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CASE STUDY

Air pollution modeling to support strategic environmental assessment: case study—National Emission Reduction Plan for coal-fired thermal power plants in Serbia

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Abstract

The paper presents a specific method of environmental impact assessment applied in Strategic Environmental Assessment (SEA) for the National Emission Reduction Plan (NERP) in the Republic of Serbia, based on air quality. The specificity of the approach is in the application of a semiquantitative method of multicriteria evaluation based on air dispersion modeling and the integration of SEA goals, indicators and criteria for assessing the impact of the NERP on the quality of air and other environmental elements in this method. When predicting changes in air quality for the planning horizon to 2028, the physical, geographical and climatic characteristics of the area were taken into account, as well as technical measures to reduce SO_2 emissions, since this was the dominant pollutant from the Serbian coal-fired power plants studied by the NERP. Air pollution modeling was carried out using the AERMOD software package based on the data collected, and the quantitative results obtained were used in a multicriteria evaluation as part of the SEA. The results of the research indicated the importance of applying this approach in order to significantly increase objectivity in the SEA process, since it is an important element of decision making at the strategic level. In addition, a comparative presentation of the modeling results before and after application of the NERP was an important part of the SEA process, and it provided a clear insight into expected changes in the air quality. This is a key argument for making appropriate policy decisions on spatial, energy, environmental and socio-economic development in the Republic of Serbia, which, like other developing countries, is sluggishly following global trends in energy transition.

Keywords Strategic environmental assessment · Semiquantitative method of multicriteria evaluation · Air dispersion modeling · Coal-fired power plants · Energy transition · Decision making

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1 Introduction

Almost three decades have passed since the introduction of Strategic Environmental Assessment (SEA) as an administrative procedure in the strategic planning process in a large number of countries. During this period, numerous authors (Partidário & Coutinho, 2011; Nilsson & Dalkmann, 2001; Josimović, 2003; Maričić & Josimović, 2005; Fischer & Onyango, 2012, White & Noble, 2013; Nenković et al., 2014; Rega & Baldizzone, 2015; Balfors et al., 2018; Krunić, et al., 2019; Josimović et al., 2021a; and many others) have dedicated their scientific work to researching the best opportunities for the application of SEA in order to make optimal decisions on key development issues, in which questions concerning environmental protection and public health are fully equal to economic and social considerations.

Due to the lack of detailed data on development projects in the strategic planning phase in general, the usual approach in SEA is based on various qualitative expert methods such as SWOT analysis, the Delphi method, qualitative environmental capacity assessment, cause and effect analysis, vulnerability assessment, and risk assessment as covered by a significant number of authors (Marsden, 2002; Kuo et al., 2005; Liou, 2006; Paliwal, 2006; García-Melón et al., 2011; Rachid & El Fadel, 2013; Josimović et al., 2016; and others). Some authors (Partidário & Coutinho, 2011; Garfi et al., 2011; Josimović et al., 2015; Ghavami, 2019 and others) strongly advise multicriteria analysis, and evaluation within which it is possible to apply different methodological approaches, techniques and methods for impact assessment in SEA. The choice of appropriate assessment techniques and methodologies used in a particular case must be made in relation to the appropriate implementation experiences accumulated through comparative studies of previously applied methodologies that have shown good results in their application (Liou et al., 2006; Josimović & Crnčević, 2009).

However, whichever expert method is applied in the SEA process, it brings subjectivity that depends on expert knowledge, attitudes about global phenomena and processes, experience, and methodological skills. It is this subjectivity that stands out as one of the most significant shortcomings of SEA, which has been clearly pointed out by some authors (Balfors et al., 2018; Marsden, 2002; Unalan & Cowell, 2019). For that precise reason, Josimović (2020) emphasizes the importance of using techniques and tools which, in specific circumstances, achieve the greatest possible objectivity in impact assessment within the SEA process. This refers to the application of different qualitative expert methods in combination with quantitative methods and modeling used in cases of so-called "partial"[1] impact assessments, and their integration into the method of semiquantitative multicriteria evaluation in SEA (Josimović et al., 2021a).

The importance of applying the SEA process to support the preparation of sustainable development policies in the energy sector is especially pronounced, given that the energy sector is an area of development that has significant environmental consequences compared to most other areas of activity, especially with regard to coal-fired power plants. This was the reason for applying the specific methodological approach to SEA in this case, in order to increase the objectivity of the approach and decision making regarding the reduction

[1] The authors use the term "partial" for all assessments that analyze the impact of a particular plan, program, strategy or project, on only one of the environmental receptors (water, air, soil, landscape, biodiversity, habitats, noise, etc.). Much has recently been written in the scientific literature about the partial assessment of the impact on individual elements of the environment (Murphy & King, 2010; Lim, 2012).

of pollutant emissions from coal-fired power plants, as seen in this paper. A model is presented of a partial assessment of the spatial distribution of air pollution and its involvement in the semiquantitative method of multicriteria evaluation in the SEA for the Republic of Serbia's National Emission Reduction Plan (NERP).

Although the SEA process considers different impacts of the planned measures for reducing emissions and their implications for different environmental and socio-economic aspects of development, i.e., the SEA objectives, the focus of the paper is to present only that part of the impact assessment concerning the spatial distribution of SO_2, as the dominant pollutant from the Serbian coal-fired power plants that were the subject of the NERP, as well as the way in which, using software modeling, a higher level of objectivity was achieved in the SEA process.

2 Case study area—initial position

The Republic of Serbia is one of the five countries in the Western Balkans – a European region, whose 18 coal-fired power plants, according to Bankwatch (2020), in 2019 emitted twice as much sulfur dioxide (SO_2) as all such plants in the European Union (EU) combined (a total of 221 plants). The extent of their impact on the health of the population and on the quality of the environment far exceeds the regional character and they have a significant impact on the European continent. For this reason, energy transition is one of the key issues in the region.

Markard (2018) gave a detailed analysis on the energy transition and its implications for research and policy, while Heuberger and associates (2018) pointed out the problems caused by inadequate decision making in planning the power system. What is characteristic of the Republic of Serbia in the context of these topics is that, in addition to the lack of political will for the dynamic implementation of energy transition, which is largely due to the expected reduction in jobs in the energy sector (social category, on the one hand, and the potential loss of votes on the other hand) and concerns about energy independence and energy availability in future that are characteristic of other countries (Debnath & Mourshed, 2018; Demski et al., 2018), an important factor in the ineffectiveness of measures to implement energy transition is insufficient awareness of the environmental and health consequences of an inert attitude toward energy transition. These facts also lead to the insufficient flexibility of the electricity generation model written about by Facchini (2017).

For these reasons, it was a huge challenge to apply this approach in the preparation of the SEA for NERP, since it will unambiguously and clearly indicate the expected changes in space and the environment possible from applying the NERP. A decision by the Ministerial Council of the Energy Community on the implementation of the EU LCP Directive (2013) enabled the signatory states to develop a National Emission Reduction Plan for old large combustion plants in order to implement the EU LCP Directive. Implementation of the NERP began on January 1, 2018, and will continue until December 31, 2027, as a combination of provisions from EU LCP Directive, 2001/80 and EU Directive 2010/75 on industrial emissions.

The NERP is a document for reducing the emissions of major pollutants originating from old large combustion plants with a rated thermal input equal to or greater than 50 MW. The goal of the NERP is to reduce the total annual emissions of sulfur dioxide (SO_2), nitrogen oxides (NO_x) and particulate matter (PM) from the old large combustion

Table 1 Combustion plants in the NERP covered by modeling in the SEA process

Domain model	Power plant	Installed capacity [MWth]
A (Kolubara)	Thermal power plant Nikola Tesla A (TENT A)	5063
	Thermal power plant Nikola Tesla B (TENT B)	3635
B (Kostolac)	Thermal power plant Kostolac A (TEKO A)	1047
	Thermal power plant Kostolac B (TEKO B)	2155

plants that it covers, in order to reach the emission limit values prescribed in Part 1 of Annex V of the IED Directive on Industrial Emissions no later than January 1, 2028.

The measures covered by the NERP envisage the introduction of limestone flue gas desulfurization systems on all blocks of thermal power plants (TPPs) for the reduction of SO_2 emissions, then the installation of primary and secondary measures for deNOx, and the reconstruction of electrostatic precipitators (ESP) in order to further reduce PM. The total investment for these measures for all TPPs amounts to approximately EUR 1 billion, reducing the SO_2 emissions by over 98%.

The combustion plants covered by the NERP and which are subject to analysis and modeling in the SEA process, as presented in this paper, are shown in Table 1.

Thermal power plants that burn domestic lignite (Table 1) not only represent over 95% of the total installed thermal capacity in the Republic of Serbia, but they are also the most significant polluters in terms of SO_2 and NO_2 emissions (SEPA, 2020). The absence and/or inefficiency of measures for the treatment of flue gases, the implementation of which is envisaged by the NERP, leads to extremely high emissions of these pollutants. The situation in which thermal power plants operate without a flue gas desulfurization system, as well as the characteristics of Serbian lignite, has led to SO_2 emissions from these four thermal power plants, in 2017, amounting to 328,900 tons, which was as much as 26% (Europe Beyond Coal, 2020) of the total SO_2 emissions of all coal-fired power plants in Europe. The research presented in Vukadinović et al. (2016) indicates a significant correlation between eco-efficiency measures and resource and impact decoupling for thermal power plants in Serbia.

It was therefore essential that on the basis of the results from the SEA process, which are based on a specific scientific and methodological approach, to point out to all users of the space in the immediate impact zone of coal-fired power plants and all decision makers the importance and scope of the territorial impacts that can be expected as a result of implementing the NERP. The specific approach presented in this paper is based on the application of the MCE (Multi-Criteria Evaluation) method with the support of a software package for partial assessment of the spatial distribution of SO_2, which is elaborated below.

3 Method

Generally, the methodological approach used in SEA, in contrast to the diverse, precise, and highly operable tools used in environmental engineering, is characterized by considerable flexibility (Liou, et al., 2006). Moreover, SEA techniques and methods should be treated as a set of different tools, which the user can choose according to his or her specific needs (Partidario & Coutinho, 2011).

In methodological terms, the SEA process is predominantly expert, qualitative and subjective, but also flexible compared with various techniques and methods used in environmental engineering and other fields that are based on the scientific postulates of Environmental Impact Assessment (EIA) (Marsden, 2002; Balfors et al., 2018; Unalan & Cowell, 2019; Josimović et al., 2021a, 2021b, 2021c/2). Finveden et al. (2003) point out some of the possibilities of applying different methodological approaches that can be applied in SEA in the energy sector, but they do not give any specific quantitative methods that can be used to increase the objectivity of the SEA process.

In this particular case, a combination of a semiquantitative method of multicriteria expert evaluation and a partial assessment of the impact on the air quality of the coal-fired power plants in the NERP was applied. For the partial impact assessment on air quality, modeling was carried out in the AERMOD software package, the results of which were expressed in quantitative terms. The idea of the author was to contribute to objectivity in the SEA process with an original approach combining different but complementary methods, which is especially important when it is known that based on the results of the SEA process, significant, almost existential, decisions will be made on future development in the energy sector.

Although the goal of the NERP is to reduce the total annual emissions of SO_2, NOx and PM, SO_2 is highlighted in this paper for the following two reasons:

- The SO_2 emitted from the facilities under consideration had no significant synergy with other SO_2 emitters in either of the domains used for modeling (these emitters are the absolute dominant source of SO_2 in the considered domains), so the results of the procedure are more precise in terms of the air quality before and after implementation of the NERP.
- The other reason lies in the way that the EAQI is applied, namely, when defining the level of pollution, the index corresponds to the worst level among all of the pollutants according to the EAQI scheme (https://airindex.eea.europa.eu/Map/AQI/Viewer/), which is SO_2 in both of the domains considered in this paper, taking into account the concentrations obtained for NOx and PM.

The methodological procedure for the NERP evaluation was carried out in several basic steps:

1. Defining the objectives and related SEA indicators;
2. Defining the evaluation criteria;
3. Modeling spatial distribution of SO_2;
4. Semiquantitative evaluation method in SEA.

1. Defining objectives and associated SEA indicators was the initial phase in the process. This phase was especially important due to the fact that the evaluation of strategic solutions in SEA is carried out precisely in relation to SEA objectives and indicators. The SEA objectives were selected according to environmental areas, and each of the specific SEA objectives was assigned corresponding indicators (one or more of them for each SEA objective). The basis for selecting the SEA objectives and indicators was determined by the national regulations in the field of environmental protection to which the EU directives were transposed. Table 2 shows the objectives and indicators used in the SEA for the NERP and the criteria for evaluating the planning solutions.

Table 2 Objectives and indicators in the SEA for NERP

SEA area	SEA objectives	Indicators*
Air and climate change	Reduce emissions of pollutants into the air	**Frequency of exceedance for SO_2**, CO_2, NO_2, PM and O_3 values **Emissions of acidifying gases (SO_2,** NO_x, NH_3) (kt/year.) Consumption of ozone depleting substances (tons of ODP) Greenhouse gas emissions (CO_2, N_2O, CH_4, SF6, HFC, PFC) (Gg CO_2 eq/year. и Gg/year.)
Water	Reduce surface and groundwater pollution	BOD and COD in watercourses under the influence of power plants Change of water quality class (%)
Land	Protect forest and agricultural land	Concentrations of pollutants in the soil as a consequence of the functioning of power plants
Natural heritage	Protect landscape Preserve biodiversity and geodiversity—avoid irreversible losses	Share of recultivated areas in the total area of degraded areas (%) Number of energy facilities that cause a change in the landscapes Number of endangered species of flora and fauna that can be affected by the activities of the energy sector
Public health	Reduce the impact of the energy sector on public health	Frequency of respiratory diseases (%) near energy facilities (TE) Frequency of diseases that can be associated with energy activities Number of people affected by noise produced by energy facilities Reduction in the population's exposure to polluted air (%)
Social development	Better quality of life for citizens Preserve rural populations	Reduction in the number of households to be displaced as a result of activities in the energy sector
Natural resources	Introduce cleaner technologies	Reduction in pollutant emissions and increase in energy efficiency (%)

*According to the UN sustainable development goals and the rulebook on the national llst of environmental protection indicators (Official Gazette of the Republic of Serbia, No 37/2011)

Nine specific objectives were identified within the seven areas of the SEA. Each of the SEA objectives was assigned a total of fifteen indicators in relation to which the solutions formulated in the NERP were evaluated. The indicators that relate to SO_2 within SEA goal 1—"Reduce emissions of pollutants into the air," are marked in orange, because they were the subject of this study. What is very important to point out is the fact that SO_2 in the table is found in the "air" category, since SO_2 has a direct impact on it; however, this compound is implicit in all of the other SEA areas, with the area of public health being particularly important. There are significant references to the impact of SO_2 on public health in scientific publications (Lim et al., 2012; OECD, 2014; Lelieveld et al., 2015; Prüss-Ustün et al., 2016; Lin et al., 2018; Guo et al., 2021; and others).

2. Defining the evaluation criteria in the SEA process is a key phase for determining the significance, size, spatial distribution and frequency of impacts (Table 3), i.e., for determining the rank of impacts.

The criteria for determining size, spatial distribution and frequency that are usually used in the SEA process were also used to evaluate the NERP for all areas of the SEA (air, water, soil, biodiversity, landscape, population, etc.). What is new in this approach is the addition of a set of criteria for determining the importance of the impact on air quality and an analysis of the results of the pollutant dispersion model, for which the European Air Quality Index (EAQI) was used.

EAQI enables users to better understand the air quality where they live, work or travel, and helps decision makers on strategic energy transition issues based on the SEA process, in order to better understand the results and/or consequences of certain decisions. The index bands (Table 3) were complemented by health-related messages that provide recommendations for both the general population and sensitive populations. The latter includes both adults and children with respiratory problems and adults with heart conditions (EEA). For SO_2, the bands reflect the limit values set under the EU Air Quality Directive (2008).

EAQI is based on concentration values for up to five key pollutants, including: particulate matter (PM10), fine particulate matter (PM2.5), ozone (O_3), nitrogen dioxide (NO_2) and sulfur dioxide (SO_2) (EEA). It reflects the potential health impacts of air quality. From the standpoint of scientific research, air quality indices can be used for preliminary analyses in space–time modeling and mapping the air quality or in assessing the impact of exposure to air pollution (Bodnar et al., 2008), which was one of the basic tasks of this paper.

3. Modeling the spatial distribution of SO_2 was performed in relation to specific criteria for air quality assessment (Table 3). The detailed characteristics of the plants under consideration before and after implementation of the measures envisaged by the NERP were taken into account for modeling. The AERMOD US EPA regulatory model was used to assess the impact of the NERP on air quality.

AERMOD is a steady-state Gaussian plume dispersion model, which is designed to predict impacts up to 50 km. The AERMOD model includes a wide range of options for modeling the air quality impacts of pollution sources, making it a popular choice among the modeling community for a variety of applications (EPA-454/B-19-027, August, 2019). AERMOD is actually a modeling system with three separate components: AERMOD (AERMIC Dispersion Model), AERMAP (AERMOD Terrain Preprocessor), and AERMET (AERMOD Meteorological Preprocessor) (Peters et al., 2003). Although AERMOD does not take into account chemical reactions, it is acceptable to use for SO_2 dispersion modeling since, according to Stevens et al. (2012) within a 50 km × 50 km domain, approximately only 0.8–9% of SO_2 would be converted to sulfate, depending on the atmospheric conditions.

Table 3 SEA criteria for evaluating the strategic solutions from NERP

Type of impact	Rank	Description	Health Advice
Significance of impact (EAQI)			
Good (0-100 μg/m^3)		Air quality is considered satisfactory, and air pollution poses little or no risk.	Enjoy your normal outdoor activities.
Fair (100-200 μg/m^3)		Air quality is acceptable; however, for some pollutants there may be a moderate health concern for a very small number of people who are unusually sensitive to air pollution.	Unusually sensitive people should consider reducing prolonged or heavy exertion outdoors. These people may experience symptoms such as coughing or shortness of breath.
Moderate (200-350 μg/m^3)		Members of sensitive groups may experience health effects. The general public is not likely to be affected.	Sensitive groups should consider reducing prolonged or heavy exertion outdoors. People with asthma or respiratory diseases may experience symptoms such as coughing or shortness of breath. They should carefully follow their medication plan and may need to use their reliever inhaler more frequently. Adults with heart problems may experience symptoms such as palpitations, shortness of breath, or unusual fatigue and if so, should seek medical advice.
Poor (350-500 μg/m^3)		Everyone may begin to experience health effects; members of sensitive groups may experience more serious health effects.	Sensitive groups, such as children with asthma and adults with severe heart or respiratory diseases, should avoid prolonged or heavy exertion outdoors. Consider moving activities indoors or re-scheduling for when air quality is expected to improve. Everyone should reduce prolonged or heavy exertion outdoors, especially if you experience symptoms such as coughing or a sore throat.
Very poor (500-750 μg/m^3)		Health warnings of emergency conditions. The entire population is more likely to be affected.	Sensitive groups should avoid all physical activity outdoors. Consider moving activities indoors or re-scheduling for when air quality is expected to improve. Everyone should avoid prolonged or heavy exertion outdoors and consider moving activities indoors or re-scheduling for when air quality is expected to improve.
Extremely poor (750-1250 μg/m^3)			
Intensity of impact			
Favorable	**+2**	Strong positive impact (visible improvements in the environment)	
Positive	**+1**	Positive impact	
Neutral	**0**	No impact, no data or not applicable	
Negative	**-1**	Negative impact	
Unfavorable	**-2**	Strong negative impact (degradation of the environment)	
Spatial dimension of the impact			
Local	**L**	Potential impact on a zone of the municipality	
Regional	**R**	Potential impact at the regional level (includes several municipalities)	
National	**N**	Potential impact at the national level	
Transboundary	**T**	Potential transboundary impact	
Frequency of impact			
Dominant	**D**	Impact exists 90% of the time	
Prevailing	**P**	Impact exists ≥ 50% of the time	
Temporary	**Te**	Impact exists ≤ 50% of the time	
Rarely	**Ra**	Impact exists ≤ 10% of the time	

In order for the impact assessment to be as accurate as possible, real periodical emission measurement results, in accordance with the relevant standards (EN ISO 16911-1:2013 and ISO 7935), were taken for each of the plants that were the subject of the NERP, instead of the usual default emission factors, for the situation prior to implementation, while for the situation after implementation of the NERP measures, the future designed process parameters and adequate emission limit values were taken into account. For all emitters, the following parameters were taken into account: height and internal diameter of the emitter, flue gas temperature, flue gas flow, and volume of the pollutant flow.

Hourly observations of meteorological data for a period of five consecutive years (a total of 43,824 h for which concentrations were calculated) from the Veliko Gradiste meteorological station (44.76°N, 21.52°E) were used as input data for AERMET for domain B (Kostolac), while MM5 (short for the Fifth-Generation Penn State/NCAR Mesoscale Model) data for Obrenovac (44.39°N, 20.12°E) were used for domain A (Kolubara), also for five consecutive years. Five consecutive years of hourly meteorological data were used in order to avoid a possible non-standard meteorological year, which could lead to wrong conclusions. With regard to input data for the AERMAP preprocessor, SRTM1 data and 16,806 receptors within a multi-tier grid were used for both domains. And both spatial domains of the model considered were 50 × 50 km, with emitters in the center.

4. The semiquantitative evaluation method in SEA was based on the formation of matrices in which each solution from the NERP was evaluated in relation to each specific SEA objective and according to criteria for determining the size, spatial distribution and frequency of impacts from Table 3. This is a common approach in SEA.

What is specific in this approach is that partial assessment of the impact of NERP on air quality was initially performed only in relation to the first group of criteria from Table 3 (significance of impact), so that after obtaining the modeling results in the AERMOD software package, they could be included in the matrices as part of the multicriteria evaluation in SEA. In this way, the modeling results were included in the SEA process and in the evaluation process according to each of the other criteria from Table 3.

In addition, the quantitative results for modeling the impact on air (SO_2) were the basis for assessing the impact of the NERP on the other SEA objectives, where assessing the impact on public health was of particular importance.

Finally, the results of the NERP impact assessment obtained in this way served to determine the rank of spatial/territorial impacts, which is the basic task, not only of the evaluation process, but of the entire SEA process.

4 Results

Bearing in mind the values of SO_2 emissions from all emitters in both domains that were subject to modeling, i.e., partial assessment of the impact of the NERP on the air quality (SO_2), as well as the thermal power plants being practically the only source of SO_2 in both domains, in this paper, SO_2 was considered as the determining pollutant for air quality classes both before and after the implementation of NERP. Table 4 shows the modeling results according to the EAQI. The results refer to the frequency of exposure of any of the domain receptors to certain ground concentrations of SO_2 (hourly averaging periods).

The modeling results (Table 4) indicate a significant reduction in SO_2 emissions in all air quality classes, of up to 30.54% in Domain A, and up to 47.43% in Domain B. The reduction is related to the implementation of NERP compared with the existing SO_2 emissions for the quality class "Good." For the next two air quality classes—"Fair" and "Moderate," the reduction of SO_2 emissions is close to 15%. Significant effects of applying NERP are evident in the last three classes of air quality ("Poor," "Very poor" and "Extremely poor"), which are also the concentrations of SO_2 that have the greatest impact on health and the environment. In this range of air quality classes, the model showed that

Table 4 Modeling results shown in accordance with EAQI

		Domain A (TENT)		Domain B (TEKO)	
		BEFORE	AFTER	BEFORE	AFTER
	ug/m^3	%		%	
Good	0-100	68.89	99.435	50.63	98.06
Fair	100-200	14.61	0.56	15.59	1.86
Moderate	200-350	14.75	0.005	14.36	0.08
Poor	350-500	1.75	/	12.64	/
Very poor	500-750	/	/	6.78	/
Extremely poor	750-1250	/	/	/	/

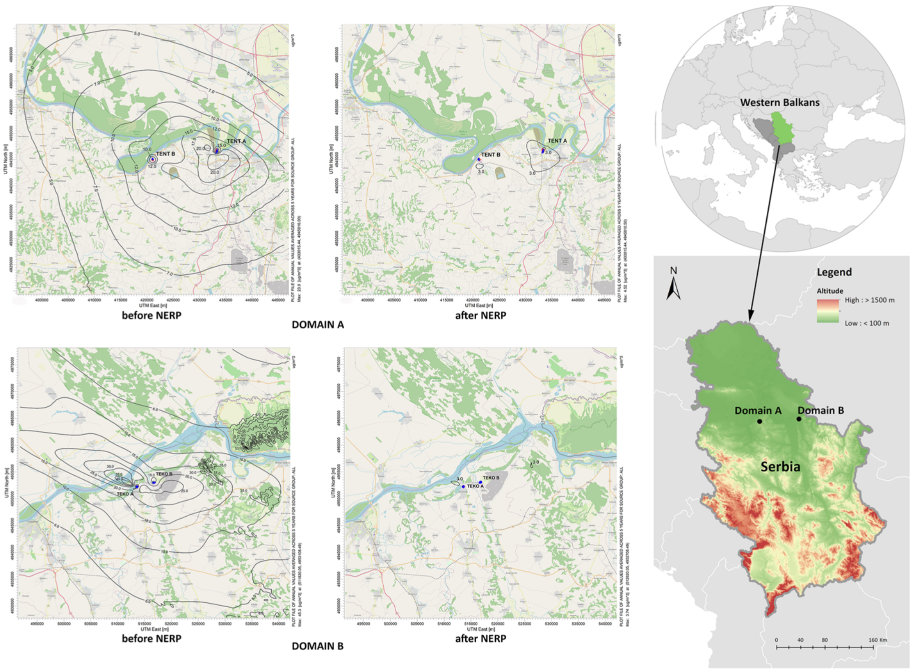

Fig. 1 Graphic presentation of the position of the Republic of Serbia in Europe and the Western Balkans with an illustrative presentation of the modeling results for the annual averaging period, by domains before and after the implementation of the NERP

the implementation of NERP results in excluding all of the concentrations of SO_2 that are characteristic of these three air quality classes.

The modeling results, for the annual averaging period, are presented graphically (Fig. 1) in order to see the spatial distribution of the expected impacts and to compare the scenarios with and without the application of NERP. Temporal averaging of pollutant concentration values is of great importance in assessing the air quality. While in shorter periods of averaging (1 h, 3 h, 8 h etc.), due to extreme weather conditions, extreme values of concentrations may occur, in longer periods of averaging (a year, more years), this effect is much less pronounced and is applied this specific case. Since the EAQI air quality classes are defined according to the values of hourly concentrations and the pollutant with the highest concentration, Table 4 is based on the results of modeling the maximum hourly concentrations, while Fig. 1 shows the spatial distribution of annual averages. These presentations clearly show the spatial effects of implementing the measures envisaged by the NERP on an annual basis, and they clearly identify the zones most affected during the year. Visualization is of special importance, not only for clear presentation of the results to decision makers, but also to all actors that are part of the transparent SEA process (population, NGO sector, state institutions, etc.), who express their views through the institutions of public insight and public debate.

After involving the quantitative modeling results in the multicriteria evaluation process, the rank of the impacts was determined in the way illustrated for key SEA objectives (Table 5). The quantitative (Table 4) and graphical (Fig. 1) modeling results were used to determine the intensity of the impact, spatial dimension of the impact and frequency of the impact according to the criteria in Table 3, and an explanation of the impact according to the domains before and after implementation of the NERP is given in Table 5.

Summarizing the results of the whole evaluation process, it is evident that a significant reduction in the frequency of high SO_2 concentrations is expected after the implementation of the NERP. Bearing in mind the air quality classes used in the modeling, and then used in the multicriteria evaluation process in the SEA, it is clear that the impacts on public health in the impact zone of Serbian coal-fired power plants will be incomparably smaller after implementing the NERP. This particularly refers to the air quality classes that represent the greatest threat to human health, since none of the concentrations of pollutants that are characteristic of these classes are expected. In this context, the implementation of the NERP has unequivocal importance in reducing the impact of SO_2 on human health.

5 Discussion

Serbian coal-fired power plants have significant implications for space, the environment and public health. These implications are not only pronounced in the Republic of Serbia, but also in other countries in the Western Balkans, as stated in the introduction. In order to see the scope of these impacts and make appropriate decisions regarding energy transition, which apart from development in the field of using renewable energy in which the Republic of Serbia is recording dynamic growth, includes modernization and the closure of coal-fired power plants, it is necessary in the phase of strategic planning to adequately identify and present the expected changes. In this case, strategic planning is represented by development of the NERP, and to assess the impact of the NERP, a widely applicable instrument for assessing environment impact at the strategic planning level was used—SEA. The task of the paper was to combine the quantitative results of modeling the spatial distribution of SO_2 and the semiquantitative method of expert evaluation in SEA, with the aim of obtaining results that give decision makers a clear idea of the intensity and scope of expected changes as a basis for appropriate decisions regarding energy transition, i.e., modernization and the closure of coal-fired power plants. Making appropriate decisions in this case is of particular importance due to the inert attitude of the state toward this problem for the reasons elaborated in the part of the study *Case study area—Initial position*. That is why

Table 5 Illustrative overview of determining the rank of impacts in relation to SEA objectives and criteria

Evaluation domain	SEA Objective		Explanation
	Reduce emissions of air pollutants	Reduce the impact of the energy sector on public health	
	Rank of impact according to criteria from Table 3.		
DOMAIN B (Kolubara – 8.698 MWth) <u>Before</u> implementation of the NERP	-1 / R / P	-1 / R / P	In the area of domain B before implementation of the NERP, negative impacts were pronounced for both of these SEA objectives. The impact rank is negative in all air quality classes, except in the "extremely poor" class for which no characteristic SO_2 concentrations occur. Most common is the air quality class "good" with a share of 68.89%, and then the share of values for other air quality classes decreases significantly. The spatial distribution of the impact has a regional character for all air quality classes, and it has a proportional impact on public health.
	-1 / R / Te	-1 / R / Te	
	-1 / R / Te	-1 / R / Te	
	-2 / R / Te	-2 / R / Te	
	-2 / R / Ra	-2 / R / Ra	
	+2 / R / D	+2 / R / D	
DOMAIN B (Kolubara – 8.698 MWth) <u>After</u> implementation of the NERP	-1 / R / D	-1 / R / D	In the area of domain B after implementation of the NERP, smaller negative impacts are expected in classes with lower concentrations of SO_2. The impact rank is positive in the most unfavorable classes: "poor", "very poor" and "extremely poor", for which characteristic concentrations of SO_2 are not expected. The air quality class "good" is dominant, with a share of as much as 99.43%. The spatial distribution of impacts has a regional character and a proportional impact on public health. Because of the closeness to international borders, cross-border impacts are possible, however, they do not exceed the limit values regulated by legislation. Significant improvements are expected compared to the situation before implementation of the NERP.
	-1 / R / Ra	-1 / R / Ra	
	-1 / L / Ra	-1 / L / Ra	
	+2 / R / D	+2 / R / D	
	+2 / R / D	+2 / R / D	
	+2 / R / D	+2 / R / D	
DOMAIN A (Kostolac – 3.202 MWth) <u>Before</u> implementation of the NERP	-1 / T / P	-1 / T / P	In the area of domain A before implementation of the NERP, negative impacts are expected in most classes with lower concentrations of SO_2 in relation to the two SEA objectives. The impact rank is negative except in the "extremely poor" class, for which no characteristic SO_2 concentrations occur. The dominant class of air quality is "good" with a share of as much as 50.63%, and then the share of values for other classes of air quality decreases significantly, with a share of up to 15%. The spatial distribution of the impacts has a predominantly regional character and it has a proportional impact on public health.
	-1 / R / Te	-1 / R / Te	
	-1 / R / Te	-1 / R / Te	
	-2 / R / Te	-2 / R / Te	
	+2 / R / Re	+2 / R / Re	
	+2 / R / D	+2 / R / D	
DOMAIN A (Kostolac – 3.202 MWth) <u>After</u> implementation of the NERP	-1 / T / D	-1 / T / D	In the area of domain A after implementation of the NERP, smaller negative impacts are expected in classes with lower concentrations of SO_2 in relation to the two SEA objectives. The impact rank is positive in the most unfavorable classes: "poor", "very poor" and "extremely poor", for which characteristic concentrations of SO_2 are not expected. The air quality class "good" is dominant, with a share of as much as 98.06%. The spatial distribution of the impacts has a regional character for all air quality classes, and it has a proportional impact on public health. Significant improvements are expected compared to the situation before implementation of the NERP.
	-1 / R / Re	-1 / R / Ra	
	-1 / L / Ra	-1 / L / Ra	
	+2 / R / D	+2 / R / D	
	+2 / R / D	+2 / R / D	
	+2 / R / D	+2 / R / D	

it was necessary to make a step forward in the methodological approach to impact assessment in SEA, which in this study was carried out using the results of modeling SO_2 in the usual expert approach in SEA.

Although it may be thought that the application of software modeling results may be sufficient in itself to perceive the expected trends in space and in the environment and that modeling is a sufficient basis for making appropriate decisions, this may not be the case in practice. Namely, modeling must be determined in an administrative document on the basis of which, in the formal and legal sense, it is possible to make appropriate strategic decisions, and it is here that SEA stands out as an indispensable instrument at the global level. In addition, modeling usually considers only one of a large number of other possible impacts, which was the case for SO_2 in this paper, while considering the comprehensive range of environmental impacts and socio-economic development is possible in the SEA process. Thus, for example, modeling is often used to determine the impact on: air quality (which was the case in this paper); spatial noise dispersion; water pollution; effects in case of chemical accident; etc., and however, modeling cannot be used to consider impacts that, as a rule, represent a subjective category, such as assessing the impact on a landscape, which always depends on the perception of the observer. On the other hand, the application of expert methods is suitable in that case, which is characteristic of SEA, as pointed out by the authors in the introduction, with references that highlight the role and significance of applying software models to achieve greater objectivity in the SEA process. This actually raises the quality of the SEA instrument, and thus, the quality of decisions made on the basis of it.

The biggest challenge was the formation of the evaluation criteria (Table 3) that were initially used in the so-called partial assessment of the impact of NERP on air quality (SO_2), which was only one of a total of nine SEA objectives, and then, by involving the quantitative results of modeling, an impact assessment was carried out for the remaining SEA objectives in order to fully consider the impacts on the areas and objectives of the SEA. The usual group of criteria were used for this which refer to: intensity of impact; spatial dimension of the impact; frequency of impact (Table 3); and the modeling results, which were also the basis for determining the ranking of the impacts (Table 5) according to all selected groups of criteria. It was shown that this combined methodological approach in the SEA process significantly raised the level of objectivity, especially in the part related to the evaluation of the impact of strategic solutions from the NERP in relation to air quality and public health, but also to most other SEA goals that were not subject of this paper.

6 Conclusion

SEA is considered to be a comprehensive instrument used at the level of strategic planning and for making appropriate strategic decisions in which environmental protection issues are considered on an equal footing with socio-economic issues. In methodological terms, SEA is predominantly based on the application of various expert qualitative methods characterized by subjectivity that depend on expert knowledge, skills and experience. However, the possibility of applying different assessment methods is not excluded, even partial assessments, which must still be involved in the comprehensive methodological framework of the SEA, i.e., in the semiquantitative method of multicriteria evaluation.

Partial impact assessment can be done in the form of a special impact assessment and then incorporated into a holistic approach in the consideration of existing spatial changes and the prediction of expected ones within SEA, as presented in this paper for the aspect of the NERP impact on air quality (SO_2). Partial impact assessment makes special sense if it is based on simulation software models that result in quantitative (measurable) results.

The authors have the position that in order to increase objectivity in the SEA process, whenever possible, it is desirable and significant to use different software simulation models, even for a partial assessment of only one environmental element processed in the SEA. The selection of specific models, methods and techniques depends on the specific case, i.e., it is not and cannot be universal.

The paper shows that although modeling the spatial distribution of SO_2 covered only one aspect of the possible impacts, the quantitative results obtained have great importance in determining the ranking of impacts in the SEA for the majority of other impacts that are directly interrelated with air quality (e.g., impact on public health). In this context, the objectivity of the SEA process is not limited to the area for which the partial assessment is performed, but rather, it has a much broader significance in the evaluation of strategic solutions.

The semiquantitative method of multicriteria evaluation used can be applied in the development of SEA for various strategic development documents, not only in the energy sector but in a wide range of social action and strategic planning.

The negative context for applying SEA generally relates to the assessment of aspects of possible impacts for which it is not possible to carry out quantitative partial assessment based on the application of software models, and which are a part of one of the universal expert methods used in SEA. In these cases, it is necessary to apply optimal techniques and tools within the SEA, which in this case can achieve the greatest possible objectivity in the assessment of environmental impact (simulation models based on visualization, GIS technologies, etc.).

When it comes to subjectivity in decision making based on the results of the SEA procedure, it is beyond the reach of experts in this field and depends on socio-political, financial and other circumstances, which can certainly be a threat to the implementation of SEA propositions. However, in this particular case, the SEA done for the NERP has shown its full capacity. Namely, the NERP was initially done without the SEA process and the state was indecisive about its adoption for a long time. After the inclusion of the SEA process with the methodological approach shown in the paper, the interested public, institutions and the non-governmental sector (through the institution of public insight and public debate), and then the competent state institutions (through the decision-making institution) were able to see the expected significant positive changes which are a result of implementing the NERP, and on that basis make a significant and perhaps crucial step in the energy transition in this part of the Western Balkan region. The Republic of Serbia formally made such a step forward by adopting the NERP in January 2020, which created the preconditions for a significant reduction in the emission of pollutants into the air from coal-fired power plants in the Western Balkans. However, the essential contribution to energy transition, which is reflected in the dynamics of implementing the NERP propositions in practice, is beyond the scope of the SEA process.

7 Author's contribution

BJ was involved in conceptualization. SEA contributed to methodology, original draft preparation. DT was involved in conceptualization, software modeling, data processing. AJ contributed to writing—reviewing and editing, supervision. BM was involved in visualization, writing—reviewing and editing.

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