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Project

ADDITIONAL DEVELOPMENT OF EU ENVIRONMENT APPROXIMATION FOR AIR, CHEMICALS AND HORIZONTAL ACQUIS

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Air pollution dispersion modelling for Serbia

Methodology and dispersion modelling results for the reference year and 2030 baseline and mitigation scenarios

Draft

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Table of Contents

List of Abbreviations

Acronyms	Meaning
AQ	Air Quality
EU	European Union
IIASA	International Institute for Applied Systems Analysis
LV	Limit Values
NO_2	Nitrogen dioxide
O_3	Ozone
PM	particulate matter
PM_{10}	particulate matter 10 micrometers or less in diameter
$PM_{2.5}$	particulate matter 2,5 micrometers or less in diameter
REF	Reference scenario
SO_2	Sulfur dioxide
WAM	With Additional Measures
WEM	With Existing Measures

This document presents 1) the methodology used to estimate the Serbian air quality in 2030 for the baseline scenario (WEM) and all three mitigation emissions projection scenarios, and 2) the associated results, including the calculation of 2030 exceedances of EU limit values and population exposure. The method used in this study is based on numerical air pollutant dispersion simulations with the chemistry transport model CHIMERE[1]. Air pollutant concentrations have been calculated on every point of the domain covering Serbia with a spatial resolution of approximatively 5km x 5km and a time resolution of 1 hour over an entire year. Input data needed by the model are meterological data[2], tranboundary transfer of pollutants entering Serbia, that are taken into account through a coarser resolution European CHIMERE run, and emissions of pollutants on every point of the domain. Spatialized and temporalized emission data over Serbia for the reference year and for the 2030 baseline and scenarios are described in details in a previous report[3] Those data have been adapted to be used by the CHIMERE model.

5 simulations have been conducted:

- a reference year REF (2015) has been chosen to validate emission datasets and calibrate the model by comparison with real measurements from Air Quality (AQ) stations in Serbia;
- 3 mitigation scenarios have been conducted for 2030 with Serbian emissions corresponding to the **WEM** (with existing measured)**, WAM A** (with additional measures A) and **WAM B** (with additional measures B) scenarios.
- A last scenario, the so called **WAM C** scenario, has been built during the simulation processes, based on air pollutant dispersion results from the other scenarios, to ensure compliance with air quality limit values.

1 Methodology and input data

1.1 Reference year 2015

1.1.1 Pollutant measurement

For the year 2015, simulated concentrations have been compared with observations from the national network for air quality monitoring in Serbia (Environmental Protection Agency) and from cities local

[1] Mailler, S., Menut, L., Khvorostyanov, D., Valari, M., Couvidat, F., Siour, G., Turquety, S., Briant, R., Tuccella, P., Bessagnet, B., Letinois, L., Markakis, K., Meleux, F. and Colette, A. (2017). CHIMERE-2017: from urban to hemispheric chemistry-transport modeling

[2] IFS meteorological fields for the year 2015 are used. They are provided by ECMWF (European Centre for medium-range Weather Forecast) at a 10kmx10km resolution

3 Methodology for development of spatially and temporally disaggregated emission inventory for the reference year and projected years (gridded emission inventory) – July 2020 and addendum December 2020

networks when available[4]. The number of measurement stations taken into account is indicated in Table 1. In 2015, no PM2.5 measurements are available at stations measuring particles, unlike more recent years. On those stations, 2015 PM2.5 annual mean concentrations have been reconstructed based on measured 2015 annual mean PM10 concentrations and on the mean PM10/PM2.5 ratios observed for the same stations in the most recent years.

Table 1: number of 2015 air quality measurement stations in Serbia used in the project

Pollutant	Number of stations in 2015
PM10	10
PM2.5	10 – based on PM10 + annual ratio
NO2	29
SO2	33
O3	4

The number of exceedances of EU Limit Values (LV) over those stations are summarized in Figure 1.

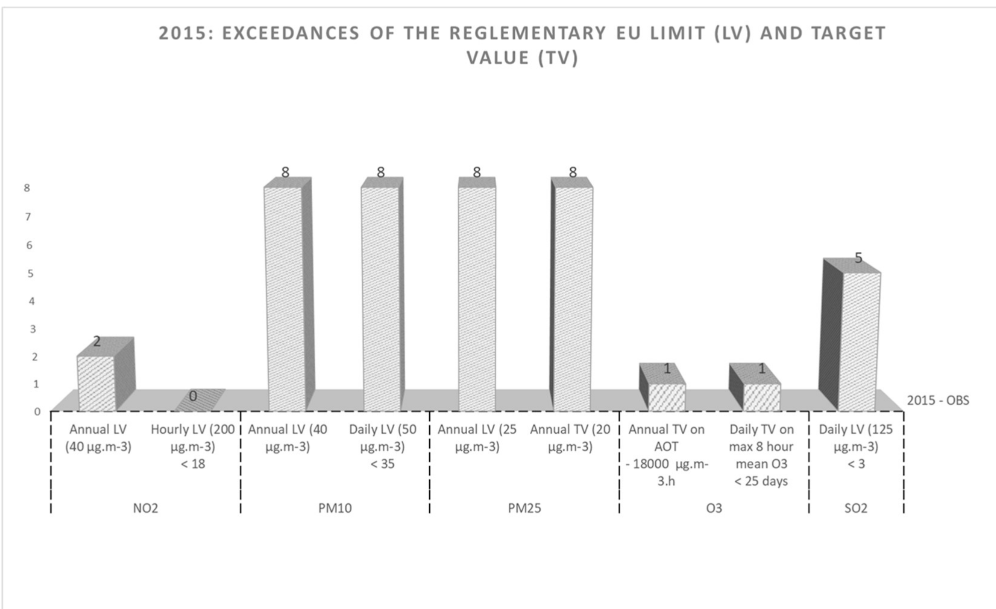

Figure 1: Number of annual exceedances of the EU regulatory limit value (LV) and targeted value (for O_3) for the year 2015

[4] Report on current state of compliance of AQ measurement network, measurements and results with the EU requirements (Report under Task 3.9) Draft report, *9 June 2020*

The most important air quality issue for Serbia is particulate matter pollution. Of the 10 PM10 measuring stations, 8 show exceedances of the PM10 EU LV. 2 out of 29 stations show exceedances of NO_2 LV (Beograd and Čačak) and 4 out of 33 stations show exceedance of SO2 LV (3 of them located in Bor).

By 2019, a larger number of stations were measuring particulate matter on the territory (33 PM10 and 16 PM2.5 measurements). Thosemeasurements for 2019 show the same AQ issue with 88% (75%) of the PM10 (PM2.5) measurement stations exceeding the LV and NO_2 and SO_2 exceedances only in Beograd and Bor respectively.

1.1.2 Model performances

Model performances can be estimated through the calculation of statistical indicators generally based on the mean bias and spatial correlation.

A first comparison of PM concentrations measured and simulated presented a relatively strong negative bias on PM10, particularly in winter. Emission source analysis from the national inventory shows that the first contributor to particle emissions is domestic heating. For this activity, average EMEP emission factors were used for the emission inventory. They are based on average values representing the European wood stove fleet. There are associated to very large uncertainties. The emission factors of PM have been increased by 20% to better represent the emissions and their variability due to the type of appliances, their quality, their conditions of use in Serbia. The spatialization of the emissions was also improved by better consider the type of appliances used (according to the different fuels). The correction allowed us to reduce the bias.

European legislation imposes quality objectives for modelled data in terms of uncertainty (Directive 2008/50/EC, Annex I.A) for PM10, PM2.5 and NO_2 based on selected fixed measurements representative of the scale covered by the model. The mean absolute errors, which is the average over all stations of the annual absolute bias, should not exceed 50% for particles and 30% for NO_2. Model performances are shown in Table 2 (only background stations are selected as they are representative of the scale covered by the model). The model does fulfil the quality objectives impose by the EU legislation.

Table 2: Average values of the absolute error and correlation calculated at each station between the CHIMERE model and the measurement

	Absolute Error	correlation
PM10	41%	0.64
PM2.5	27%	0.64
NO2	21%	0.54

1.2 Prospective simuations for year 2030

Once the model has been validated for the base year, it is used to simulate pollutant concentrations in Serbia for the year 2030 under the different emission scenarios WEM, WAM A and WAM B. Meteorological data are the same than for the year 2015 and emissions outside Serbia are representative of the WEM scenario[5]. Pollutants entering Serbia through transboundary air pollution are taken into account through a coarser resolution European CHIMERE run for the year 2030.

Unlike the other scenarios, scenario C was not developed before the modelling phase, but rather after the modelling of mitigations scenarios WAM A and B with the aim to develop a full control scenario that would ensure compliance with air quality limit values. Cities where exceedances were still simulated with the most stringent scenario (WAM B) were targeted (Užice Valjevo, Beograd, Niš and Kragujevac for particles and Bor for SO_2).

For these cities, domestic heating is the sector where the levers to reduce emissions are the most important. In order to estimate the emission reductions needed to avoid exceedances, we decided to use a linear inverse modelling approach. Two test simulations were conducted with 50 and 100% emission reductions from the domestic heating sector. Assuming that the concentration changes related to the emission changes are linear in parts between 0-50% and 50-100%, it is possible to reconstruct for each emission reduction the daily concentrations over the year, and thus to estimate the emission reduction to avoid exceedances. (Table 3). For SO_2, the assumption of a direct linear behavior between emission and daily concentration have been made.

Table 3: approximated emissions reductions estimated by inverse modelling necessary to avoid LV exceedances for particulate matter (left table, applied on domestic heating sources only) and for SO_2 (right table, all sources included)

PM10 and PM2.5

Cities	Needed reduction for domestic heating compared to WAMB
Uzice	65%
Valjevo	50%
Kragujevac	15%
Nis	50%
Beograd	20%

SO2

Cities	Needed reduction compared to WAMB
Bor	55% - 60%

In a last step, the WAM C Scenarios has been designed by identifying the required additional measures which could lead to the emission reduction estimated by this approximate inverse modelling strategy. This is how CITEPA designed the final WAM C Scenario which was subsequently simulated by the full CHIMERE model to confirm if LVs were respected.

2 Results

2.1 Limit value exceedances

[5] from national emissions GAINS data (IIASA) for PRIMES REF scenario activity projections post 2014 (climate policy adopted up until 2016) and spatialized according to EMEP emission proxies.

Exceedances of EU LV are calculated with the baseline and the 3 initial mitigation scenarios at the location of the measurement stations for NO_2, SO_2, PM10 and PM2.5. Ozone is not subject to limit values in Europe but to target values, which are less restrictive in regulatory terms. Moreover, even these target values are only slightly exceeded in Serbia (one exceedance in 2015 and no exceedance in 2019) and no exceedance is simulated in 2030 in any scenario. For this reason, O_3 is not detailed in this study.

To be more realistic and cope with model representativity issues, 2030 simulated concentrations extracted at the station location are corrected with observations taken in 2015[6] for all pollutants. Concerning particles, to be more representative of the whole Serbia, we decided to also include concentrations for the year 2030 at the location of stations added to the monitoring network between 2015 and 2019, therefore extending the PM monitoring network from 10 to 33 sites. No corrections are applied to those concentrations.

Annual concentrations and number of exceedances of the daily mean threshold, simulated at station locations are shown in Figure 2 to Figure 6 for the 4 pollutants. The EU LV imposed by the air quality directive (2008/EC/50) are also shown as dotted red lines.

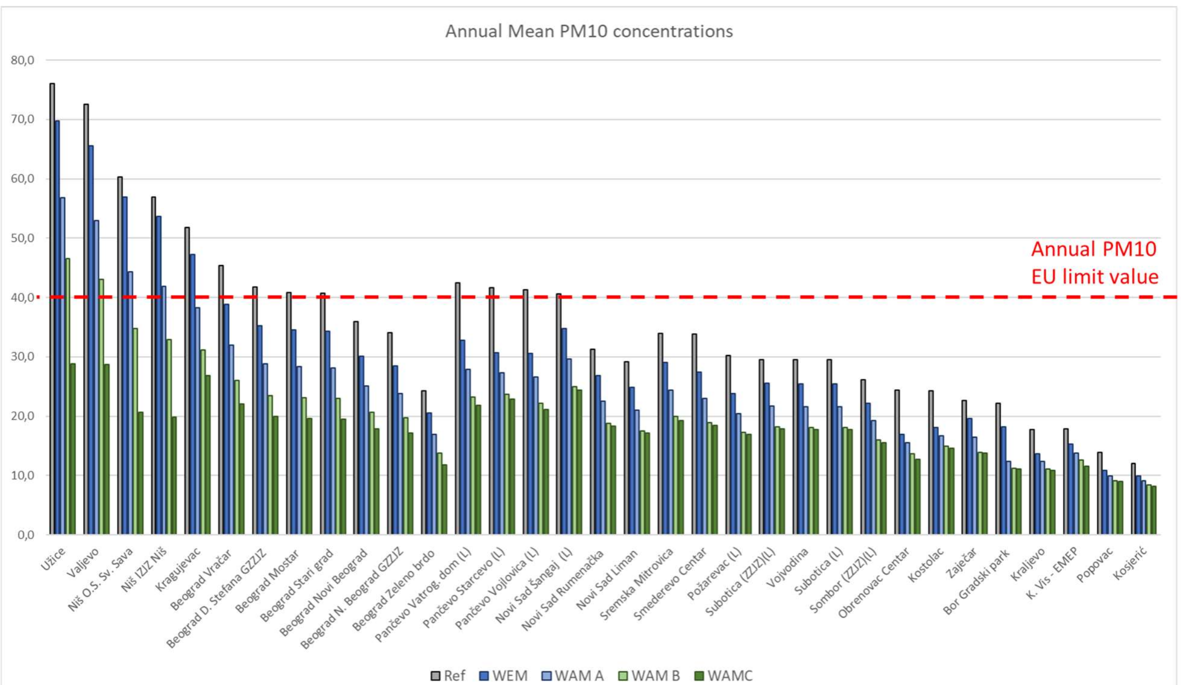

Figure 2: Annual mean PM10 concentrations simulated by the model for the reference year (2015 in grey), the 2030 WEM scenario (dark blue) and the 3 mitigations scenarios (WAM A, WAM B and WAM C respectively inlignth blue, light green and dark green). Stations measuring particles in 2015 are Užice, Valjevo, Beograd Vračar, Beograd Zeleno brdo, Pančevo Vatrog. dom, Pančevo Starcevo, Pančevo Vojlovica, Kragujevac, Novi Sad and K. Vis – EMEP.

[6] the hourly bias of the modelling is calculated in 2015 and applied as a relative bias (in % of the simulated concentrations) on the simulated concentrations in 2030

For those stations, due to modelling data correction, simulated concentrations in 2015 are the same than observed. The annual PM10 LV is 40 µg.m^{-3}.

For the baseline 2030 scenario, the reduction in concentrations associated to reduction in primary particles but also to reduction in gases that form secoundary particles by condensation leads to important reduction in annual average concentrations and a reduction of about 62% of the number of stations in exceedances (from 13 to 5). Those stations in exceedances are reduced to respectively 4 and 2 with WAM A and WAM B scenario (Uzice and Valjevo). There are no more exceedances simulated with the WAM C scenario.

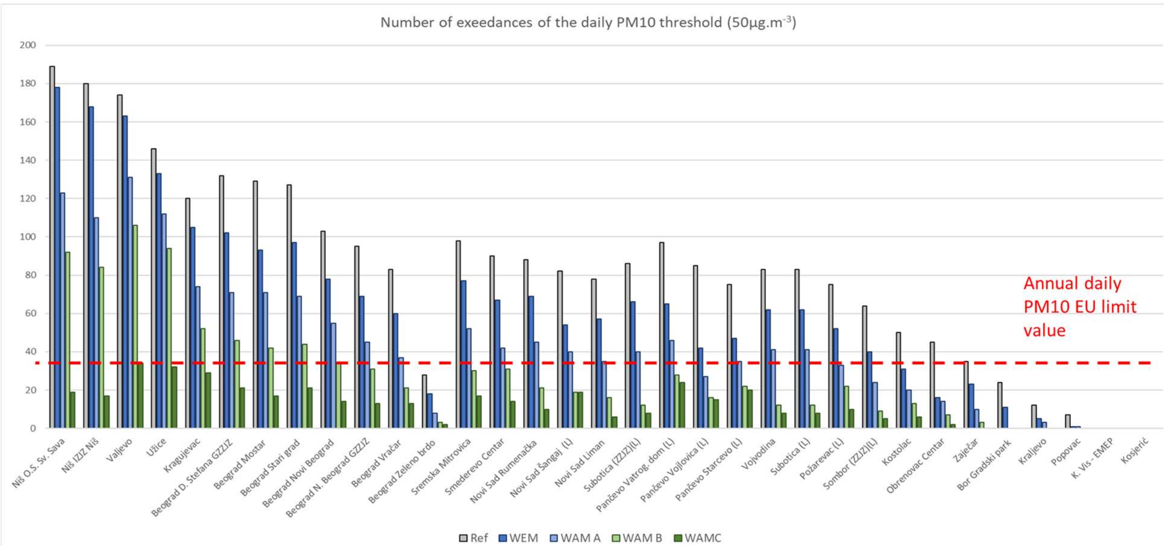

Figure 3: Number of exceedances of the daily PM10 concentrations threshold (50 µg.m^{-3}) simulated by the model for the reference year (2015 in grey), the 2030 WEM scenario (dark blue) and the 3 mitigations scenarios (WAM A, WAM B and WAM C respectively inlignth blue, light green and dark green). Stations measuring particles in 2015 are Užice, Valjevo, Beograd Vračar, Beograd Zeleno brdo, Pančevo Vatrog. dom, Pančevo Starcevo, Pančevo Vojlovica, Kragujevac, Novi Sad and K. Vis – EMEP. Due to modelling data correction, for those stations simulated concentrations in 2015 are the same than observed. The number of days showing exceedance of the daily threshold should not exceed 35.

For most stations, the number of days exceeding the daily PM10 LV concentration threshold is well above 35 days. For this reason, and contrary to what we have seen for the annual average PM10, the emission reductions of the WEM scenario, or even the WAM A scenario, are not sufficient to have a large reduction of the number of stations in exceedance. With WAM B additional emissions reduction and associated concentration reductions, a majority of stations have seen their number of exceedance days fall below the LV but 8 stations and 5 cities are still in exceedance (Užice, Valjevo, Beograd, Niš and Kragujevac). With the targeted emissions reductions, the WAM C scenario avoids exceedances at all stations.

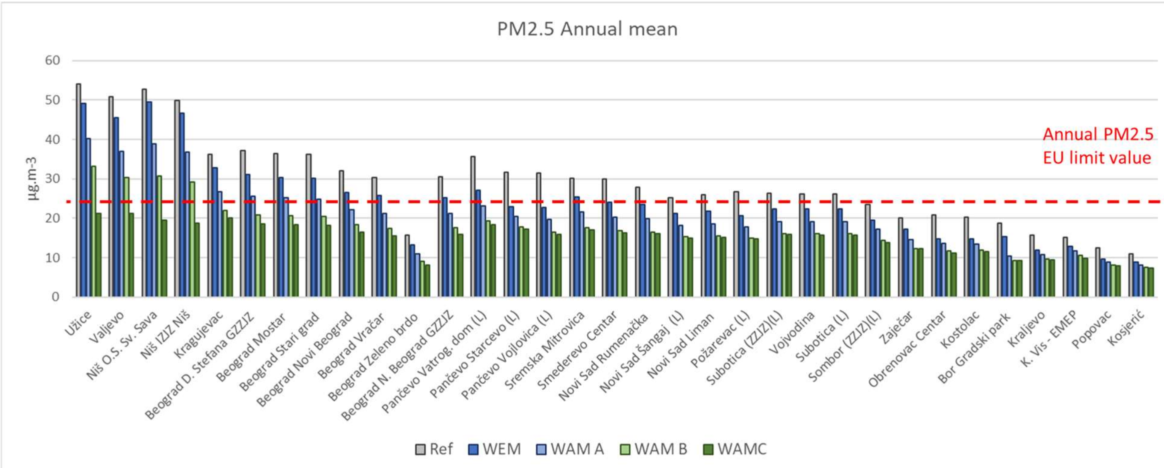

Figure 4: Annual mean PM2.5 concentrations simulated by the model for the reference year (2015 in grey), the 2030 WEM scenario (dark blue) and the 3 mitigations scenarios (WAM A, WAM B and WAM C respectively inligth blue, light green and dark green). Stations measuring PM10 in 2015 are Užice Valjevo, Beograd Vračar, Beograd Zeleno brdo, Pančevo Vatrog. dom, Pančevo Starcevo, Pančevo Vojlovica, Kragujevac, Novi Sad and K. Vis – EMEP. For those stations, PM2.5 measurements have been reconstructed based on PM10 measurement and PM10/PM2.5 ratio observed over several years. Due to modelling data correction, the simulated concentration in 2015 are the same than reconstructed observation. The annual PM25 LV is 25 µg.m^{-3}.

Stations in exceedances of the annual mean PM2.5 concentration LV are reduced by 44% with the WEM scenario (from 23 to 13), reduced to 8 stations with WAM A and 4 with WAM B in 3 cities: Užice Valjevo, and Niš. With the targeted emissions reductions, the WAM C scenario avoids exceedances at all stations.

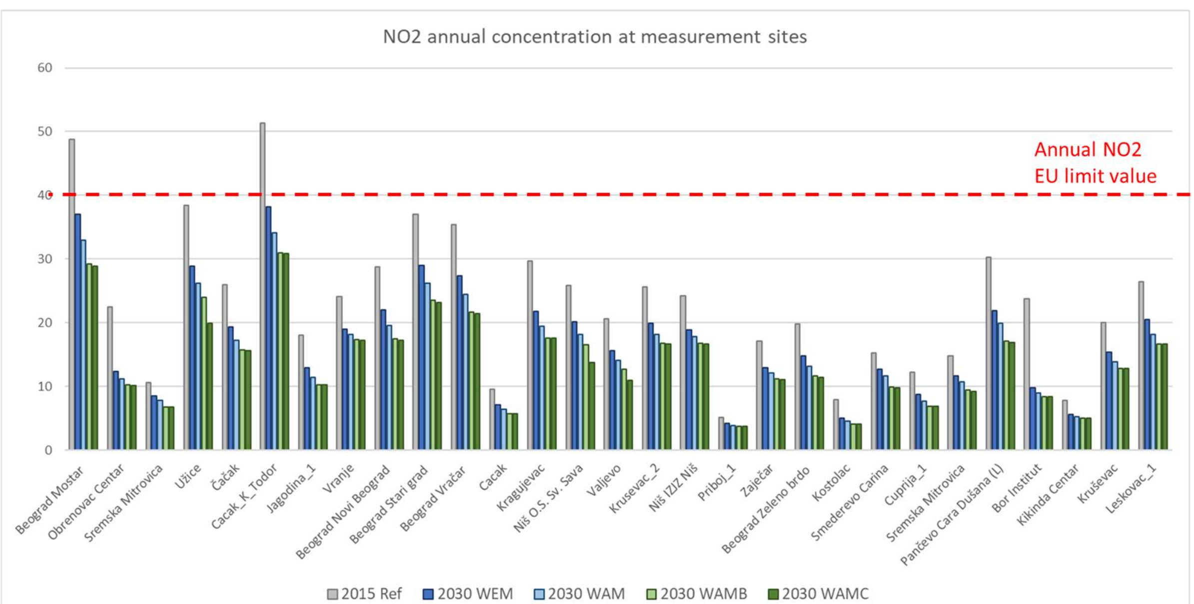

Figure 5: Annual mean NO_2 concentrations simulated by the model for the reference year (2015 in grey), the 2030 WEM scenario (dark blue) and the 3 mitigations scenarios (WAM A, WAM B and WAM C respectively in ligth blue,

light green and dark green). Due to modelling data correction, simulated concentrations in 2015 are the same than observed. The annual NO2 LV is 40 µg.m^{-3}.

The important reduction in emissions associated with the baseline scenario for 2030 (WEM) allows to completely avoid NO_2 exceedances.

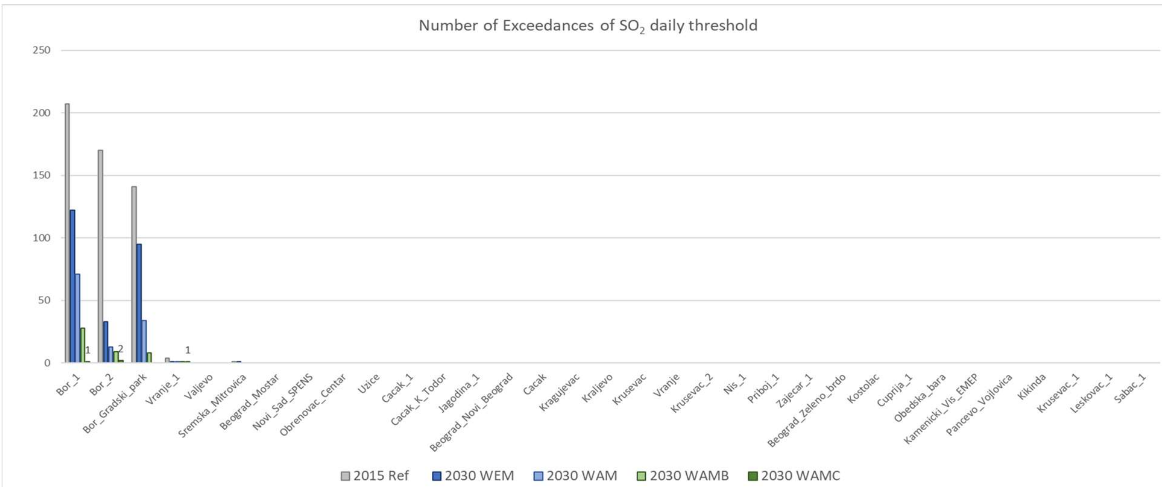

Figure 6: Number of exceedances of the daily mean SO_2 concentrations (125 µg.m^{-3}) simulated by the model for reference year (2015 in grey), the 2030 WEM scenario (dark blue) and the 3 mitigations scenarios (WAM A, WAM B and WAM C respectively inlignth blue, light green and dark green). Due to modelling data correction, simulated concentrations in 2015 are the same than observed. The number of days showing exceedance of the daily threshold of 125 µg.m^{-3} should not exceed 3.

The important reduction in SO_2 emissions associated with the WEM scenario allows an important reduction in SO_2 concentration. If these reductions are enough to avoid exceedance in Vranje, it does not allow to avoid exceedances in Bor. Additional reduction in SO_2 emissions are not important for WAM A or WAM B. Only the important reduction targeted in scenario WAM C allows to avoid LV in all 3 stations in Bor.

The following table summarized the cities showing exceedances of particles (based on either annual or daily mean LV), NO_2 or SO_2 for at least one station for each simulation.

Table 4: Cities showing exceedances of at least one station measuring particles (based on either annual or daily mean LV), NO_2 or SO_2, for each simulation

	2015 Ref	2030 - WEM	2030 - WAM A	2030 - WAM B	2030 - WAM C
Užice	PM10 & PM2.5	PM10 & PM2.5	PM10 & PM2.5	PM10 & PM2.5	
Valjevo	PM10 & PM2.5	PM10 & PM2.5	PM10 & PM2.5	PM10 & PM2.5	
Niš	PM10 & PM2.5	PM10 & PM2.5	PM10 & PM2.5	PM10 & PM2.5	
Kragujevac	PM10 & PM2.5	PM10 & PM2.5	PM10 & PM2.5	PM10	
Beograd	PM10 & PM2.5 & NO2	PM10 & PM2.5	PM10 & PM2.5	PM10	
Pančevo	PM10 & PM2.5	PM10 & PM2.5	PM10		
Novi Sad	PM10 & PM2.5	PM10	PM10		
Sremska Mitrovica	PM10 & PM2.5	PM10 & PM2.5	PM10		
Smederevo	PM10 & PM2.5	PM10	PM10		
Vojvodina	PM10 & PM2.5	PM10	PM10		
Subotica	PM10 & PM2.5	PM10	PM10		
Požarevac	PM10 & PM2.5	PM10 & PM2.5			
Sombor	PM10 & PM2.5	PM10 & PM2.5			
Obrenovac	PM10				
Kostolac	PM10				
Zaječar	PM10				
Vranje	SO2				
Bor	SO2	SO2	SO2	SO2	
Cacak	NO2				

2.2 Population exposure

The exposure of the population has been calculated by crossing the pollutant concentrations fields simulated by CHIMERE with the inhabitant-densities in each grid for the year 2015 (GHS-POP https://ghsl.jrc.ec.europa.eu/ghs_pop2019.php). The average exposure of the population to $PM_{2.5}$, O_3 and NO_2 is thus calculated for the reference year and each scenario. These average exposures are used to quantify the health impact of air quality in Serbia and calculate the health effects avoided by the implementation of air pollution reduction measures in each of these mitigation scenarios and, thus, to quantify the health benefits of these measures in monetary terms for the target year studied (2030).

3 Conclusions

- Despite the halving of PM emissions in the WAM B scenario compared to the 2015 base year, LV exceedances are still simulated in some cities in Serbia: Užice, Valjevo, Beograd, Niš and Kragujevac. Furthermore, SO_2 reductions are not sufficient to eliminate exceedances in Bor.

- The WAM C scenario, based on locally adapted emissions reductions on domestic heating sector, on a phase out of agricultural waste burning and on stricter limit values for industrial plants in Bor, solves the remaining exceedance problems in Serbia, but requires considerable efforts in terms of emission reductions for the cities concerned.