Environmental Energy Security Indicators as Tools for Environmental Protection

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ENVIRONMENTAL ENERGY SECURITY INDICATORS AS TOOLS FOR ENVIRONMENTAL PROTECTION

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Abstract: *Environmental acceptability has become an indispensable synthetic indicator of every valid energy analysis for the last two-three decades. Energy security is in direct harmony with Environmental acceptability through many prescribed political goals, economic benefits, criminal justice systems, etc. Environmental energy security indicators present one of basic elements for energy security determination and powerful tools for routing energy sector to sustainable development. In this paper, the analysis was concentrated on environmental energy security indicators related to the natural gas sector in the Republic of Serbia. Implementation of measures that leads to energy security growth has a significant, positive effect on less environmental pollution.*

Keywords: *energy security, environmental energy indicator, environmental protection, environmental acceptability*

1. INTRODUCTION

Energy is essential ingredient for world's development. Key priority for almost all countries is to insurance of adequate energy supply to sustain the country's economy, provide new investments and develop markets. Energy security is one of the most important indicators in determining the current state and defining the future development. Bearing in mind that demand for energy in the South East Europe is growing, and that supply sources are increasingly limited and unevenly distributed, it is clearly that the concept of energy security is becoming an important item for monitoring for each country facing major energy changes. Energy security is a parameter whose specificity lies in the influence of many factors, so it is not possible to define a unique methodology for determining it [1]. Namely, each country brings into consideration some specificity and its own approach to energy development. Defining a methodological approach for determining the energy security of a country is possible only if the geopolitical moment, climatic conditions, wealth and availability of energy resources are taken into account, as well as using them by type and intensity, economic growth, demographic indicators, political priorities and energy scenarios [2-4].

One of the key elements of energy policy in the Republic of Serbia, which has been actively promoted, is energy security. Energy security is a synthesis of the geopolitical and energy aspects of energy availability in various forms in satisfactory quantities and at affordable prices. Energy security as indicator is described with a group of synthesis indicators. It is necessary to continually observe energy security in the context of global techno-economic and environmental changes. One of those indicators is Environmental Energy Security Indicator, precisely Environmental Acceptability.

According to Energy sector development Strategy of the Republic of Serbia up to 2025, with the projections up to 2030 [5] and Program of implementation, energy security is defined as one of the basic cursors for ensuring the transition to sustainable energy development. Republic of Serbia is in the process of accession to the EU, with the status of a candidate country. Serbia has signed and ratified the Treaty establishing the Energy Community in 2006. [6]. Based on the Treaty, implementation of core parts of the EU acquits Communautaire in environment and energy sector are obligations of Serbia.

In this paper energy security and environmental energy security indicators in energy sector are shortly analyzed as tools for environmental protection. Energy scenarios of development of natural gas sector based of historical trends and Action plan [5] are used as example of model analysis. These scenarios are than modified in sense of determination of energy security and assessment of the highest level of environmental acceptability. Comparison of anticipate emissions in scenarios shows the strength of level of environmental energy security indicator as a tool for environmental protection.

2. ENERGY SECURITY

Energy security is one of the most important indicators in determining the current energy and economic situation and orienting the future development. Considering that energy demand is increasing, and supply sources become limited and unevenly distributed, the energy security is becoming an essential indicator. Energy security is a top priority issue for rapidly developing countries and, in energy terms, the demand for available energy is growing intensively [7].

In general, energy security is inextricably linked to the national security of a country and as such, can be considered in the context of general national state security as well as independently [8]. According to [9], energy security is defined as the continuous availability of energy in various forms, at reasonable prices and in enough quantities. On the other hand, energy security is an important geopolitical issue. Energy security need to be analyzed from various aspects: technical, economic, environmental, etc. An analysis of Energy Security has been done with mathematical model which bases are the theory of the fuzzy logic and the fuzzy conclusion considering energy, economic, ecological and social indicators.

If the goal of the model is to decide on a scenario assessment that would demonstrate a rational, sustainable and energy-friendly development plan, technical or energy, political, economic and environmental indicators are most commonly used. In some studies, social indicators also occur [10].

Indicators of the technical and/or energy aspect may be secure of supply, availability of energy (different sources and directions of supply), energy production, stability and price level of energy, as well as technical availability of the system.

Socio-economic indicators include partial indicators of investment justification, financial and administrative feasibility, institutional capacity, savings opportunities, economic growth, market development and local economy, etc.

The environmental indicators are standardized and include greenhouse gas emission and other pollutants emission. Traditionally, the most important indicator for the energy security is the indicator of secure of supply, while the general aspiration for "cleaner energy" has contributed that the emission of CO_2 and other pollutants, with investment costs being indispensable partial indicators of observation. The aspect of social indicators, with partial indicators of social acceptability and provision of comfort, is increasingly used in the evaluation of the energy scenario [11].

3. ENVIRONMENTAL ACCEPTABILITY SYNTHESIS INDICATOR

The Environmental acceptability synthesis indicator shows the total contribution to an environmental condition, which can be represented by a group of partial indicators. Some of them, such as greenhouse gas and/or other pollutant emissions, are directly measurable, while others represent the accompanying results of acts or emissions under the analysed energy development scenarios. The partial indicators of GHG emissions and pollutant emissions within the synthesis indicator Ecological applicability are distinguished by the possibility of numerically quantifying the values describing the mentioned emissions. Both partial indicators are defined based on the amount of pollutants emitted by stoichiometric calculation or standard emission estimates depending on the type of energy source. At the same time, through the mentioned partial indicators, one can see the reduction or increase of emissions at the national as well as the sector level, the proportions of the use of renewable sources, as well as the energy intensity by sectors, reduction of energy use (total or sectorial), etc. [11]. The indirect environmental effect parameter is quantified by expert evaluation of the indirect environmental impact of the emission.

3.1 Partial indicator GHG emissions

Greenhouse gas emissions are a universal environmental indicator that monitors all anthropogenic impacts that result in greenhouse gas emissions. Effective monitoring and reporting of greenhouse gas emissions is the basis for progress towards achieving emission reductions. The main cause of climate change is gases, which usually have very little in the atmosphere. By natural and anthropological

influence, they reach the atmosphere, where they linger, absorbing some of the heat energy of the Sun's radiation and re-emitting it towards the surface of our planet. This effect is known as the greenhouse effect, hence the name of the gases that cause this phenomenon. The most represented greenhouse gas is carbon dioxide (84%), followed by methane (8.5%) and nitrous oxide (6.5%), while trace per flour-carbonates (1%) [12]. Concentration of carbon dioxide in the atmosphere is thought to have increased by more than 30% since the end of the 18th century [12].
For the purpose of defining the partial greenhouse gas emission indicator, carbon dioxide emissions will be considered as the dominant and most represented representative of greenhouse gases. Carbon dioxide emissions are almost exclusively the result of burning fossil fuels (about 98%). For the same amount of heat generated, ther is different amounts of emissions resulting from the combustion of fossil fuels. The reason for this is the different chemical composition of the energy that it burns. Their contribution to the emission of greenhouse gases, primarily carbon dioxide, is not the same, so a carbon dioxide emission factor k (CO_2) is introduced for the purposes of comparable energies. This coefficient expresses the amount of CO_2 emitted reduced per unit of energy. The carbon dioxide emission factor can be determined as:

$$k_{CO_2} = 3.67 \cdot \frac{g_c}{H} \qquad (1)$$

where:
g_c is mass fraction of fuel carbon in fuel,
3.67 is stoichiometric coefficient,
H - thermal power of fuel (MJ / kg).
The CO_2 emission factors per unit of energy produced for different energy products are given in Table 1.

Table 1. *The CO_2 emission factors [13]*

Fuel	Emission [kg CO_2/GJ]
Biomass	109.6
Peat	106
Stone coal	101.2
Brown coal	97.09
Lignite	96.43
Diesel	77.4
Crude oil	74.1
Kerosene	73.3
Gasoline	71.5
LPG	63.1
Natural gas	56.1

The amount of greenhouse gases emitted is standard expressed per tons of CO_{2eq} emitted. CO_{2eq} is a unit based on the global warming potential (GWP) of different greenhouse gases. It measures and expresses the impact of one tons of any other GH gases emitted relative to the impact of one tons of CO_2. Moreover, and when there is no clearly measured emission result, it is possible to calculate the emission based on known standard CO_2 emission measures per unit of energy. This process considering the amount of energy required, so the amount of CO_{2eq} emitted can be obtained.

3.2 Partial indicator Emission of pollutants

Emission of pollutants (particulate matter, NOx, SOx, CO, VOC, etc.) is a partial indicator describing the type, intensity and mode of emission of the remaining pollutants (excluding the greenhouse gases). As with GHG emissions, effective monitoring and reporting of pollutant emissions is the basis for progress towards achieving emission reductions.

3.2.1. Sulfur oxides (SOx)

Sulfur oxides cause acid rain, which has a profound effect on the living world, especially plants and soil.
The sulfur oxides in the flue gases as combustion products are found because of the oxidation of sulfur, which is part of the combustion fuel. Sulfur in the combustion process is oxidized to a large extent to sulfur dioxide - SO_2 and to a lesser extent to sulfur trioxide - SO_3 [14]. However, when emitted into the atmosphere, sulfur dioxide is further transformed into sulfur dioxide, which reacts with the humid

substances in the atmosphere to produce droplets of sulfuric acid, known as acid rain. These rains in contact with the earth gradually increase the acidity, which affects the slow growth and development of the flora. At the same time, contact with water located on the surface of our planet adversely affects the flora and fauna in the water itself [15].

Analyzes show that coal combustion is the largest source of sulfur oxide emissions. Petroleum derivatives and fuel oil also emit sulfur oxides, but to a lesser extent than in the case of coal [16]. Combustion of biomass does not lead to the emission of sulfur oxide, because sulfur is not present, or only in the chemical composition of wood biomass. Natural gas is also characterized by no sulfur oxide emissions, unless the gas has hydrogen sulfide in its chemical composition. The easiest comparison of sulfur oxide emissions for different energy sources is to find the amount of SO_2 emitted per unit of energy produced. The SO_2 emission factors per unit of energy produced for different energy products are given in Table 2.

Table 2. *The SO_2 emission factors [16]*

Fuel	Emission [g SO_2/GJ]
Coal	1000
Fuel-oil	670
Natural gas	0
Fire wood	0

3.2.2 Nitrogen oxides (NOx)

Nitrogen damage is manifested through combustion sub-products - nitrogen oxides. The most significant nitrogen oxides whose effects on the health of living things and the environment are the largest are nitrogen oxide (NO), nitrogen dioxide (NO_2) and nitrogen sub-oxide (N_2O). The common name for these nitrogen oxides is NOx. The vast amount of nitrogen oxide emitted is made up of nitric oxide (more than 90%) [17]. However, its reactivity with oxygen particles in the atmosphere makes almost all amounts of nitric oxide treated as nitrous dioxide. Nitrogen sub-oxide is a greenhouse gas, which is found in trace amounts of combustion products of standard fossil fuels, so its impact on emissions is negligible [18]. The emission factors of the NOx to the unit of energy produced are shown in Table 3.

Table 3. *The emission factors of the NOx [19]*

Fuel	Emission [g NO_x/GJ]
Coal	1.5
Fuel-oil	0.6
Natural gas	0.1
Fire wood	3.2

3.2.3 Solid particles

Combustion of fossil fuels, in addition to the emission of harmful gases, leads to the emission of particles. The particles further initiate the binding of other matter to the atmosphere, affecting the formation of smog in the lower atmosphere [20]. How much particulate matter will be emitted into the atmosphere depends primarily on the type of energy used and the sector used, which causes the combustion regime, the existence of filters, etc. The emission factors of the solid particles and the unit of energy produced are shown in Table 4.

The use of energy sources (low efficiency devices, without modern measurement, control and regulatory elements) in the field of consumer consumption affects the emission of particulates and ash. Industrial plants are often in sub-optimal operating modes (frequent change of load, downtime, etc.), which causes an increase in emissions. It is characteristic of the thermal power plants that the primary process of such plants is the combustion of fossil fuels for the production of thermal energy, and very careful consideration is given to the modes of operation of the plant, equipment and adequacy of equipment, as well as regular maintenance of it.

***Table 4.** The emission factors of the solid particles [21]*

Fuel	Sector	Emission [$g_{particulars}$/GJ]
Coal	Public and Commercial	400
	Industry	180
	District Heating Plant	120
Fuel-oil	Public and Commercial	2
	Industry	30
	District Heating Plant	1
Natural gas	Public and Commercial	0
	Industry	0
	District Heating Plant	0
Fire wood	Public and Commercial	200
	Industry	90
	District Heating Plant	60

3.3 Partial Indicator of Indirect Environmental Effect

The Indirect environmental effect is a partial indicator that can be viewed through the effects arising from the lived and worked environment, called externalities. These effects can differently affect the so-called neighboring economic activities, while at the same time bringing some additional costs and benefits to others - the so-called negative and positive externalities [22]. In the context of environmental acceptability and the broader picture of energy security, this partial indicator describes the impact of the use of fossil fuels on health care costs, increase or decrease in GDP, decrease in working ability of the population, etc. An Indirect environmental effect can be an important long-term indicator of (incorrect) correctness of an energy policy, but it is often difficult to determine and prove the link between an environmental disorder and the additional costs. It can also be noted that the relationship between pollution costs and pollution reduction costs is inversely proportional [22]. In the process of fuzzification of the input data for this partial indicator, a questionnaire was formed. They are the basis for expert analysis of the Indirect environmental effect. The surveyed analysts select one or more linguistic variables within the questionnaire in a proportion that most accurately describes the partial indicator.

3.4 Synthesis of Environmental Acceptability

The Environmental acceptability synthesis indicator is more closely defined by three partial indicators. Synthesis of this indicator is related to the composition of Emission of GHG (E1), Emissions of pollutants (E2) and Indirect environmental effects (E3) into ENVIRONMENTAL ACCEPTABILITY (E). A synthetic procedure is accomplished using the appropriate stage composition with a ranked outcome. The synthesis model is presented in optimal form according to the partial (Pi) and synthetic (M) indicator.

$$M = E; P1 = E1, P2 = E2, P3 = E3 \quad (2)$$

This has been done by tailoring the model in several steps (Figure 1).

During the process, data is collected, which can be done on statistical level (based on calculation, software model result, projections, statistical processing, etc.) or based on expert analysis, i.e. attitude and court of experts. The partial indicators within this synthesis indicator are entered the model itself in two ways. One of them, Indirect environmental effect is subjected to expert analysis through a questionnaire. The remaining two are measurable and they are entering the model through numerical data that are the result of active monitoring.

The data are then classified and fed into the analysis model itself in an adequate form. Such data are entered the synthesis model by the phase *proposition* procedure, where they are further classified and defined as the input data of the fuzzy set.

At the same time, next step called *ranking*, is done. It can be performed by several different methods. Ranking based on the application of the AHP (Analytic Hierarchy Process) method was used for the purposes of developing this synthesis model.

In this way, ranking data is used as input to the fuzzy set, which is further analyzed in the *fuzzy composition* process. As a result of the *fuzzy composition*, an environmental energy security assessment is generated in a fuzzy form.

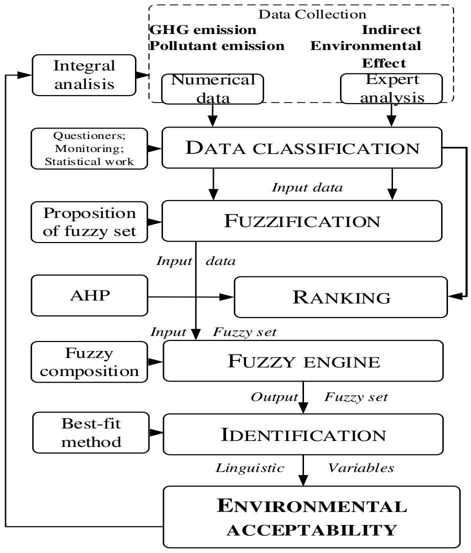

Figure 1. *Schematic diagram of a model for environmental energy security assessment*

The output of the fuzzy set is *identified* in next step. At the end, there is quantification result for environmental energy security indicator.

4. SCENARIO DEVELOPMENT AND RESULTS

4.1 Natural gas energy scenario development

For the purpose of demonstrating the impact of energy security on environmental protection, through the Indicator of environmental acceptability, the scenario of development of the natural gas sector of the Republic of Serbia [5] will be considered through the model.

Concerning gas consumption, numerous projections can be developed following different assumptions (for example- real GDP growth, the degree of implementation of energy efficiency measures, the level of increase in the use of gas for electricity production, etc.). For the analysis in this case study, two characteristic projections of natural gas consumption were identified. Table 5 lists the projections of absolute natural gas consumption [5, 23].

In terms of infrastructure development, according to [24] three characteristic scenarios were selected for further consideration:

- The pessimistic scenario for the development of natural gas infrastructure (PES) assumes a lack of investment in new infrastructure projects and the retention of the current level of infrastructure development [23];
- The reference scenario (BAU) envisages the development of gas sector infrastructure in accordance with key strategic document projects [24];
- The optimistic scenario for the development of natural gas infrastructure (OPT) is more ambitious and implies the introduction of two additional supply corridors compared to BAU and the construction of large additional underground storage facilities. This scenario is in line with the goals of the Energy Community in the SEE region [6].

Table 5. *Natural gas consumption projection [5]*

Scenario	Referent		Intensive consumption		units
Sector	*2020*	*2025*	*2020*	*2025*	
Households	269.570	305.172	341.591	379.267	million m^3
District Heating Plant	602.335	641.740	683.183	767.325	
Industry and others	938.095	1129.669	1855,226	2203.408	
Total	1810	2076.581	2880	3350	

Combination of infrastructure development and natural gas consumption scenarios results in six possible projections for the future development of the natural gas sector in the Republic of Serbia by 2025.

4.2 Results and discussion

The amount of CO_2 emitted is directly related to projections of natural gas consumption. The table 6 present energy produced by natural gas consumption. This table also shows the amount of CO_2 emitted using a carbon dioxide (equation 1) emission factor related to the natural gas consumption. It should be noted that this partial indicator does not look at the total absolute value of the emission, but rather the change in emissions relative to the capacity of natural gas-fired plants. The needs to reduce partial indicators numerically to emissions per unit of energy produced arises from the idea of comparing, in the most realistic way, scenarios of intensive consumption of natural gas and a reference scenario where the demand for gas is significantly lower. At the same time, this avoids viewing emissions as absolute values related to the use of one energy source, neglecting the savings and benefits that more intensive consumption of natural gas brings through e.g. substitution of fossil fuels with worse environmental characteristics.

The intensive consumption scenario envisages higher consumption of natural gas compared to the Reference scenario, primarily due to projections for the construction of gas power plants for combined production of electricity and heat. For 2020, based on the projection of consumption, for the Reference and Intensive Consumption Scenarios, there is a difference in CO_2 emissions of just over 2 million tons, i.e. about 37%. Similar is the case for the 2025 projections (an increase of 38% or 2.38 million tons of CO_2). For pollutant emissions from natural gas combustion, it is noticeable that solid particulates do not exist, nor does sulfur oxide emissions, except when hydrogen sulfide is included in the natural gas composition. The amount of NOx emitted is directly related to projections of natural gas consumption. Table 6 lists the projections of natural gas consumption specifically per unit of energy produced. At the same time, the table also shows the amount of NOx emitted, which was obtained by using the nitrogen oxide emission factor (Table 3).

Table 6. *The amount of CO_2 and NO_x emitted in different scenario consumption projection*

Scenario	**Referent**		**Intensive consumption**		**Units**
					k_{CO2} 56.1 kg/GJ
	2020	*2025*	*2020*	*2025*	***k_{NOx} 0.1 kg/GJ***
Heat power	33.338	33.338	33.338	33.338	MJ/m³
Households	8986925	10173824	11387961	12644003	GJ
District Heating Plant	20080644	21394328	22775955	25581081	
Industry and others	31274211	37660905	61849524	73457215	
Total	**60341780**	**69229057**	**96013440**	**111682300**	
CO_2 emission	**3385174**	**3883750**	**5386354**	**6265377**	t CO_2
NO_x emission	**6034**	**6923**	**9601**	**11168**	kg NO_x

For the purpose of comparing different projections of natural gas consumption, six possible projections were analysed in model. Results of combined scenario of OPT scenario of infrastructure development with Referent consumption scenario is presented. Figure 2 and Table 7 shows the affiliation of Environmental energy security indicator for OPT-Referent scenario which is characterized by intensive infrastructural development combined with expected consumption following the current trend.

Table 7. *Environmental acceptability for OPT-Referent scenario*

ENVIRONMENTAL ACCEPTABILITY	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
GHG emission	0	0	0	0	0	0,169	0,51	0,513	0,486	0,486
Emission of pollutants	0	0	0	0	0	0,099	0,301	0,301	0,698	0,698
Indirect Env. Effect	0,02	0,02	0,34	0,58	0,592	0,533	0,4	0,16	0	0

Environmental energy security indicator for this combination of scenario is dominantly described with variables "high" (31%).

The environmental energy security value in scenario OPT-REF is, for the most part, located to the right within the field describing the medium, and with a slightly smaller surface, the variable of high environmental energy security. This combined scenario is characterized by the high environmental acceptability. The largest contribution to this is due to the influence of the partial indicator Emissions of pollutants. The impact of each individual partial indicator on the overall environmental acceptability score is presented in Figure 3.

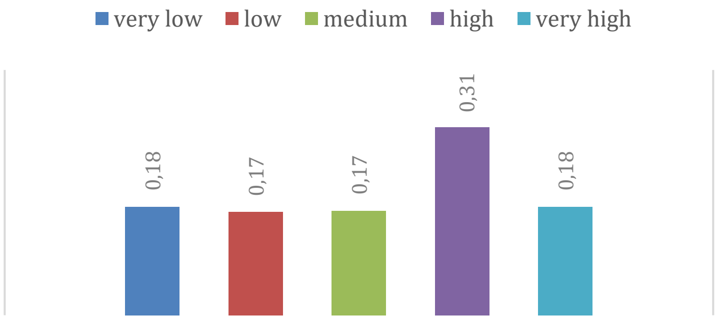

Figure 2. *Environmental energy security indicator for OPT-Referent scenario*

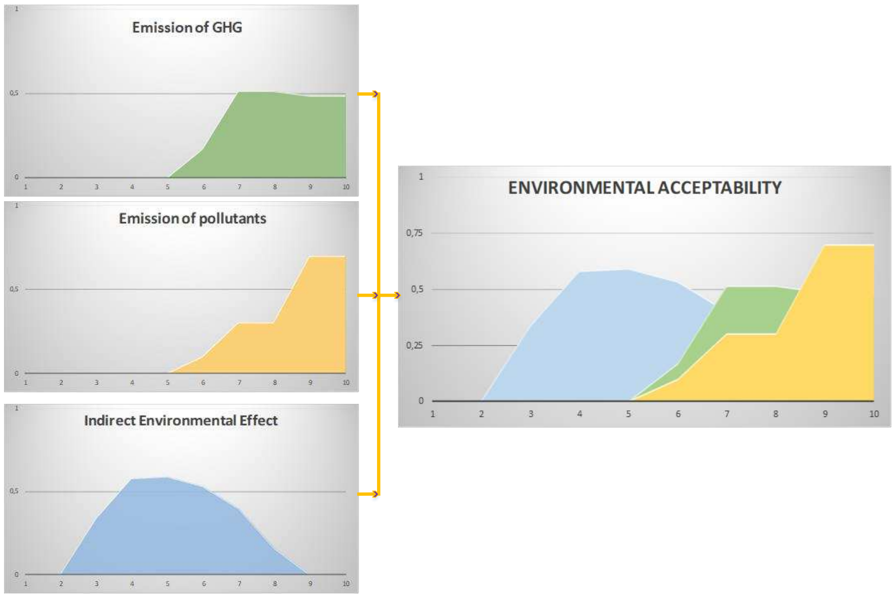

Figure 3. *Impact of partial indicators on Environmental energy security indicator for OPT-Referent scenario*

It is noted that optimistic infrastructure development always raises the level of energy security. On the other hand, the Environmental energy security indicator is sensitive to any increase in the intensity of energy consumption. As it is already mentioned, it is not enough to observe the absolute values of the emissions, but a broader energy situation must be observed. For some other energy sectors, a detailed analysis would have to be done.

5. CONCLUSION

Increasing of level of Energy security is one of the priority directions of energy development in Serbia. It is noticeable that raising the level of energy security gives results on environmental protection. Energy Security indication can be a tool for environmental protection.

In this paper, the analysis was concentrated on energy security and, especially environmental energy security indicators related to the natural gas sector in the Republic of Serbia. It was shown that the implementation of measures that leads to energy security growth have a significant, positive effect on less environmental pollution.

The model shows that the higher the energy security rating, the environmental acceptability indicator shows values that are more acceptable. It is also noticeable that in each combination with the intensive consumption scenario the value of the environmental acceptability indicator is lower. This phenomenon requires additional analysis, since the energy development scenarios of the Republic of Serbia envisage complete or partial substitution of certain fossil fuels (primarily lignite). In this case, not only the absolute value of the emission of a pollutant, but also its difference with the amount of non-emitted pollutant produced by substitution must be taken into account.

REFERENCES

1. Radovanovic, M., Filipovic, S., Pavlovic, D., Energy security measurement – A sustainable approach, *Renewable and Sustainable Energy Reviews*, 2017, *Volume 68*, 2017, pp. 1020–1032
2. Golušin, M., Munitlak-Ivanović, O., Andrejević, A., Vučenov, S., Survey of socio economic growth in SE Europe – new conceptual frame for sustainability metrics, *J Econ. Surv*, 2014, *Volume 28*, pp. 152–168
3. Umbach, F., Global energy security and the implications for the EU, *Energy Policy*, 2010, *Volume 38*, pp. 1229–1240
4. Vivoda, V., Evaluating energy security in the Asia-Pacific region: a novel methodological approach, *Energy Policy*, 2010, *Volume 38*, pp. 5258–5263
5. Ministry of Mining and Energy (2015): Strategy of Energy Development of Serbia up to 2025 with projections up to 2030, available online URL: http://www.mre.gov.rs/dokumenta-efikasnost-izvori.php (6.7.2016.)
6. Government of the Republic of Serbia, Ministry of Energy and Mining, AERS, (2005): The Treaty on energy community, available at URL: http://www.aers.rs/Files/EnergetskaZajednica/Eng/UGOVOR%20O%20OSNIVANJU%20ZAJEDNICE%20ZA%20ENERGETIKU.pdf (20.7.2006)
7. Kruyt, B., Van Vuuren, D.P., de Vrijes, H.J.M., Groenenberg, H., Indicators for energy security, *Energy Policy*, 2010, *Volume 37*, pp. 2166–2181
8. Downs, E.S., *The Chinese security debate*, *China Q,* 2014, *Volume 177*, pp. 21–41
9. Dyer, H., Trombetta, M.J., The concept of energy security: broadening, deepening transforming, *International handbook of energy security*, 2013, Edward Elgar Publishing Limited, pp. 3–18
10. Wang, J.J., Jing, Y.Y., Zhang, C.F., Zhao, J.H., *Review on multi-criteria decision analysis aid in sustainable energy decision-making*, Renewable and Sustainable Energy Reviews, Volume 13 (9), 2009, pp. 2263-227
11. Konidari, P., Mavrakis D., A multi-criteria evaluation method for climate change mitigation policy instruments, Energy Policy, Volume 35, 2007, pp. 6235–6257
12. Scheraga, J., Leary, N., *Improving the efficiency of policies to reduce CO2 emissions*, Energy Policy, Volume 20 (5), 1992, pp 394-404
13. IPCC, Guidelines for National Greenhouse Gas Inventories, 2006
14. Lide. D.R., CRC Handbook of Chemistry and Physics, Boca Raton, 2006
15. Holleman, A. F., Wiberg, E., *Inorganic Chemistry*, San Diego: Academic Press. ISBN 0-12-352651-5, 2001
16. EPA, United States Environmental Protection Agency, *Sulphur oxide* ,2018
17. Soud, H., Fukasawa, K., *Developments in NOx abatement and control*, IEACR/89, IEA Coal Research, London, 1996.
18. Carpenter, A., Davidson, R., *NOx emissions and control*, IEA Clean Coal Centre, London, UK, 2006.
19. IEA, *NOx Emissions from Fuel Combustion,* 2018b, доступно на: https://webstore.iea.org/co2-emissions-from-fuel-combustion-2018-highlights
20. Henry, W.M., Knapp, K.T., *Compound forms of fossil fuel fly ash emissions*, Environmental Science Technology 2010, Volume 4, pp. 450-456
21. Jovašević-Stojanović, M., Bartonova, A., *Current State of Particulate Matter Research and Management in Serbia*, CICEQ, Volume 16 , 2010, pp. 207-212
22. Djukić P., Djukanović S., (2015), Održivi razlozi: ekonomsko-ekološki izozavi, Tehnološko-metalurški fakultet, Beograd.
23. Madžarević, A., Ivezić, D., Živković, M., Tanasijević, M., Ivić, M., Assessment of vulnerability of natural gas supply in Serbia: State and perspective, *Energy Policy*, 2018, *Volume 121*, pp. 415-425
24. Ministry of Mining and Energy (2017), Program for the Implementation of the Energy Development Strategy of the Republic of Serbia until 2025 with projections until 2030 for the period 2017 to 2023, *Proposal of Regulation*, Serbia