21st International Conference on
Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes
27-30 September 2022, Aveiro, Portugal

Evaluation of the Impact of the Projected Future Emissions from Energy on the Air Quality in Bulgaria

Georgi Gadzhev[1], Kostadin Ganev[1], Ivelina Georgieva [1] and Vladimir Ivanov[1]

[1] National Institute of Geophysics, Geodesy and Geography - Bulgarian Academy of Sciences

Abstract: The strategic plans for future development of the energy production in Bulgaria will lead to a substantial change of the emissions from this source category. The evaluation of the impact of the projected future emissions from energy on the air quality in Bulgaria is the objective of the present study.
The studies are performed applying computer simulations. The simulations are performed with the US EPA Models-3 System: Meteorological model WRF; Emission model SMOKE; Atmosphere Composition Model CMAQ for the period 2008 – 2014. The provided model simulations are with horizontal resolution 9 kilometers for the region of Southeastern Europe, in particular Bulgaria. The NCEP Global Analysis Data meteorological background with 1°x 1°resolution is used as a meteorological background. The models nesting capabilities were applied to downscale the simulations to 9 km resolution.
The 2005 emissions (reference period) are taken as basic. The projected emissions (including emissions from energy production) for year 2030 are calculated for two scenarios - with existing measures (WEM) and with additional measures (WAM). Computer simulations are performed for these scenarios, as well as with the one with energy emissions reduced by a factor of 0.8. The comparison of the concentrations, simulated with the different scenarios makes it possible to evaluate the impact of different options of the future development of the energy production on the air quality in Bulgaria.

***Key words:** air quality, chemical-transport models, emission scenarios, WAM, WEM.*

INTRODUCTION

The strategic plans for the future development of energy production in Bulgaria will lead to a substantial change in the emissions from this source category. The evaluation of the impact of the projected future emissions from energy on the air quality in Bulgaria is the objective of the present study.
Most countries, including Bulgaria, have developed systems for air quality forecasts (Syrakov et al., 2014, Kukkonen et al., 2012). They contain different modules for ingesting many kinds of input data and using them for simulation of the meteorological part as well as the processes of advection, diffusion, chemistry, and transformation of atmospheric pollutants. The advantage of these systems is their capability to simulate the different processes in a physically consistent way, which allows studying their influence on the atmospheric composition more thoroughly. Previous studies of the air quality adverse effects on the human body in Bulgaria (Georgieva, Ivanov, 2018) as a whole and the capital city Sofia (Georgieva, Ivanov, 2017, Georgieva 2021) have shown that their influence varies within the day, season, and the dominant pollutant. We carry out the research on the impact of projected emissions from the energy sector on the air quality in Bulgaria based on the modeling system used for forecasting the chemical weather in our country. The study takes into consideration 4 scenarios for projected emissions. The comparison of the concentrations, simulated with the different scenarios, makes it possible to evaluate the impact of different options for the future development of energy production on the air quality in Bulgaria.

METHODOLOGY

3D simulations by the US EPA Models-3 system developed by different collectives and funded mainly by the United States Environment Agency (US EPA) are made, and thus a database was created suitable for extensive research of the atmospheric composition. The system consists of three main modules. The first one is the emission preprocessor SMOKE - Sparse Matrix Operator Kernel Emissions Modelling System

(CEP, 2003). It is used for preparation of the emissions from the TNO inventory (Denier van der Gon et al., 2010) for foreign territories and the National Inventory provided by the Bulgarian Executive Environmental Agency for the territory of Bulgaria. The second module is the numerical weather prediction model - WRF version 3.4.1 (Shamarock et al. 2007, UCAR/NCAR). The initial and boundary conditions are taken from the NCEP Global Analysis Data with a horizontal resolution of 1º x 1º. The third module is the chemical-transport model CMAQ version 4.6 - Community Multi-Scale Air Quality model (Byun et al., 1998), (Byun and Ching, 1999) for simulation of the air composition based on the information from the meteorological model and emission preprocessor.
The simulations are performed for the period 2008 – 2014, and use the nesting capability of the US EPA Models-3 system (Figure 1). The meteorological data from the NCEP are used as a background for the large European domain (D1) with a resolution 81 km. The other two domains of the nesting chain are the Balkan Peninsula domain, with a spatial resolution 27 km (D2), and the Bulgaria domain (D3), with a horizontal resolution 9 km. Our study is based on the simulations from the D3.

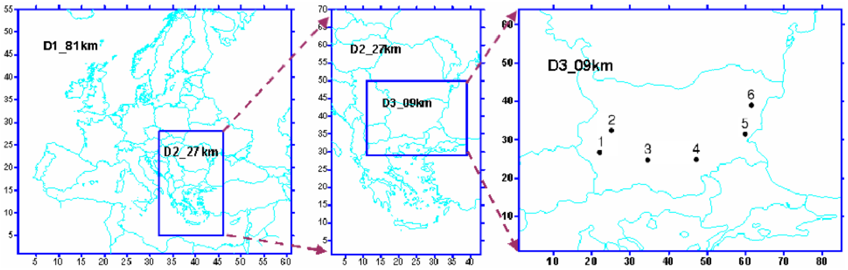

Figure 1. Model domains: Downscaling from domain Europe (81 km) to domain Bulgaria (09 km) and pointed location of some industrial zones in Bulgaria – 1 - TPP Bobovdol, 2 – Sofia city, 3 – Plovdiv city, 4 - TPP Maritsa Iztok, 5 – Burgas city, 6 - Devnya Industrial Area.

Every EU member state reports a set of emission projections scenarios (EEA Technical report No 4/2015). A projection scenario with "existing measures" (WEM) means projections of anthropogenic Greenhouse Gas (GHG) or air pollutant emissions by sources that encompass the effects of currently implemented or adopted policies and measures; projections scenario "with additional measures" (WAM) means projections of anthropogenic GHG or air pollutant emissions by sources that encompass the effects of policies and measures which have been adopted and implemented, as well as planned policies that are judged to have a realistic chance to be adopted and implemented in the future.
The forecast of air pollutant emissions according to the Bulgarian National Air Pollution Control Program 2020-2030 is given in Table 1.

Table 1. Projected air pollutant emissions for Bulgaria.

Pollutant	Emissions 2005 [kt]	Emissions 2030 WEM [kt]	Reduction factor [%]	Emissions 2030 WAM [kt]	Reduction factor [%]
SO_2	771.3	85.6	11.09	68.6	8.89
NO_X	183.2	85.4	46.61	67.8	37.01
NMVOC	80.7	55.9	69.27	47	58.24
NH_3	51.6	47	91.08	43.8	84.88
$PM_{2.5}$	30.9	18.5	59.87	8.8	28.47

Parallel calculations were carried out with 4 emission scenarios:
Scenario 1: WEM emission data for Bulgaria for 2030, with emissions from all source categories renormalized according to the ratios of the tabulated values for 2005 and projected values for 2030.
Scenario 2: WAM emission data for Bulgaria for 2030, with emissions from all source categories renormalized according to the ratios of the tabulated values for 2005 and projected values for 2030.
Scenario 3: WEM emission data for Bulgaria for 2030, with emissions from the Energy sector reduced by 20%.
Scenario 4: WAM emission data for Bulgaria for 2030, with emissions from the Energy sector reduced by 20%.
The comparison between scenarios 1 and 3 makes it possible to estimate the contribution of the sources from the Energy sector to the air quality for the whole country under the WEM scenario, and the comparison

between scenarios 2 and 4 makes it possible to estimate the contribution of the sources from the Energy sector to the air quality for the whole country under the WAM scenario.
It should be clarified here that only the Bulgarian emissions for 2030 have been modified according to the forecast scenarios (Table 1).

RESULTS
The present paper presents part of the results obtained in the frame of an extensive study of the effects of different emission scenarios on the air quality in Bulgaria. Due to volume limitations, only the impact of future emissions from the energy sector on the surface SO_2 concentrations in Bulgaria will be demonstrated.
Figure 2 shows the contribution of the energy sector to the formation of surface concentrations of SO_2 for the 2030 WAM scenario. On average for the year, it would be almost entirely positive, reaching up to 10-15% in the midday and morning hours in the summer above the thermal power plant areas. Due to the more intensive transport from above and across the boundary and mixing with the layers aloft, and due to the non-linear chemical and aerosol processes and the strong emission reduction for 2030, areas with a weak negative contribution of the energy sector to the formation of ground SO_2 concentrations for this scenario are obtained.

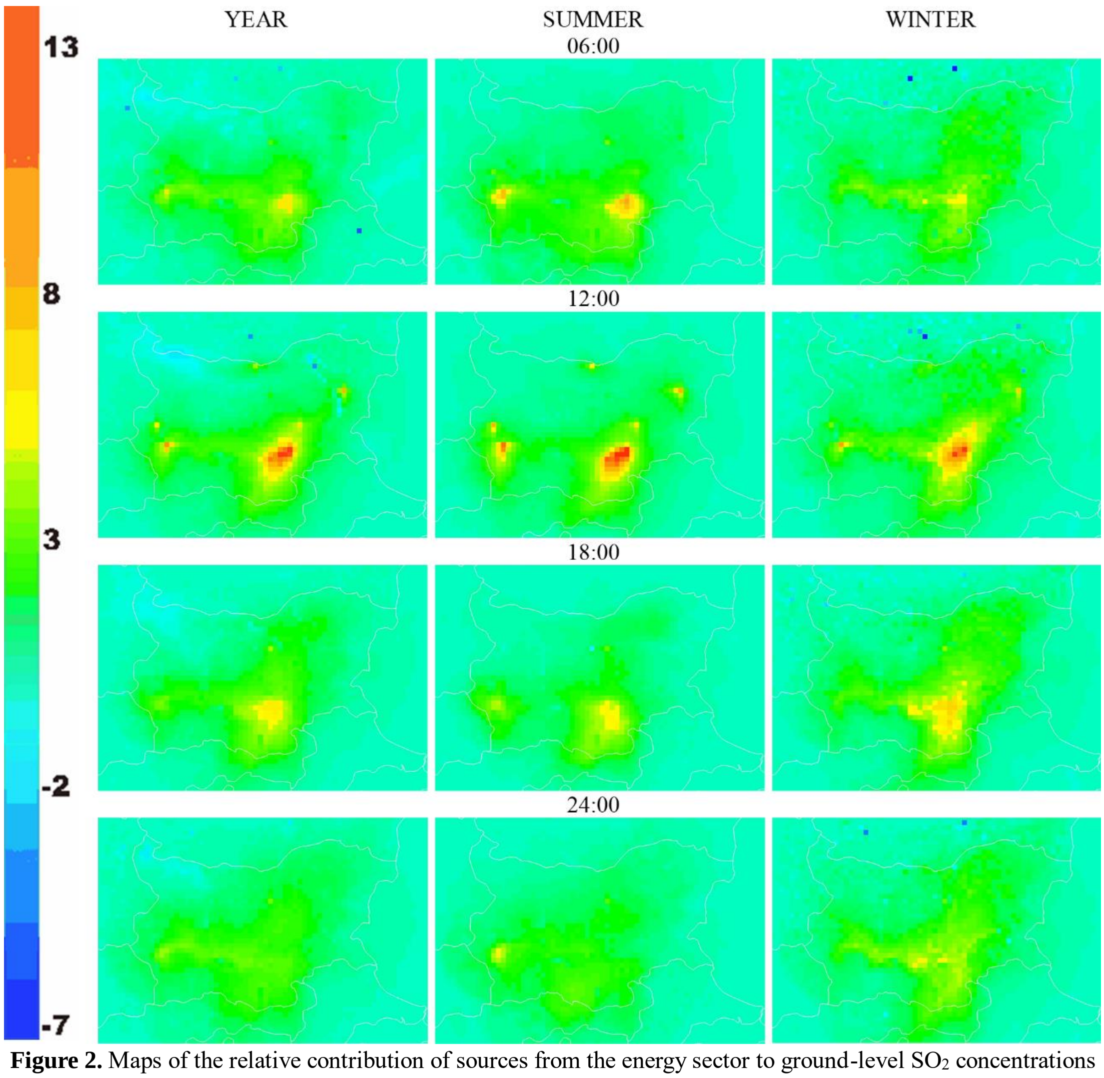

Figure 2. Maps of the relative contribution of sources from the energy sector to ground-level SO_2 concentrations obtained with 2030 WAM emissions averaged over the entire ensemble annually, for the summer and winter periods at 6, 12, 18 and 24 hours local time.

The picture for the WEM emission scenario is similar (Figure 3), with the contribution of the energy sector to the formation of SO_2 concentrations being more pronounced, especially in the winter when the energy consumption is higher.

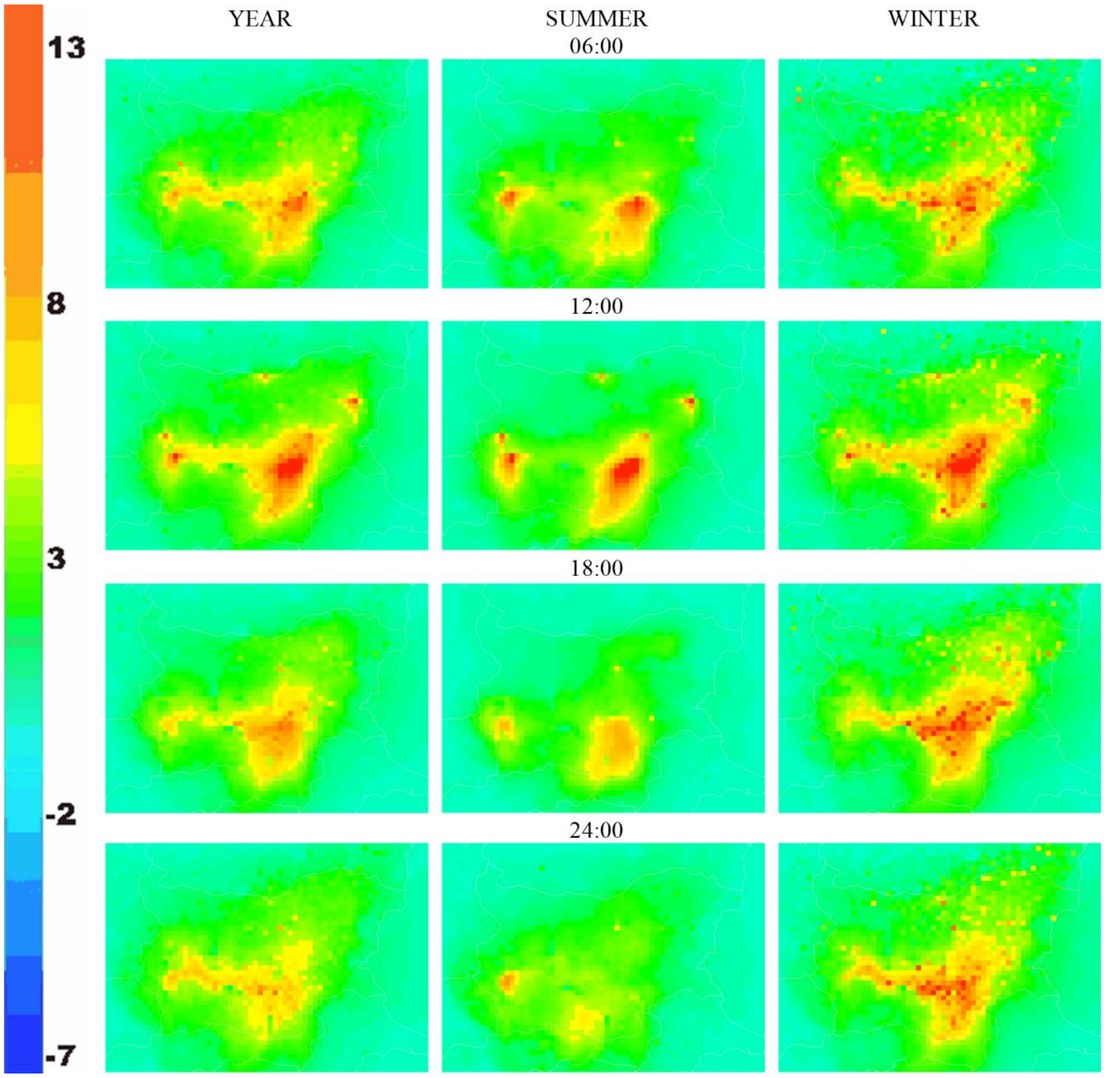

Figure 3. Maps of the relative contribution of sources from the energy sector to ground-level SO_2 concentrations obtained with 2030 WEM emissions averaged over the entire ensemble annually, for the summer and winter periods at 6, 12, 18 and 24 hours local time.

CONCLUSIONS

The differences in the estimates for the contribution of the emissions from the energy sector obtained for WAM and WEM emission scenarios are quite significant, and obviously, the 2030 WAM scenario is more favorable in terms of ambient air quality. This is well displayed for both winter and annually in the higher relative contribution and larger areas around the Thermal Power Plants in WEM scenarios (Figure 3).

ACKNOWLEDGEMENTS

This work has been carried out in the framework of the National Science Program "Environmental Protection and Reduction of Risks of Adverse Events and Natural Disasters", approved by the Resolution of the Council of Ministers № 577/17.08.2018 and has been accomplished with the financial support by the Ministry of Education and Science (MES) of Bulgaria (Agreement № D01-279/03.12.2021) and the project" NATIONAL GEO-INFORMATION CENTER", subject of the National Road Map for Scientific Infrastructure 2017–2023, funded by Contr. No D01-161/28.08.2018.

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