176.28
Púchov	21.30	42.59	63.89	5.73	8.43	19.46	63.24	126.48	189.73	17.02	25.04	57.79
Revúca	26.22	52.45	78.67	7.06	10.38	23.96	66.52	133.04	199.57	17.91	26.34	60.79
Rimavská Sobota	55.82	111.64	167.46	15.02	22.10	51.01	138.72	277.45	416.17	37.34	54.93	126.77
Rožňava	34.24	68.48	102.73	9.22	13.56	31.29	95.96	191.92	287.89	25.83	38.00	87.69
Ružomberok	50.67	101.34	152.02	13.64	20.06	46.30	108.12	216.25	324.37	29.10	42.81	98.80
Sabinov	17.78	35.56	53.34	4.79	7.04	16.25	59.16	118.32	177.49	15.92	23.43	54.06
Senec	30.21	60.42	90.63	8.13	11.96	27.60	82.15	164.30	246.46	22.11	32.53	75.07
Senica	28.06	56.12	84.18	7.55	11.11	25.64	84.46	168.92	253.38	22.73	33.44	77.18
Skalica	21.92	43.85	65.77	5.90	8.68	20.03	64.48	128.96	193.45	17.36	25.53	58.92
Snina	17.48	34.96	52.45	4.71	6.92	15.97	54.36	108.72	163.08	14.63	21.53	49.67
Sobrance	13.65	27.31	40.96	3.67	5.41	12.48	37.49	74.98	112.47	10.09	14.85	34.26
Spišská Nová Ves	27.24	54.49	81.73	7.33	10.79	24.89	95.99	191.99	287.98	25.84	38.01	87.72
Stará Ľubovňa	8.46	16.92	25.38	2.28	3.35	7.73	42.75	85.49	128.24	11.51	16.93	39.06
Stropkov	8.91	17.83	26.74	2.40	3.53	8.15	26.40	52.79	79.19	7.10	10.45	24.12
Svidník	12.57	25.14	37.71	3.38	4.98	11.49	39.69	79.37	119.06	10.68	15.72	36.27
Šaľa	31.76	63.52	95.29	8.55	12.58	29.02	82.04	164.08	246.13	22.08	32.49	74.97
Topoľčany	42.70	85.40	128.10	11.49	16.91	39.02	112.38	224.75	337.13	30.25	44.50	102.69
Trebišov	66.46	132.92	199.38	17.89	26.32	60.73	168.46	336.93	505.39	45.34	66.71	153.94
Trenčín	46.39	92.78	139.16	12.49	18.37	42.39	146.76	293.52	440.28	39.50	58.11	134.11
Trnava	67.29	134.58	201.87	18.11	26.65	61.49	179.56	359.12	538.67	48.33	71.10	164.08
Turčianske Teplice	7.08	14.15	21.23	1.90	2.80	6.47	25.69	51.38	77.07	6.91	10.17	23.47
Tvrdošín	7.63	15.25	22.88	2.05	3.02	6.97	31.53	63.05	94.58	8.49	12.48	28.81
Veľký Krtíš	27.49	54.99	82.48	7.40	10.89	25.12	73.65	147.29	220.94	19.82	29.16	67.30

	WHO guideline value						Zero pollution guideline value					
	Valuations Via VSL			Valuations Via VLYL			Valuations Via VSL			Valuations Via VLYL		
District	Lower Bound	Mean	Upper Bound	Slovak Law	Median	Mean	Lower Bound	Mean	Upper Bound	Slovak Law	Median	Mean
Total	**2,498**	**4,997**	**7,495**	**672**	**989**	**2,283**	**6,866**	**13,732**	**20,598**	**1,848**	**2,719**	**6,274**
Vranov nad Topľou	42.70	85.40	128.10	11.49	16.91	39.02	106.79	213.58	320.37	28.74	42.29	97.58
Zlaté Moravce	22.94	45.89	68.83	6.18	9.08	20.97	65.19	130.38	195.56	17.55	25.81	59.57
Zvolen	35.67	71.34	107.01	9.60	14.12	32.59	96.28	192.55	288.83	25.91	38.12	87.98
Žarnovica	10.23	20.46	30.70	2.75	4.05	9.35	39.00	77.99	116.99	10.50	15.44	35.63
Žiar nad Hronom	19.49	38.98	58.47	5.25	7.72	17.81	65.36	130.72	196.08	17.59	25.88	59.73
Žilina	132.56	265.12	397.67	35.68	52.49	121.13	273.13	546.27	819.40	73.52	108.15	249.59

Table 5:
Value of Losses from Morbidity (Euros Million)

	WHO guideline value					Zero pollution guideline value				
District	RADs (mean)	Workdays Lost (mean)	Chronic Bronchitis (low)	Chronic Bronchitis (mean)	Chronic Bronchitis (high)	RADs (mean)	Workdays Lost (mean)	Chronic Bronchitis (low)	Chronic Bronchitis (mean)	Chronic Bronchitis (high)
Total	**413.13**	**52.2**	**60.74**	**96.17**	**126.54**	**1123.44**	**141.75**	**567.54**	**898.61**	**1182.38**
Bánovce nad Bebravou	2.74	0.35	0.53	0.83	1.1	7.5	0.95	4.01	6.35	8.35
Banská Bystrica	10.06	1.3	1.65	2.61	3.43	24.53	3.18	12.41	19.64	25.85
Banská Štiavnica	0.5	0.06	0	0	0	2.61	0.33	1.44	2.27	2.99
Bardejov	3.68	0.46	0.06	0.09	0.12	13.82	1.71	7.17	11.35	14.94
Bratislava	33.06	4.16	5.34	8.46	11.13	89.12	11.2	46.11	73.01	96.07
Brezno	2.85	0.36	0	0	0	10.94	1.38	5.69	9	11.84
Bytča	1.94	0.24	0.12	0.19	0.25	5.96	0.75	2.98	4.72	6.2
Čadca	4.91	0.64	0.06	0.09	0.12	16.72	2.17	8.57	13.57	17.85
Detva	1.39	0.18	0	0	0	5.6	0.71	3.08	4.87	6.41
Dolný Kubín	2.3	0.29	0.01	0.02	0.03	7.45	0.94	3.69	5.84	7.69
Dunajská Streda	9.32	1.22	1.49	2.36	3.11	25.12	3.28	13.07	20.69	27.22
Galanta	7.6	0.99	1.16	1.84	2.42	19.87	2.59	10.21	16.17	21.27
Gelnica	0.86	0.1	0	0	0	5	0.59	2.55	4.04	5.32
Hlohovec	3.5	0.44	0.51	0.81	1.06	9.4	1.19	4.84	7.66	10.07
Humenné	5.27	0.68	0.73	1.15	1.52	13.43	1.74	6.74	10.66	14.03
Ilava	4.26	0.56	0.92	1.46	1.93	12.03	1.57	6.68	10.57	13.91
Kežmarok	2.02	0.23	0	0	0	11.73	1.36	5.27	8.34	10.97
Komárno	8.48	1.1	1.43	2.27	2.98	21.83	2.82	11.38	18.02	23.71
Košice	27.73	3.52	6.16	9.76	12.84	58.93	7.48	28.99	45.89	60.39
Košice - okolie	10.99	1.33	1.68	2.65	3.49	27.61	3.35	12.89	20.4	26.84
Krupina	1.37	0.17	0.15	0.24	0.32	4.28	0.54	2.25	3.56	4.69
Kysucké Nové Mesto	2.41	0.31	0.11	0.17	0.22	6.71	0.86	3.21	5.08	6.69
Levice	9.19	1.18	1.57	2.48	3.26	23.78	3.05	12.35	19.55	25.72
Levoča	1.53	0.19	0	0	0	5.93	0.73	2.93	4.64	6.11
Liptovský Mikuláš	5.61	0.71	0.08	0.13	0.17	15.05	1.91	7.03	11.13	14.64
Lučenec	7.11	0.89	1.3	2.05	2.7	16.74	2.1	8.23	13.03	17.14
Malacky	4.26	0.53	0.36	0.57	0.75	13.79	1.73	7.09	11.23	14.78
Martin	10.22	1.3	1.88	2.98	3.92	22.83	2.9	11.13	17.62	23.19
Medzilaborce	0.44	0.05	0	0	0	2.01	0.25	1.1	1.73	2.28
Michalovce	9.86	1.23	1.61	2.55	3.35	24.31	3.03	11.77	18.63	24.51

	WHO guideline value					Zero pollution guideline value				
District	RADs (mean)	Workdays Lost (mean)	Chronic Bronchitis (low)	Chronic Bronchitis (mean)	Chronic Bronchitis (high)	RADs (mean)	Workdays Lost (mean)	Chronic Bronchitis (low)	Chronic Bronchitis (mean)	Chronic Bronchitis (high)
Total	**413.13**	**52.2**	**60.74**	**96.17**	**126.54**	**1123.44**	**141.75**	**567.54**	**898.61**	**1182.38**
Myjava	1.09	0.14	0.04	0.07	0.09	4.57	0.58	2.66	4.21	5.54
Námestovo	2.84	0.34	0	0	0	10.95	1.32	4.83	7.64	10.06
Nitra	13.23	1.68	2.65	4.2	5.53	34.24	4.35	18.03	28.54	37.56
Nové Mesto nad Váhom	3.68	0.46	0.57	0.9	1.19	11.83	1.48	6.58	10.42	13.72
Nové Zámky	11.83	1.52	2.04	3.23	4.25	30.12	3.87	15.68	24.83	32.67
Partizánske	3.86	0.49	0.65	1.03	1.35	9.84	1.25	5.11	8.1	10.65
Pezinok	4.27	0.53	0.53	0.83	1.1	12.58	1.57	6.39	10.12	13.31
Piešťany	4.89	0.62	0.78	1.23	1.62	13.09	1.65	6.88	10.89	14.33
Poltár	1.42	0.18	0.15	0.24	0.32	4.25	0.54	2.23	3.54	4.66
Poprad	2.8	0.35	0	0	0	16.46	2.05	8.21	13	17.1
Považská Bystrica	3.63	0.48	0.33	0.53	0.7	11.82	1.55	6.36	10.07	13.25
Prešov	17.09	2.11	3.43	5.43	7.15	39.84	4.92	19.29	30.54	40.18
Prievidza	10	1.29	1.49	2.36	3.11	27.6	3.57	14.64	23.19	30.51
Púchov	2.95	0.38	0.44	0.69	0.91	8.75	1.13	4.68	7.41	9.75
Revúca	3.43	0.42	0.56	0.88	1.16	8.65	1.06	4.19	6.64	8.74
Rimavská Sobota	7.47	0.92	1.19	1.89	2.48	18.47	2.27	8.85	14.02	18.45
Rožňava	4.54	0.57	0.48	0.75	0.99	12.68	1.58	6.22	9.85	12.96
Ružomberok	6.55	0.83	0.92	1.46	1.92	13.96	1.76	6.31	9.99	13.15
Sabinov	3.46	0.4	0.17	0.26	0.35	11.28	1.31	5.27	8.34	10.97
Senec	6.45	0.8	0.86	1.36	1.79	17.49	2.16	8.35	13.23	17.41
Senica	3.96	0.51	0.53	0.83	1.1	11.86	1.52	6.3	9.98	13.13
Skalica	3.18	0.41	0.5	0.79	1.04	9.32	1.19	4.96	7.86	10.34
Snina	2.28	0.3	0.19	0.3	0.39	7.06	0.92	3.71	5.88	7.73
Sobrance	1.72	0.21	0.23	0.37	0.49	4.7	0.59	2.38	3.77	4.96
Spišská Nová Ves	5.23	0.63	0.07	0.11	0.15	18.22	2.18	8.79	13.91	18.3
Stará Ľubovňa	1.78	0.21	0	0	0	8.8	1.06	4.36	6.9	9.08
Stropkov	1.38	0.18	0.13	0.21	0.28	4.07	0.52	2.07	3.29	4.32
Svidník	2	0.26	0.18	0.28	0.37	6.28	0.81	3.27	5.17	6.81
Šaľa	4.3	0.55	0.67	1.06	1.39	11.11	1.43	5.66	8.97	11.8
Topoľčany	5.67	0.73	1.14	1.8	2.36	14.88	1.92	7.97	12.62	16.6
Trebišov	9.09	1.13	1.49	2.35	3.1	22.87	2.84	11.09	17.57	23.11
Trenčín	6.91	0.87	1.75	2.78	3.65	21.84	2.75	12.71	20.12	26.48
Trnava	10.33	1.32	1.63	2.57	3.39	27.51	3.52	14.17	22.43	29.52
Turčianske Teplice	0.79	0.1	0.02	0.03	0.04	2.88	0.37	1.57	2.49	3.28
Tvrdošín	1.51	0.19	0	0	0	6.22	0.78	3.03	4.8	6.32
Veľký Krtíš	3.43	0.44	0.52	0.82	1.08	9.17	1.19	4.76	7.54	9.92
Vranov nad Topľou	7.13	0.87	1.06	1.68	2.21	17.65	2.14	8.21	13	17.1
Zlaté Moravce	2.9	0.37	0.45	0.71	0.94	8.2	1.04	4.39	6.95	9.15
Zvolen	5.32	0.68	0.72	1.15	1.51	14.31	1.83	7.37	11.66	15.35
Žarnovica	1.22	0.16	0.02	0.03	0.05	4.65	0.59	2.56	4.05	5.33
Žiar nad Hronom	2.62	0.33	0	0	0	8.78	1.11	4.54	7.19	9.46
Žilina	19.42	2.47	3.26	5.17	6.8	39.95	5.09	18.07	28.61	37.65

IV. Reduction scenario after the implementation of the NAPCP and the possible health impacts

The NAPCP for Slovakia has been formulated to meet the air quality and emission reduction targets by 2030 and consists of several measures to reduce emissions of $PM_{2.5}$, nitrogen oxides (NO_x), sulfur dioxide (SO_2) and ammonia (NH_3) across transport, residential heating and agriculture sectors. Table 6 lists the measures in the NAPCP.

Table 6: Set of measures to reduce emissions of SO_2, NO_x, NMVOC, NH_3 and $PM_{2.5}$

Sector	Potential Measures
Road Transport	▪ Subsidy for replacement of old diesel vehicles ▪ Introducing subsidies for alternatively-fueled vehicles ▪ Stricter NO_x periodical technical controls of vehicles ▪ Frequency of technical controls of vehicles older than 8 years to be raised from currently once every two years to once a year ▪ Road emission controls for DPF removal – raising frequency of control
Residential heating	▪ Incentives for replacement of unsuitable boilers by using a scrapping scheme ▪ Incentives for replacement of unsuitable boilers: subsidy scheme ▪ Introduction of differentiated registration fees for different categories of heating devices to promote more environmentally friendly devices ▪ Connect households using wood or coal for heating to natural gas ▪ Fuel standards mandating the use of wood that has a moisture content of less than 25% ▪ Introduction of a "control system" (based on the Czech model) – each household that uses solid fuel would have an obligation to have its device regularly inspected ▪ Awareness raising campaigns and education
Economic instruments	▪ Unification of tax rate for petrol and diesel over a period of 5 years
Agriculture	▪ Manure storage and application to soil

Source: World Bank and Ministry of Environment (2019) Report

The measures in Table 6 were analyzed in detail in an earlier study regarding reductions in emissions Slovakia can achieve over the period 2020 to 2030, as well as the economic and fiscal costs of the reductions[19]. That ***assessment of emissions reductions achievable through the NAPCP showed that emission reductions would not be sufficient to meet the 2030 Emission Reduction Commitments for $PM_{2.5}$*** as set out in the National Emission Ceilings Directive 2016/2284. While NOx, non-methane volatile organic compound (NMVOC), SO_2, and NH_3 emissions would be below the 2030 target, $PM_{2.5}$ emissions would be above the 2030 target. Therefore, the impacts of air pollution on health will need to be reduced further even after a full implementation of the NAPCP if the commitments are to be met for all emissions.

This section reports the reductions in health impacts achieved by 2030 if the NAPCP is fully implemented. These are reported in physical units as well as in monetary terms, using valuations of different health impacts elaborated in previous sections.

[19] World Bank and Ministry of Environment: Final Report, Slovak Republic Air Protection Strategy, May 2019. This report is a foundation of the National Air Pollution Control Programme, which has been approved by the government in 2020.

The health impacts of the implementation of the NAPCP have been calculated for all health indicators. Two reduction scenarios have been calculated for each district—one scenario calculates the concentrations for the year 2020 and is used to benchmark the no policy case. A second scenario is calculated for the year 2030, which includes the overall impact of all measures proposed in the NAPCP. The total impact of the NAPCP is calculated as the difference between these two scenarios. The physical as well as monetary impacts of these interventions are approximately the same for both guideline systems (WHO maximum recommended concentrations as well as zero pollution values used by the EEA), with the impact being slightly larger for indicators showing impacts of PM_{10} pollution with the zero reference case. Table 7 shows the reductions in mortality and selected morbidity indicators by district. Tables 8 and 9 reflects monetary values associated with these reductions. In total, the NAPCP is expected to save about 116 lives in 2030, and reduces restricted activity days by 195,000, workdays lost by 92,000 and chronic bronchitis cases by about 81.

Table 7: Estimates of Premature Mortality Reductions due to Implementation of the NAPCP based on WHO baseline values

	Mortality reductions			Morbidity reductions		
District	**All-cause mortality ($PM_{2,5}$)**	**Neonatal mortality (PM_{10})**	**Mortality (NO_2)**	**Restricted activity days ($PM_{2,5}$)**	**Workdays lost ($PM_{2,5}$)**	**Chronic bronchitis cases in adults (PM_{10})**
Total	**116.0**	**0.4**	**0.0**	**195133.7**	**91902.0**	**80.5**
Bánovce nad Bebravou	1.0	0.0	0.0	1450.7	688.3	0.9
Banská Bystrica	4.3	0.0	0.0	7018.3	3391.6	2.8
Banská Štiavnica	0.4	0.0	0.0	553.2	264.8	0.0
Bardejov	1.0	0.0	0.0	1794.4	828.3	0.0
Bratislava	1.1	0.0	0.0	14333.6	6724.0	7.8
Brezno	2.3	0.0	0.0	2917.4	1371.6	0.0
Bytča	0.8	0.0	0.0	1201.7	563.2	0.0
Čadca	2.4	0.0	0.0	3497.5	1693.8	0.0
Detva	1.0	0.0	0.0	1331.8	631.5	0.0
Dolný Kubín	1.0	0.0	0.0	1876.3	886.6	0.0
Dunajská Streda	1.7	0.0	0.0	2505.6	1222.3	1.4
Galanta	1.9	0.0	0.0	2615.6	1271.8	1.4
Gelnica	0.6	0.0	0.0	927.1	405.8	0.0
Hlohovec	1.0	0.0	0.0	1387.3	657.1	0.9
Humenné	1.0	0.0	0.0	1489.6	719.7	0.9
Ilava	1.3	0.0	0.0	1922.6	935.9	1.4
Kežmarok	0.9	0.0	0.0	2134.4	924.8	0.0
Komárno	1.8	0.0	0.0	2187.4	1054.5	1.4
Košice	1.9	0.0	0.0	10946.9	5187.9	6.0
Košice - okolie	2.5	0.0	0.0	4358.5	1971.0	2.3
Krupina	0.7	0.0	0.0	811.9	380.5	0.5
Kysucké Nové Mesto	1.3	0.0	0.0	1750.7	836.9	0.0
Levice	3.4	0.0	0.0	4289.6	2056.1	2.3
Levoča	0.6	0.0	0.0	1173.3	540.0	0.0
Liptovský Mikuláš	3.0	0.0	0.0	4402.4	2079.4	0.0
Lučenec	2.9	0.0	0.0	3892.4	1825.6	2.3
Malacky	0.7	0.0	0.0	1060.7	496.3	0.5
Martin	3.3	0.0	0.0	5068.4	2406.7	2.8
Medzilaborce	0.2	0.0	0.0	200.9	91.5	0.0
Michalovce	1.4	0.0	0.0	2087.9	971.0	0.9
Myjava	0.5	0.0	0.0	568.8	268.8	0.0

	Mortality reductions			Morbidity reductions		
District	**All-cause mortality ($PM_{2,5}$)**	**Neonatal mortality (PM_{10})**	**Mortality (NO_2)**	**Restricted activity days ($PM_{2,5}$)**	**Workdays lost ($PM_{2,5}$)**	**Chronic bronchitis cases in adults (PM_{10})**
Total	**116.0**	**0.4**	**0.0**	**195133.7**	**91902.0**	**80.5**
Námestovo	1.2	0.0	0.0	2701.6	1218.1	0.0
Nitra	4.0	0.0	0.0	5962.5	2826.1	3.2
Nové Mesto nad Váhom	1.2	0.0	0.0	1581.1	738.8	0.9
Nové Zámky	3.6	0.0	0.0	4253.7	2038.4	2.3
Partizánske	1.4	0.0	0.0	2035.1	968.3	0.9
Pezinok	0.8	0.0	0.0	1421.4	663.9	0.9
Piešťany	1.4	0.0	0.0	1895.6	892.8	0.9
Poltár	0.8	0.0	0.0	1018.3	480.3	0.5
Poprad	1.7	0.0	0.0	3132.7	1458.5	0.0
Považská Bystrica	1.7	0.0	0.0	2536.5	1239.0	0.5
Prešov	3.4	0.0	0.0	6310.9	2908.0	3.2
Prievidza	4.3	0.0	0.0	6347.4	3065.3	3.7
Púchov	1.3	0.0	0.0	1798.8	865.9	0.9
Revúca	1.5	0.0	0.0	2006.6	919.7	0.9
Rimavská Sobota	2.9	0.0	0.0	3987.5	1825.8	2.3
Rožňava	2.3	0.0	0.0	3089.5	1437.9	0.9
Ružomberok	3.3	0.0	0.0	4417.6	2078.1	2.3
Sabinov	0.9	0.0	0.0	1841.4	797.9	0.0
Senec	1.0	0.0	0.0	2216.4	1021.0	0.9
Senica	0.7	0.0	0.0	1058.7	507.6	0.5
Skalica	0.5	0.0	0.0	725.2	344.9	0.5
Snina	0.5	0.0	0.0	613.4	298.0	0.5
Sobrance	0.2	0.0	0.0	268.9	125.3	0.0
Spišská Nová Ves	1.9	0.0	0.0	3809.2	1700.5	0.0
Stará Ľubovňa	0.6	0.0	0.0	1333.9	597.6	0.0
Stropkov	0.3	0.0	0.0	459.4	219.5	0.5
Svidník	0.4	0.0	0.0	733.0	351.4	0.5
Šaľa	1.1	0.0	0.0	1493.1	716.5	0.9
Topoľčany	1.8	0.0	0.0	2445.1	1174.9	1.4
Trebišov	1.3	0.0	0.0	1866.8	863.6	0.9
Trenčín	2.2	0.0	0.0	3426.6	1609.2	2.3
Trnava	2.2	0.0	0.0	3493.2	1667.2	1.8
Turčianske Teplice	0.6	0.0	0.0	641.5	303.7	0.0
Tvrdošín	0.7	0.0	0.0	1412.5	658.5	0.0
Veľký Krtíš	1.3	0.0	0.0	1712.3	826.0	0.9
Vranov nad Topľou	1.2	0.0	0.0	2097.9	951.7	0.9
Zlaté Moravce	1.3	0.0	0.0	1695.4	804.9	0.9
Zvolen	2.4	0.0	0.0	3605.2	1722.0	1.4
Žarnovica	0.8	0.0	0.0	1021.0	484.4	0.0
Žiar nad Hronom	1.4	0.0	0.0	1913.9	907.0	0.0
Žilina	6.0	0.0	0.0	8996.1	4276.6	4.6

V. Economic impacts of the NAPCP

Tables 8 and 9 reflect monetary values of reduction in concentrations associated with the NAPCP. Map 5 illustrates the same information in form of a map comparing health costs in 2030 with health costs in 2020. As we discuss in the next section, however, the NAPCP generates benefits in the intervening years. Therefore, the full value of the NAPCP is more complex than this comparison suggests. In spite of this, the tables and associated maps are useful in indicating how the values of health impacts for 2020 and 2030 stand up against each other. This can be seen in Map 5, which depicts the value of avoided premature mortality and reductions in morbidity for each district per year. The biggest value can be achieved through the implementation of air quality measures in districts with the highest current population exposure to pollutants.

Map 5: Value of Avoided Losses from Premature Mortality and Reduced Morbidity (Euros Million)

Source: own elaboration

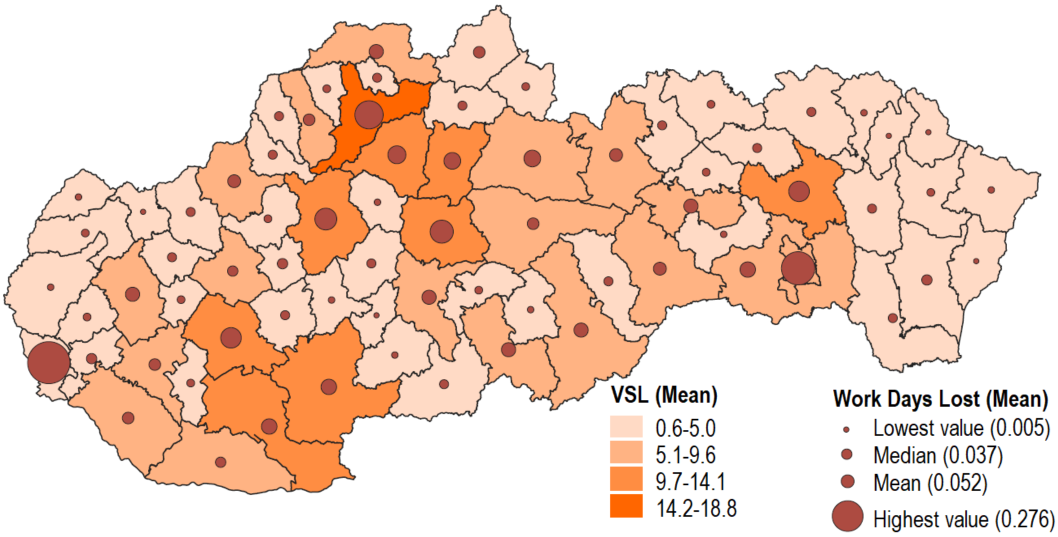


Table 8 reports on the values of reduced mortality (€397-€1,192 million via VSL and €107-€363 million via VLYL). Table 9 reports on the values of reduced morbidity (€97-€124 million). These figures are based on calculations obtained relative to the WHO guideline values. The estimates are similar to using the zero-pollution guideline value for mortality. For morbidity the estimates are about 8% higher using a zero-pollution guideline value.

Table 8: Value of Losses from Premature Mortality Avoided Through Implementation of NAPCP (Euros Million)

	Valuations Via VSL.			Valuations Via VLYL		
District	**Lower Bound**	**Mean**	**Upper Bound**	**Legislation**	**Median**	**Mean**
Total	182.8	365.6	548.4	49.2	72.4	167.0
Bánovce nad Bebravou	1.6	3.3	4.9	0.5	0.6	1.5
Banská Bystrica	6.8	13.5	20.3	1.8	2.7	6.2
Banská Štiavnica	0.6	1.3	1.9	0.2	0.3	0.6
Bardejov	1.6	3.2	4.9	0.4	0.6	1.5
Bratislava	1.8	3.6	5.4	0.5	0.7	1.7
Brezno	3.5	7.1	10.7	1.0	1.4	3.3
Bytča	1.3	2.6	3.9	0.3	0.5	1.2
Čadca	3.7	7.4	11.1	1.0	1.5	3.4
Detva	1.6	3.1	4.7	0.4	0.6	1.4
Dolný Kubín	1.7	3.3	4.9	0.5	0.6	1.5
Dunajská Streda	2.6	5.2	7.9	0.7	1.1	2.4
Galanta	2.9	5.9	8.8	0.8	1.2	2.7
Gelnica	1.0	2.0	3.0	0.3	0.4	0.9
Hlohovec	1.5	3.0	4.5	0.4	0.6	1.4
Humenné	1.5	3.0	4.6	0.4	0.6	1.4
Ilava	2.1	4.2	6.3	0.6	0.8	1.9
Kežmarok	1.5	2.9	4.4	0.4	0.6	1.3
Komárno	2.8	5.7	8.5	0.8	1.1	2.6
Košice	3.0	6.0	9.0	0.8	1.2	2.7
Košice - okolie	3.9	7.8	11.7	1.1	1.6	3.6
Krupina	1.0	2.1	3.1	0.3	0.4	0.9
Kysucké Nové Mesto	2.0	4.0	5.9	0.6	0.8	1.8
Levice	5.4	10.8	16.2	1.5	2.2	5.0
Levoča	1.0	2.0	3.0	0.3	0.4	0.9
Liptovský Mikuláš	4.7	9.5	14.2	1.3	1.9	4.3
Lučenec	4.6	9.2	13.8	1.2	1.8	4.2
Malacky	1.1	2.1	3.2	0.3	0.4	1.0
Martin	5.2	10.4	15.6	1.4	2.1	4.7
Medzilaborce	0.3	0.6	0.8	0.1	0.1	0.2
Michalovce	2.2	4.4	6.5	0.6	0.9	2.0
Myjava	0.7	1.5	2.2	0.2	0.3	0.7
Námestovo	1.9	3.8	5.7	0.5	0.7	1.7
Nitra	6.3	12.7	19.0	1.7	2.5	5.8
Nové Mesto nad Váhom	1.9	3.8	5.7	0.5	0.7	1.7
Nové Zámky	5.6	11.2	16.9	1.5	2.2	5.2
Partizánske	2.2	4.4	6.6	0.6	0.9	2.0
Pezinok	1.2	2.4	3.7	0.3	0.5	1.1
Piešťany	2.3	4.5	6.7	0.6	0.9	2.0
Poltár	1.3	2.6	4.0	0.4	0.5	1.2
Poprad	2.7	5.4	8.1	0.7	1.1	2.4
Považská Bystrica	2.7	5.4	8.1	0.7	1.1	2.4
Prešov	5.3	10.7	16.0	1.4	2.1	4.9
Prievidza	6.8	13.6	20.4	1.8	2.7	6.2
Púchov	2.0	4.0	6.0	0.6	0.8	1.8
Revúca	2.3	4.7	7.1	0.6	0.9	2.2

	Valuations Via VSL.			Valuations Via VLYL		
District	**Lower Bound**	**Mean**	**Upper Bound**	**Legislation**	**Median**	**Mean**
Total	182.8	365.6	548.4	49.2	72.4	167.0
Rimavská Sobota	4.6	9.2	13.8	1.2	1.8	4.2
Rožňava	3.6	7.1	10.7	1.0	1.4	3.3
Ružomberok	5.2	10.5	15.7	1.4	2.1	4.8
Sabinov	1.5	2.9	4.4	0.4	0.6	1.3
Senec	1.6	3.2	4.8	0.4	0.6	1.5
Senica	1.2	2.3	3.5	0.3	0.5	1.1
Skalica	0.8	1.5	2.3	0.2	0.3	0.7
Snina	0.7	1.4	2.2	0.2	0.3	0.6
Sobrance	0.3	0.6	1.0	0.1	0.1	0.3
Spišská Nová Ves	3.0	6.1	9.1	0.8	1.2	2.8
Stará Ľubovňa	1.0	1.9	2.9	0.3	0.4	0.9
Stropkov	0.5	0.9	1.4	0.1	0.2	0.4
Svidník	0.7	1.4	2.1	0.2	0.3	0.6
Šaľa	1.7	3.4	5.1	0.5	0.7	1.6
Topoľčany	2.8	5.7	8.5	0.8	1.1	2.6
Trebišov	2.1	4.2	6.3	0.6	0.8	1.9
Trenčín	3.5	7.0	10.6	1.0	1.4	3.2
Trnava	3.5	7.0	10.5	0.9	1.4	3.2
Turčianske Teplice	0.9	1.7	2.6	0.2	0.4	0.8
Tvrdošín	1.1	2.2	3.3	0.3	0.4	1.0
Veľký Krtíš	2.1	4.2	6.3	0.6	0.8	1.9
Vranov nad Topľou	1.9	3.9	5.8	0.5	0.8	1.8
Zlaté Moravce	2.1	4.1	6.2	0.6	0.8	1.9
Zvolen	3.7	7.4	11.1	1.0	1.5	3.4
Žarnovica	1.3	2.6	3.9	0.4	0.5	1.2
Žiar nad Hronom	2.2	4.4	6.5	0.6	0.9	2.0
Žilina	9.4	18.8	28.2	2.5	3.7	8.6

Table 9:
Value of Losses from Morbidity Avoided Through Implementation of NAPCP (Euros Million)

	WHO guideline value					Zero pollution guideline value				
District	**RADs (mean)**	**Workdays Lost (mean)**	**Chronic Bronchitis (low)**	**Chronic Bronchitis (mean)**	**Chronic Bronchitis (high)**	**RADs (mean)**	**Workdays Lost (mean)**	**Chronic Bronchitis (low)**	**Chronic Bronchitis (mean)**	**Chronic Bronchitis (high)**
Total	29.85	3.77	11.33	17.94	23.60	29.85	3.77	15.02	23.78	31.29
Bánovce nad Bebravou	0.22	0.03	0.12	0.19	0.25	0.22	0.03	0.12	0.19	0.25
Banská Bystrica	1.07	0.14	0.40	0.63	0.82	1.07	0.14	0.54	0.86	1.13
Banská Štiavnica	0.08	0.01	-	-	-	0.08	0.01	0.05	0.07	0.10
Bardejov	0.28	0.03	-	-	-	0.28	0.03	0.14	0.23	0.30
Bratislava	2.19	0.28	1.14	1.80	2.36	2.19	0.28	1.14	1.80	2.36
Brezno	0.45	0.06	-	-	-	0.45	0.06	0.23	0.37	0.48
Bytča	0.18	0.02	0.02	0.03	0.05	0.18	0.02	0.09	0.15	0.19
Čadca	0.53	0.07	-	-	-	0.53	0.07	0.28	0.43	0.57
Detva	0.20	0.03	-	-	-	0.20	0.03	0.11	0.18	0.23
Dolný Kubín	0.29	0.04	-	-	-	0.29	0.04	0.14	0.23	0.29
Dunajská Streda	0.38	0.05	0.20	0.32	0.41	0.38	0.05	0.20	0.32	0.41
Galanta	0.40	0.05	0.21	0.33	0.43	0.40	0.05	0.21	0.33	0.43
Gelnica	0.14	0.02	-	-	-	0.14	0.02	0.07	0.12	0.15
Hlohovec	0.21	0.03	0.11	0.17	0.23	0.21	0.03	0.11	0.17	0.23
Humenné	0.23	0.03	0.12	0.18	0.24	0.23	0.03	0.12	0.18	0.24
Ilava	0.29	0.04	0.16	0.26	0.34	0.29	0.04	0.16	0.26	0.34
Kežmarok	0.33	0.04	-	-	-	0.33	0.04	0.15	0.23	0.30
Komárno	0.34	0.04	0.17	0.28	0.36	0.34	0.04	0.17	0.28	0.36
Košice	1.67	0.21	0.82	1.31	1.72	1.67	0.21	0.82	1.31	1.72
Košice - okolie	0.67	0.08	0.31	0.49	0.65	0.67	0.08	0.31	0.49	0.65
Krupina	0.12	0.01	0.05	0.07	0.09	0.12	0.01	0.06	0.10	0.14
Kysucké Nové Mesto	0.27	0.03	0.00	0.00	0.00	0.27	0.03	0.13	0.20	0.27
Levice	0.66	0.08	0.34	0.54	0.71	0.66	0.08	0.34	0.54	0.71
Levoča	0.18	0.02	-	-	-	0.18	0.02	0.09	0.14	0.18
Liptovský Mikuláš	0.67	0.09	-	-	-	0.67	0.09	0.31	0.50	0.65
Lučenec	0.59	0.07	0.29	0.46	0.61	0.59	0.07	0.29	0.46	0.61
Malacky	0.16	0.02	0.08	0.13	0.17	0.16	0.02	0.08	0.13	0.17
Martin	0.78	0.10	0.38	0.60	0.79	0.78	0.10	0.38	0.60	0.79
Medzilaborce	0.03	0.00	-	-	-	0.03	0.00	0.02	0.03	0.04
Michalovce	0.32	0.04	0.16	0.24	0.32	0.32	0.04	0.16	0.24	0.32
Myjava	0.09	0.01	-	-	-	0.09	0.01	0.05	0.08	0.11
Námestovo	0.41	0.05	-	-	-	0.41	0.05	0.18	0.29	0.38
Nitra	0.91	0.12	0.48	0.76	1.00	0.91	0.12	0.48	0.76	1.00
Nové Mesto nad Váhom	0.24	0.03	0.13	0.21	0.28	0.24	0.03	0.13	0.21	0.28
Nové Zámky	0.65	0.08	0.34	0.54	0.70	0.65	0.08	0.34	0.54	0.70
Partizánske	0.31	0.04	0.16	0.26	0.34	0.31	0.04	0.16	0.26	0.34
Pezinok	0.22	0.03	0.11	0.17	0.23	0.22	0.03	0.11	0.17	0.23
Piešťany	0.29	0.04	0.15	0.24	0.32	0.29	0.04	0.15	0.24	0.32

	WHO guideline value					Zero pollution guideline value				
District	**RADs (mean)**	**Workdays Lost (mean)**	**Chronic Bronchitis (low)**	**Chronic Bronchitis (mean)**	**Chronic Bronchitis (high)**	**RADs (mean)**	**Workdays Lost (mean)**	**Chronic Bronchitis (low)**	**Chronic Bronchitis (mean)**	**Chronic Bronchitis (high)**
Total	29.85	3.77	11.33	17.94	23.60	29.85	3.77	15.02	23.78	31.29
Poltár	0.16	0.02	0.04	0.06	0.08	0.16	0.02	0.08	0.13	0.17
Poprad	0.48	0.06	-	-	-	0.48	0.06	0.24	0.38	0.50
Považská Bystrica	0.39	0.05	0.08	0.12	0.16	0.39	0.05	0.21	0.33	0.44
Prešov	0.97	0.12	0.47	0.74	0.98	0.97	0.12	0.47	0.74	0.98
Prievidza	0.97	0.12	0.50	0.79	1.04	0.97	0.12	0.52	0.81	1.07
Púchov	0.28	0.04	0.14	0.23	0.29	0.28	0.04	0.15	0.23	0.31
Revúca	0.31	0.04	0.15	0.23	0.31	0.31	0.04	0.15	0.23	0.31
Rimavská Sobota	0.61	0.07	0.29	0.46	0.61	0.61	0.07	0.29	0.46	0.61
Rožňava	0.47	0.06	0.13	0.21	0.28	0.47	0.06	0.23	0.37	0.48
Ružomberok	0.68	0.09	0.30	0.48	0.63	0.68	0.09	0.30	0.48	0.63
Sabinov	0.28	0.03	0.02	0.04	0.05	0.28	0.03	0.13	0.21	0.28
Senec	0.34	0.04	0.16	0.26	0.34	0.34	0.04	0.16	0.26	0.34
Senica	0.16	0.02	0.09	0.14	0.18	0.16	0.02	0.09	0.14	0.18
Skalica	0.11	0.01	0.06	0.09	0.12	0.11	0.01	0.06	0.09	0.12
Snina	0.09	0.01	0.05	0.08	0.10	0.09	0.01	0.05	0.08	0.10
Sobrance	0.04	0.00	0.02	0.03	0.04	0.04	0.00	0.02	0.03	0.04
Spišská Nová Ves	0.58	0.07	-	-	-	0.58	0.07	0.28	0.45	0.58
Stará Ľubovňa	0.20	0.02	-	-	-	0.20	0.02	0.10	0.16	0.21
Stropkov	0.07	0.01	0.04	0.06	0.07	0.07	0.01	0.04	0.06	0.07
Svidník	0.11	0.01	0.06	0.09	0.12	0.11	0.01	0.06	0.09	0.12
Šaľa	0.23	0.03	0.12	0.18	0.24	0.23	0.03	0.12	0.18	0.24
Topoľčany	0.37	0.05	0.20	0.32	0.42	0.37	0.05	0.20	0.32	0.42
Trebišov	0.29	0.04	0.14	0.22	0.29	0.29	0.04	0.14	0.22	0.29
Trenčín	0.52	0.06	0.30	0.48	0.63	0.52	0.06	0.30	0.48	0.63
Trnava	0.53	0.07	0.28	0.44	0.58	0.53	0.07	0.28	0.44	0.58
Turčianske Teplice	0.10	0.01	-	-	-	0.10	0.01	0.06	0.08	0.11
Tvrdošín	0.22	0.03	-	-	-	0.22	0.03	0.11	0.17	0.22
Veľký Krtíš	0.26	0.03	0.14	0.22	0.29	0.26	0.03	0.14	0.22	0.29
Vranov nad Topľou	0.32	0.04	0.15	0.23	0.31	0.32	0.04	0.15	0.23	0.31
Zlaté Moravce	0.26	0.03	0.12	0.20	0.26	0.26	0.03	0.14	0.22	0.29
Zvolen	0.55	0.07	0.22	0.34	0.45	0.55	0.07	0.29	0.45	0.59
Žarnovica	0.16	0.02	-	-	-	0.16	0.02	0.09	0.14	0.18
Žiar nad Hronom	0.29	0.04	-	-	-	0.29	0.04	0.15	0.24	0.32
Žilina	1.38	0.17	0.62	0.98	1.30	1.38	0.17	0.62	0.98	1.30

VI. Cost benefit analysis of the NAPCP

The health benefits of NAPCP can be compared with the costs of implementing the NAPCP through a conventional cost benefit analysis. Ideally, each component of the NAPCP would be evaluated separately to determine whether the benefits it provided exceeded the costs. This was not possible as data on marginal changes in concentrations were not available by measure; but only for the whole NAPCP. Future work on individual elements of the strategy is recommended.

The analysis calculates the present value of benefits (PVB) as well as the present value of costs (PVC). PVB is a measure of the sum of benefits received each year from the NAPCP, but with future benefits discounted using an agreed discount rate. Similarly, PVC is the sum of the costs incurred each year to implement the Programme, but with future costs discounted. The choice of the discount rate is explained further below.

The difference between the two (PVB-PVC) is the net present value of the NAPCP (NPV). An alternative is the benefit to cost ratio BCR = PVB/PVC. An NPV > 0 or a BCR > 1 is generally considered necessary to justify a program. When funds are limited, governments might ask for a BCR considerably greater than 1[20]. In order to derive the NPV estimates, future costs and benefits are discounted before adding them up to obtain the aggregate figure. The choice of the discount rate is elaborated further below.

In this cost benefit analysis, the cost component for the analysis is considered first, followed by the benefit component, before bringing the two together to calculate the NPV and BCR values for the ranges of cost and benefit estimates.

Costs of the NAPCP

There are two different concepts of cost against which the BCR can be estimated: the economic cost and the financial cost. The economic cost measures in monetary terms the value of scarce resources used while implementing the project. Where measures involve the use of real resources the full cost of these resources is included, but where measures involve a shift of funds from one agent to another, only the real loss associated with the shift is considered. The financial cost measures monetary flows required to implement the program. In this study we conduct the analysis with respect to both, the economic cost as well as the financial cost, namely the monetary flows required from government sources for the program implementation. This interpretation of the financial cost is also referred to as the fiscal cost of the program. For each component of the program the cost is given with an explanation of the method used to calculate it.

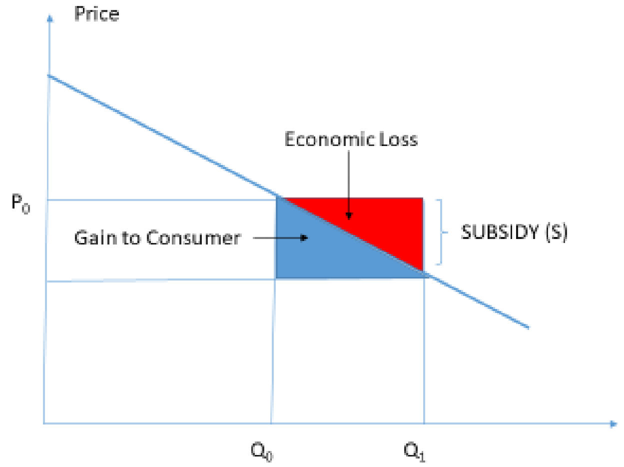
[20] For more details on cost benefit analysis for public projects and programmes see: HM Treasury (2018): The Green Book. UK Government: London. A European Commission publication that covers similar material but in a more specific context is: EC Directorate-General for Regional and Urban Policy (2014): Guide to Cost-Benefit Analysis of Investment Projects Economic appraisal tool for Cohesion Policy 2014-2020: EC: Brussels. Available at: https://ec.europa.eu/regional_policy/sources/docgener/studies/pdf/cba_guide.pdf. The guide has been adapted for the Slovak context by the IEP in 2019, available in Slovak at: https://www.minzp.sk/files/iep/cba_metodika.pdf

The costs of the program are incurred over the period 2020 to 2030 (11 years) and are accounted for in annual terms.

Transport: Replacement of Old Diesel Vehicles. The fiscal cost of the program was estimated at €14 million in 2019, made up of a state subsidy of around €33 million, offset by value-added tax (VAT) recovered from the additional sales of €45 and other fees of €1.5 million. The economic cost, however, is different. Taxes and subsidies are transfers between the government and other agents in the economy and do not use up valuable resources. The only economic cost occurs because the subsidy results in an inefficient use of funds, whereby there is a loss of welfare from the reallocation of resources. Figure 1 below representing the demand curve for the product shows this loss. The subsidy S lowers the price to the consumer who has a gain in welfare equal to the shaded blue triangle from an addition of Q1 – Q0 new cars. The total subsidy, however, is the rectangle made up of the blue triangle and the red one. The net cost is therefore equal to the red triangle, which is half the direct subsidy if the demand curve is linear. It is also referred to in the literature as the deadweight loss from the subsidy. In that case the economic cost amounts to €16.5 million. Both fiscal and economic costs are a one-off item at the start of the program.

Transport: Plug-in Hybrid Electric Vehicles. This was a small program with a €5 million subsidy. The fiscal cost was estimated at €5 million and the economic cost, based on the analysis presented above, is about €2.5 million.

Figure: Economic Cost of a Subsidy



Transport: Control of NO_x Emissions from Cars. An annual fiscal cost of €1.6 million is incurred. This is also an economic cost as it represents real resources used for monitoring and control.

Transport: More Frequent Control of Emissions from Old Cars. This case is similar to the previous one, with fiscal and economic costs being the same. The estimate is €6.25 million annually over the implementation period.

Transport: Roadside Emissions Controls. The same applies here with annual costs of €0.16 million.

Residential Heating: Subsidies for Old Boilers. The fiscal cost of the program is €27 million in the first year, followed by €54 million in year 4 and 7 and finally €27 million in year 10. In this case the economic cost is taken as the same, based on the assumption that the replacement does not provide any additional benefit to the households, for which they would be willing to pay. This may be an underestimate of their personal benefit as the new boilers are cleaner and probably easier to use. Without further information, however, it was not possible to estimate the value of such benefits.

Residential Heating: Differential Fees for Boilers. In this case the fiscal cost is the gain of revenue by increasing the fee payable to the government on purchase of conventional boilers. The economic cost, however, is less and similar to the estimate shown in the figure on subsidy, except that in this case there is a tax, also resulting in a deadweight loss. This was calculated in the 2019 analysis of the program as €2.6 million.

Residential Heating: Connecting Homes to Gas. The fiscal cost of this program over the period 2020-2030 is €459 million. For the same reasons as given in the case of subsidies for old boilers, this was also taken as the economic cost. Again, there may be some benefit for the conversion to gas that some households may derive, but it was not possible to estimate those.

Fuel Standards for Wood Moisture. This program with a cost of €0.1 million a year is the fiscal cost. In addition, there is an increase in the cost of wood to the consumers estimated at €1.04 million a year.

Awareness Program for Fossil Fuel Stoves. The program has a fiscal cost of €0.3 million, which is also an economic cost of the resources used in implementing it.

Tax Harmonization for Petrol and Diesel. There is a big difference between the fiscal and economic costs of this program. The former is highly negative, with a €552 million gain for the government. Most of this, of course, is simply a transfer from citizens to the government and is not an economic gain. The latter, calculated in the 2019 analysis of the NAPCP, was estimated at around €1 million a year initially, rising to €75 million by the end of the period.

Support for Medium-sized Farms to Adopt NH_3 Controls. The economic cost of the program in resource terms is estimated at €0.49 million a year, with the government picking up €0.39 million (i.e. 80%). Thus, the economic cost is €0.1 million more than the fiscal cost.

Residential Heating: Insulation Program and District Heating Connection Programme. These two programs were added to the NAPCP to bring $PM_{2.5}$ emissions closer to the target level by 2030. The fiscal costs are €154 million (insulation program) and €262 million (DH connection program). For the DH program the fiscal costs are also the economic costs. There is an increase in operating costs, which are included in the fiscal cost figure. For the insulation program the fiscal cost is 72% of the total investment cost, so households bear 28%, leading to a total cost of €214 million. On the other hand, households benefit from the program in form of lower energy bills. Taking account of these reductions decreases the economic cost to 70.5 million.

Tables 10 and 11 give the fiscal and economic costs of the NAPCP from 2020 to 2030. At €398 million in NPV terms (with a 5% discount rate) the fiscal cost is considerably lower than the economic cost, estimated at €1,125 million. The main reason for the lower fiscal costs is the gain in revenue from the tax on diesel, which lowers the fiscal but not the economic cost.

Benefits of the NAPCP

The gains in benefits from the NAPCP have so far been calculated based on the difference in concentrations of key pollutants in 2020 and 2030 with the NAPCP. However, the benefits from the NAPCP will arise not only in 2030 but in earlier years as well, as pollutant emissions are continuously reduced by NAPCP measures. We may also expect some benefits after 2030 as the NAPCP will lower concentrations from where they would have been in the absence of the NAPCP. On the other hand, the 2019 analysis of emissions under NAPCP and without NAPCP showed a decline in emissions of key pollutants even without NAPCP. In other words, emissions are expected to decline in the base case scenario with no NAPCP, but will decline stronger with the NAPCP.

In order to capture this complex situation, we have used the emission profiles for $PM_{2.5}$, the only pollutant that affects health, and attributed a percent of the benefits calculated in the comparison between 2020 and 2030 to each year. Furthermore, we have allowed for the base case decline in emissions between 2020 and 2030, so not all benefits for 2030 reported in the previous section are attributed to the NAPCP. Details of emissions are given in the Annex II. The adjustments made are as follows:

1. Reduction in $PM_{2.5}$ emissions between 2020 and 2030: 6,564 MT
2. Reduction in emissions due to NAPCP: 2,921 MT
3. Percent of gain in benefits in 2030 due to NAPCP: 44.5%

For the annual benefits between 2020 and 2030 the percent reduction of the 2030 level was taken to estimate the benefits for each year. The NAPCP-based reductions by year as a percent of the 2030 reduction are given in Table 12.

Finally, there is the question of what benefits might remain after 2030. It is reasonable to assume there will be some, as the base case without NAPCP cannot be expected to converge automatically to the NAPCP level of concentration. However, it is difficult to estimate the gap precisely. As an approximation, a sensitivity calculation has been made in the case of economic costs, assuming the gap in 2030 between concentrations under the base case and the NAPCP remains for another ten years. In this case the annual costs of the NAPCP for the period 2031-2040 are estimated as being the same as the maintenance costs for 2030 for each of the programs where such costs are incurred.

The benefits profile depends on which valuation of mortality and morbidity are taken from the range estimates in Tables 8 and 9. Tables 13 and 14 summarize estimated benefits covering this range on NPV terms, using a 5% discount rate. Table 13 illustrates the estimates based on VSL and Table 14 the estimates based on VLYL. The range of benefits with VSL mortality valuation and counting benefits only to 2030 is €1.2 billion to €3.2 billion, i.e. with a variation of +/- 45% around the mean. With a VLYL valuation for the same time period the range is €504 million to €1,240 million, the upper bound being 87% greater than the median value and the lower bound, based on Slovak legal data, being about 24% less than the median value. Overall, the VSL approach gives estimates that are approximately 2.5 higher than those from the VLYL approach.

Extending the analysis to 2040 on the basis suggested above increases the value of the benefits by a factor of about 80%, but this has to be considered speculative.

Table 10:
Fiscal Costs of the NAPCP (negative values represent net fiscal revenue)

Measure/Year	NPV @ 6%	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Replacement of old diesel vehicles		-14,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Subsidy for PHEV vehicles		5,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Control of NOx emissions from cars		1,60	1,60	1,60	1,60	1,60	1,60	1,60	1,60	1,60	1,60	1,60
More frequent control of emissions from old cars		6,25	6,25	6,25	6,25	6,25	6,25	6,25	6,25	6,25	6,25	6,25
Roadside emissions controls		0,16	0,16	0,16	0,16	0,16	0,16	0,16	0,16	0,16	0,16	0,16
Subsidies for replacement of old boilers (with supplement)		27,00	0,00	0,00	54,00	0,00	0,00	54,00	0,00	0,00	54,00	0,00
Differentiated fees for boilers		6,9	2,59	2,59	2,59	2,59	2,59	2,59	2,59	2,59	2,59	2,59
Connecting homes to gas (With supplement)		20,80	23,40	52,33	54,93	57,53	60,13	62,73	65,33	20,80	20,80	20,80
Fuel standards for wood moisture		0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1	0,1
Awareness programs for fossil stove users		0,30	0,30	0,30	0,30	0,30	0,30	0,30	0,30	0,30	0,30	0,30
Tax harmonisation for petrol and diesel		-43,97	-86,07	-126,45	-165,21	-202,45	-161,12	-86,93	-12,74	61,44	135,63	135,63
Support for medium-sized farms to adopt NH3 controls		0,39	0,39	0,39	0,39	0,39	0,39	0,39	0,39	0,39	0,39	0,39
Insulation Program		30,81	0,00	30,81	0,00	30,81	0,00	30,81	0,00	30,81	0,00	0,00
DH Connection Program		10,97	16,15	21,33	26,52	31,70	25,92	25,92	25,92	25,92	25,92	25,92
Total	**€ 422,94**	**52,30**	**-35,13**	**-10,59**	**-18,37**	**-71,02**	**-63,68**	**97,92**	**89,90**	**150,36**	**247,74**	**193,74**

Source: World Bank and Ministry of Environment (2019) Report

Table 11:
Economic Costs of the NAPCP (Euros Million)

Measure/Year	NPV @ 5%	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Replacement of old diesel vehicles		16,48	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Subsidy for PHEV vehicles		2,50	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Control of NOx emissions from cars		1,60	1,60	1,60	1,60	1,60	1,60	1,60	1,60	1,60	1,60	1,60
More frequent control of emissions from old cars		6,25	6,25	6,25	6,25	6,25	6,25	6,25	6,25	6,25	6,25	6,25
Roadside emissions controls		0,16	0,16	0,16	0,16	0,16	0,16	0,16	0,16	0,16	0,16	0,16
Subsidies for replacement of old boilers (with supplement)		27,00	0,00	0,00	54,00	0,00	0,00	54,00	0,00	0,00	54,00	0,00
Differentiated fees for boilers		2,59	2,59	2,59	2,59	2,59	2,59	2,59	2,59	2,59	2,59	2,59
Connecting homes to gas (With supplement)		20,80	23,40	52,33	54,93	57,53	60,13	62,73	65,33	20,80	20,80	20,80
Fuel standards for wood moisture		1,14	1,14	1,14	1,14	1,14	1,14	1,14	1,14	1,14	1,14	1,14
Awareness programs for fossil stove users		0,30	0,30	0,30	0,30	0,30	0,30	0,30	0,30	0,30	0,30	0,30

Measure/Year	NPV @ 5%	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Tax harmonisation for petrol and diesel		1,00	3,85	8,40	14,40	21,85	32,55	43,25	53,95	64,70	75,40	75,40
Support for medium-sized farms to adopt NH3 controls		0,49	0,49	0,48	0,47	0,47	0,47	0,47	0,47	0,47	0,47	0,46
Insulation Program		13,90	0,00	13,90	0,00	13,90	0,00	13,90	0,00	13,90	0,00	0,00
DH Connection Program		10,97	16,15	21,33	26,52	31,70	25,92	25,92	25,92	25,92	25,92	25,92
Total	**€ 1 124,70**	**105,16**	**55,92**	**108,48**	**162,36**	**137,49**	**131,11**	**212,31**	**157,71**	**137,82**	**188,62**	**134,62**

Source: See Text

Table 12: Estimated cumulated percent of 2030 reduction in $PM_{2.5}$ concentrations in Years 2020 to 2030

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Reduction	29%	36%	42%	59%	65%	71%	87%	92%	93%	100%	100%

Table 13: Benefits from NAPCP over the period 2020-2030 with VSL mortality valuation (Euros Million)

	Lower Bound			Middle Case			Upper Bound		
	Mortality	**Morbidity**	**Total**	**Mortality**	**Morbidity**	**Total**	**Mortality**	**Morbidity**	**Total**
Benefits to 2030	978	240	1,218	1,333	320	2,365	2,933	347	3,280
Benefits to 2040	1,776	437	2,213	3,552	501	4,053	5,328	630	5,959

Notes:

1. *The lower, middle and upper bound of mortality values are as explained in the VSL valuation section.*
2. *The morbidity values for the lower, middle and upper bounds are derived for the range for chronic mortality.*
3. *Estimates are derived from Tables 8 and 9 using the WHO Guidelines benchmarks. The other benchmark makes very little difference.*

Table 14: Benefits from NAPCP over the period 2020-2030 with VLYL mortality valuation (Euros Million)

	Lower Bound			Middle Case			Upper Bound		
	Mortality	**Morbidity**	**Total**	**Mortality**	**Morbidity**	**Total**	**Mortality**	**Morbidity**	**Total**
Benefits to 2030	263	240	504	387	276	663	893	347	1,240
Benefits to 2040	478	436	915	703	501	1,204	1,622	631	2,253

Notes:

1. *The lower, middle and upper bound of mortality values are, respectively the legal VLYL, the median VLYL and the mean VLYL.*
2. *The morbidity values for the lower, middle and upper bounds are derived for the range for chronic mortality.*
3. *Estimates are derived from Tables 8 and 9 using the WHO Guidelines benchmarks. The other benchmark makes very little difference.*

Combining benefits and costs of the NAPCP

As explained earlier the benefit cost analysis compares the costs against the benefits. In this case, we make one comparison based on the fiscal costs and another based on the economic costs. The benefits are taken as the same in both cases; they consist of the health gains from the reduced concentrations of air pollutants measured in monetary terms. They only represent financial flows in the case of reduced morbidity expenditures, but the mortality benefits are not measured on a financial basis. Hence to that extent, while the analysis based on economic costs is a full economic cost benefit analysis, the one based on fiscal costs is a hybrid, with the costs being net outlays by the public sector and the benefits being full economic benefits.

In undertaking the present value calculations, it is necessary to discount future costs and benefits at an agreed rate. For this purpose, we have used the EC guidance values for financial and economic cost benefit analysis in cohesion countries, which include Slovakia (see footnote 20). They recommend a discount rate of 4% for financial cost benefit analysis and 5% for economic cost benefit analysis.

The summary statistics for each evaluation given here are the NPV, which is the discounted value of the stream of benefits minus the costs of the NAPCP and the BCR, which is the present value of the benefits divided by the present value of the costs.

The time profiles of the economic and fiscal costs are shown in Figure 2, along with the benefits under VSL (mean value) and under VLYL (median value). It should be noted that the profiles from 2030 to 2040 are estimates based on a continuation of the NAPCP beyond 2030. As explained above this is not certain, nor are the details fully determined. The figures show fiscal costs that are well below economic costs initially, even going negative (as tax receipts exceed outlays) but after 2028 they rise above the economic costs. The benefits under VSL are always above both costs but under VLYL they are always below the economic costs and below the fiscal costs after 2027.

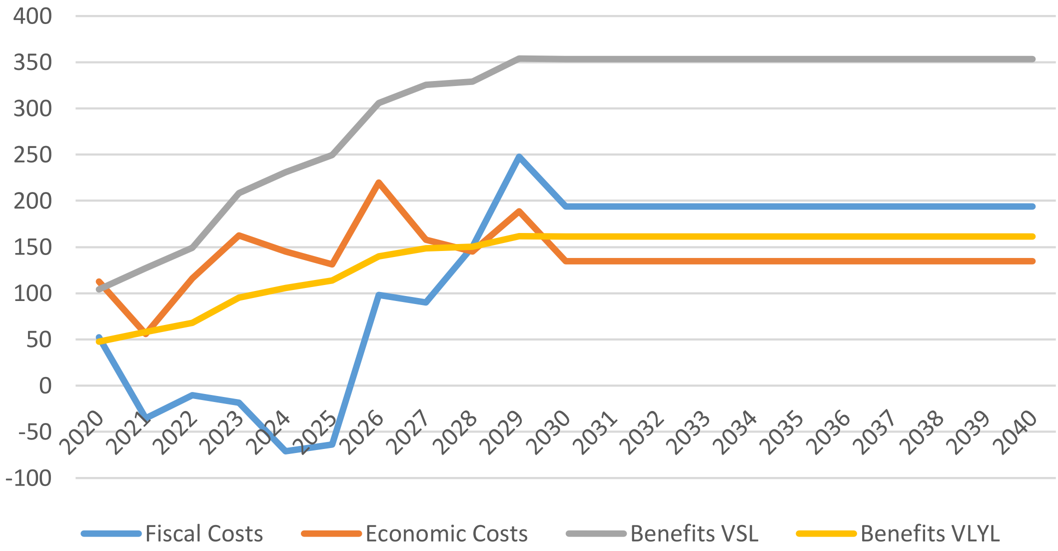


Figure 2: Time Profile of Costs and Benefits of the NAPCP

Source: own elaboration

Economic Cost Benefit Indicators

Table 15 gives the NPV and the BCR for the benefits relative to the economic costs of the NAPCP.

Table 15: NPV and BCR for the NAPCP Based on Economic Costs

Benefit to Cost Ratios to 2030			
With VSL	Lower Bound	Mean	Upper Bound
	1.06	1.93	2.84
With VLYL	Legal Value	Median	Mean
	0.44	0.57	1.07

NPVs to 2030 Euros Million			
With VSL	Lower Bound	Mean	Upper Bound
	63.90	1,076.85	2,065.26
With VLYL	Legal Value	Median	Mean
	-650.65	-491.52	-0.25

The results indicate the following:

a. Under a VSL valuation of premature mortality the NAPCP has a BCR greater than one for the whole range of VSL values. Correspondingly the NPV is positive. This holds for the estimation of benefit to 2030; for an extension to 2040 the BCR rises by about 20%.
b. Under a VLYL valuation the BCR exceeds one only if the mean value of the VLYL is taken, with the NPV being positive only in that case. Under the value that is set by the Slovak legislation to estimate the cost effectiveness of new medications, the ratio is only 0.44 and under a median value it is 0.57. This means that the benefits of the whole period 2021 to 2030 only represent 44% and 57% of the costs respectively. Extending the analysis to 2040 means bringing in the benefits of the NAPCP after 2030. Doing that raises the BCR, so where in Table 15 the BCR is 0.57 (median with VLYL) it goes up to 0.67 – i.e. it rises by about 18%. However, even with this extension the BCR still only exceeds one with the mean value of VLYL.

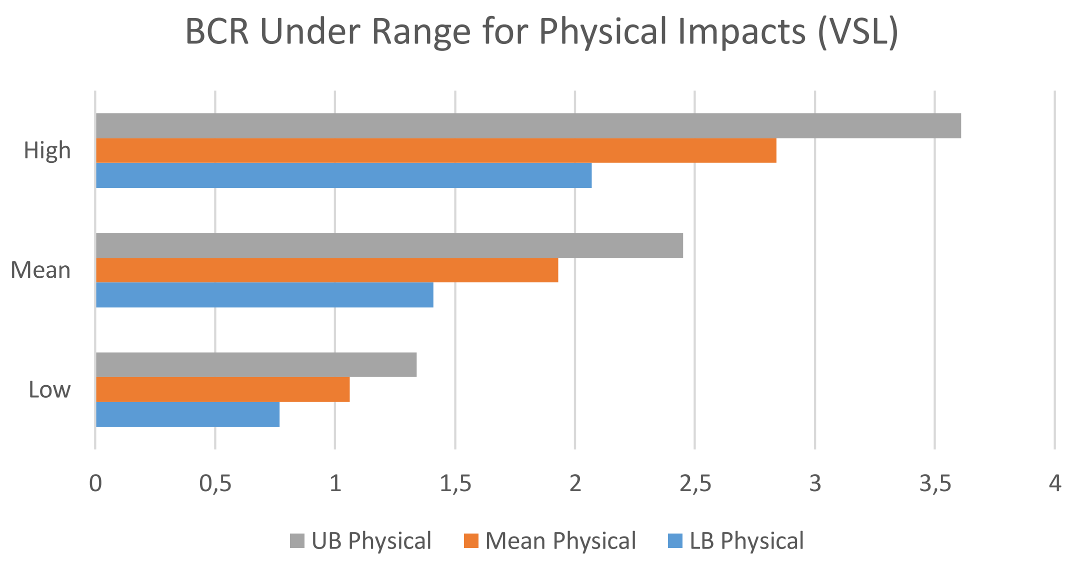
Further sensitivity analysis can be carried out using the range of physical health impacts. As stated in Section III, the 95 % CI for the range of impacts is approximately +/-27%. Applying this range to the BCRs leads to Figures 3 below for the VSL valuation and the VLYL valuation.

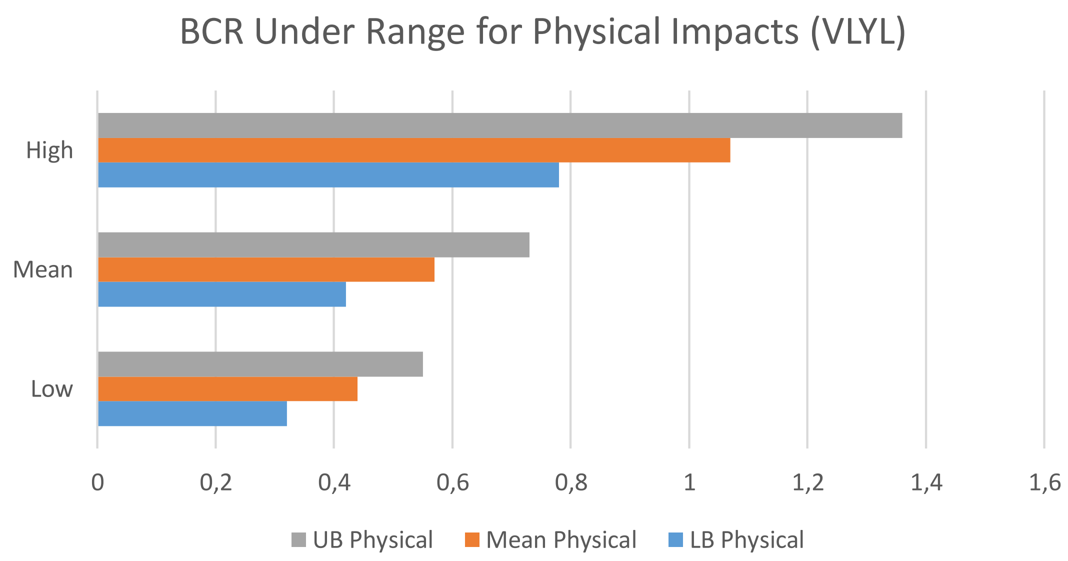
These figures, which are for the benefits to 2030 only, show that allowing for the uncertainty in physical impacts keeps the BCR above one for all VSL cases, except for the combination of the low VSL value and the lower bound physical impact. Under the VLYL, however, the BCR only exceeds one with high VLYL and under physical impacts at or above the mean.

Figure 3: BCR Ranges Under Different Health Valuation Metrics

Source: own elaboration

BCR Range Under 95% CI Physical Impacts with VSL Values





BCR Range Under 95% CI Physical Impacts with VLYL Values

Fiscal Cost Benefit Indicators

The cost benefit analysis based on fiscal costs is reported in Table 16. As the data on fiscal costs is highly uncertain beyond 2030, no sensitivity analysis for the period is carried out extending the estimation beyond 2030.

Table 16: NPV and BCR for the NAPCP Based on Fiscal Costs

Benefit to Cost Ratios to 2030			
With VSL	Lower Bound	Mean	Upper Bound
	3.07	5.63	8.27
With VLYL	Legal Value	Median	Mean
	1.27	1.67	3.13

NPVs to 2030 Euros Mn.			
With VSL	Lower Bound	Mean	Upper Bound
	876.26	1,956.50	2,969.48
With VLYL	Legal Value	Median	Mean
	114.23	283.93	765.58

The fiscal costs are considerably less than the economic costs. Tables 10 and 11 shows that the fiscal costs are €398 billion while the economic costs are €1,124 billion, or 2.8 times as high. Since the benefits are the same the NAPCP has a higher BCR when judged under these costs. As the table shows, the BCR is now above one and the NPV is positive in all cases. Under VSL the BCR ranges from over 3 to over 8, and under VLYL the range is over 1 to over 3. Allowing for the +/-27% physical impacts CI, the BCR remains above unity in all cases.

VII. Conclusions and recommendations

The study illustrates that the NAPCP has benefits in excess of fiscal costs for a wide range of benefit estimates. The comparison relative to the economic costs suggests that the case is less clear. Some discussion is needed on what method of mortality valuation is appropriate for Slovakia before proceeding further. If the VLYL method is chosen, a further review will have to be made of whether methods used to determine the values at the European level are appropriate or whether Slovakia wants to take a conservative value based on Slovak legislation for years of life saved. If the latter is taken, the NAPCP needs further investigation to determine which components are justified on benefit-cost grounds. This can be done as a follow-up to this work, as noted below.

The study should be seen as a first step in analyzing the effectiveness of air pollution control measures in terms of benefits and costs. While this study considers the entire NAPCP, a more in-depth evaluation is necessary to consider each component of the NAPCP. As a result, components can be ranked according to their effectiveness and new ones can be considered where some are found to be particularly ineffective. This requires more air quality modelling than was possible for this initial assessment. The toolkit created as part of this work will allow for such an extension to be undertaken in the future.

The granular data assembled here can be used to determine the benefits and costs of regional policies. With information on impacts for each of the 72 districts, local measures can be analyzed, such as traffic restrictions and local bans on high emission heating devices, but will require more detailed air quality modelling.

Lastly, data used as inputs for the study should be reconsidered and updated regularly. In particular, baseline data on workdays lost is limited and data on other morbidities are taken from default European values. As information becomes available, the initial data used can be replaced by local ones. The datasets used for the calculations of health impacts and their economic valuations should also be regularly updated to reflect the changes and allow policy makers to use the tool efficiently in the future.

Annex I:
List of districts

Map of districts (several districts in Bratislava and Košice are merged into one district each)

Nº	District
SK0221	Bánovce nad Bebravou
SK0321	Banská Bystrica
SK0322	Banská Štiavnica
SK0411	Bardejov
SK0101	Bratislava
SK0323	Brezno
SK0311	Bytča
SK0312	Čadca
SK0324	Detva
SK0313	Dolný Kubín
SK0211	Dunajská Streda
SK0212	Galanta
SK0421	Gelnica
SK0213	Hlohovec
SK0412	Humenné
SK0222	Ilava
SK0413	Kežmarok
SK0231	Komárno
SK0422	Košice
SK0426	Košice - okolie
SK0325	Krupina
SK0314	Kysucké Nové Mesto
SK0232	Levice
SK0414	Levoča

Nº	District
SK0315	Liptovský Mikuláš
SK0326	Lučenec
SK0106	Malacky
SK0316	Martin
SK0415	Medzilaborce
SK0427	Michalovce
SK0223	Myjava
SK0317	Námestovo
SK0233	Nitra
SK0224	Nové Mesto nad Váhom
SK0234	Nové Zámky
SK0225	Partizánske
SK0107	Pezinok
SK0214	Piešťany
SK0327	Poltár
SK0416	Poprad
SK0226	Považská Bystrica
SK0417	Prešov
SK0227	Prievidza
SK0228	Púchov
SK0328	Revúca
SK0329	Rimavská Sobota
SK0428	Rožňava
SK0318	Ružomberok

Nº	District
SK0418	Sabinov
SK0108	Senec
SK0215	Senica
SK0216	Skalica
SK0419	Snina
SK0429	Sobrance
SK042A	Spišská Nová Ves
SK041A	Stará Ľubovňa
SK041B	Stropkov
SK041C	Svidník
SK0235	Šaľa
SK0236	Topoľčany
SK042B	Trebišov
SK0229	Trenčín
SK0217	Trnava
SK0319	Turčianske Teplice
SK031A	Tvrdošín
SK032A	Veľký Krtíš
SK041D	Vranov nad Topľou
SK0237	Zlaté Moravce
SK032B	Zvolen
SK032C	Žarnovica
SK032D	Žiar nad Hronom
SK031B	Žilina

Annex II:

$PM_{2.5}$ emissions profiles in the base case and under NAPCP

Emissions are in MT

$PM_{2.5}$	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Base	26 006	25 535	25 108	24 833	24 483	24 120	23 769	23 426	23 070	22 714	22 363
All WAM Measures	25 355	24 770	24 233	23 671	23 209	22 719	22 060	21 587	21 202	20 639	20 291
Plus Supp. Replacement of Conv. Stoves W/Gasification	25 355	24 770	24 233	23 545	23 083	22 594	21 809	21 336	20 951	20 387	20 039
Plus Supp. Replacement of Conv. Stoves W/Condensing Gas	25 324	24 709	24 141	23 423	22 931	22 411	21 596	21 093	20 707	20 144	19 796
Plus Supp. Replacement of Conv. Stoves W/DH	25 281	24 621	24 010	23 248	22 712	22 192	21 377	20 874	20 489	19 925	19 577
Plus Supp. Insulation Program	25 146	24 487	23 875	23 113	22 577	22 057	21 242	20 739	20 354	19 790	19 440
Target for 2030+	19 125	19 125	19 125	19 125	19 125	19 125	19 125	19 125	19 125	19 125	19 125

Source: World Bank and Ministry of Environment (2019) Report

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