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Aleksandar Madžarević, Miroslav Crnogorac

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Sigurnost snabdevanja kao glavni deo slagalice energetske bezbednosti

Security of supply as a major part of the energy security puzzle

Aleksandar Madžarević, Miroslav Crnogorac
Faculty of Mining and Geology, University of Belgrade, Serbia

***Rezime* -** Sigurnost snadbevanja prirodnim gasom Republike Srbije se kroz poslednje dve decenije tretira kao hitno, strateško, političko i bezbednosno pitanje. U sektoru prirodnog gasa, Republika Srbija je veoma zavisna od gasa koji uvozi iz Rusije. Indikatori sigurnosti snadbevanja predstavljaju jedan od osnovnih elemenata za određivanje energetske bezbednosti i snažne alate za usmeravanje energetskog sektora ka održivom razvoju. Metodolaška analiza prikazana u radu je bila koncentrisana na pokazatelje sigurnosti snadbevanja u oblasti energetske bezbednosti koji se odnose na sektor prirodnog gasa u Republici Srbiji.

Ključne reči - energetska bezbednost, sigurnost snabdevanja, energetski indikator, dostupnost energije, diversifikacija izvora i pravaca

***Abstract* -** The security of natural gas supply of the Republic of Serbia has been treated as an urgent, strategic, political and security issue for the last two decades. In the natural gas sector, the Republic of Serbia is very dependent on gas imported from Russia. Security of supply indicators are one of the basic elements for determining energy security and powerful tools for guiding the energy sector towards sustainable development. The methodological analysis presented in the paper was concentrated on security of supply indicators in the field of energy security related to the natural gas sector in the Republic of Serbia.

Index Terms - energy security, security of supply, energy indicator, availability of energy, diversification of sources and routes

I. INTRODUCTION

Energy is an essential part of the development of the world. Energy is a lively power source for all social and economic activities and an immersive part of the puzzles of the sustainable development. Energy efficiency, energy security and secure energy supply, are most important components for the economy rise, new investments and market development [1].

One of the most actively promoted elements of energy policy in the Republic of Serbia 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 [2]. Energy security is bestowed on the continuous availability of energy in different forms, at affordable prices and in sufficient quantities [6].

Specificity of energy security lies in the influence of many factors, so it is not possible to define a unique methodology for determining it [2]. For different region or country, various features and approaches of energy development are into consideration. 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 considered, as well as using them by type and intensity, economic growth, demographic indicators, political priorities, and energy scenarios, etc. [4-6].

According to strategy of Energy development Strategy of the Republic of Serbia up to 2025, with the projections up to 2030 [7] and Program of implementation, energy security is basic elements 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. [8], and it is in the EU accession process with the status of a candidate country. All this means that implementation of core parts of the EU acquits Communautaire in environment and energy sector are obligations of Serbia.

In this paper energy security and security of energy supply indicators in energy sector are analysed as tools for security of fuel supply. Different scenarios of natural gas sector development based of historical trends and Strategy [7] are used as example of model analysis. To evaluate the security of the natural gas supply in Serbia these scenarios are than analysed and modified. Results show level of security of supply and vulnerability of energy supply system, throw the indicator of Security of Energy Supply Indicator, precisely Synthesis indicator Security of supply.

II. ENERGY SECURITY

The energy security is one of the most important parameters for the status and the definition of the recommended development for countries and regions. The concept of energy security is becoming an important item for monitoring because of major changes in the energy field. Energy demand in the region of Southeast Europe is growing, but energy sources are limited, and unevenly arranged. Energy security is a top priority issue for rapidly developing countries because the demand for energy is strongly and intensively growing [9].

Energy security is also related to the concept of national security and as such can be viewed in the context of general national security of the state, as well as independently [10]. Energy security is an important geopolitical issue. Different technical, economic, environmental aspects are included in analyses of Energy security. Mathematical model based on the theory of the fuzzy logic and the fuzzy conclusion considering energy, economic, ecological, and social indicators has been done.

The establishment of an indicator structure is an initial step in modelling an integrated analysis of energy security assessment of energy development scenarios. Figure 1 shows the indicator structure, with synthesis indicators and groups of partial indicators accompanying them.

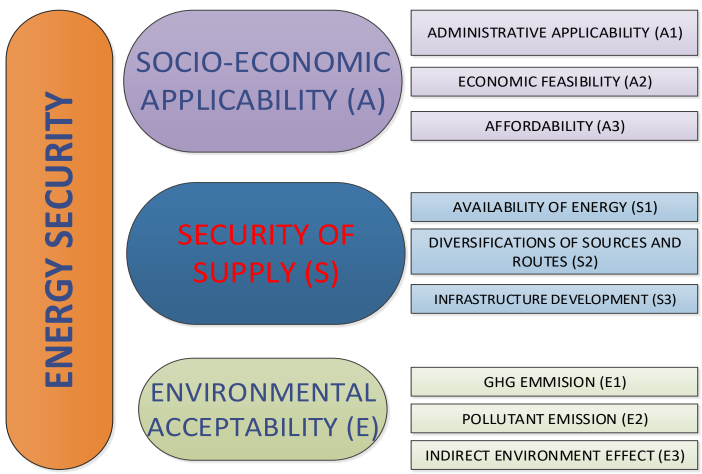

Figure 1. Indicator’s tree - Energy security with synthesis indicators

If the goal of the model is to evaluate and create a scenario that would demonstrate a rational, sustainable, and energy-friendly development plan, technical or energy, political, economic, and environmental indicators are most often used. In some studies, social indicators also appear [11].

Indicators of technical and energy aspects that are often analysed are security of supply, energy production, stability, availability of energy (different sources and directions of supply), the level of energy prices, as well as technical availability of the system [11].

Socio-economic indicators most often include partial indicators of economic growth, financial and administrative feasibility, institutional capacity, savings opportunities, investment justification, market development and local economy, etc [11].

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 [12].

III. Synthesis indicator Security of supply

The synthetic security of supply indicator can be viewed in a very broad context. It is generally defined by a group of partial indicators, such as: technical availability of the system, availability of energy, accessibility, acceptability, security, and political stability [13]. However, for the purposes of developing a methodology that will analyse energy development scenarios in the context of energy security assessment, the synthetic indicator of security of supply primarily refers to the satisfied needs of consumers. The quality of the working condition of a system whose role is the supply, transformation and utilization of an energy source primarily depends on the availability of energy, the availability of infrastructure and the ability to achieve supply [14]. Security of supply is the most common aspect of observing the concept of energy security and its impact on energy security itself is crucial. The reason for this is that one of the basic principles that define energy security is actually security of supply in terms of continuous and uninterrupted supply of energy with minimal possibility of interruption of supply and the existence of a current alternative supply solution. Security of supply can be viewed from different aspects - individually from the level of supply of a particular energy source or generally through an overview of the entire energy sector. The Synthesis of Supply Security Indicator is described using three different partial indicators, each of which is defined by numerical input of input data.

A. Partial indicator Availability of energy (S1)

Availability of energy is a partial indicator that depends on the type and quantity of energy used, self-sufficiency in the production and use of energy, and thus import dependence, which can be an important element of security of supply. The availability of energy is also a function of the possibility of energy storage, the participation of renewable energy sources, the level of use of locally available energy sources and the like. [14]. The energy availability is a basic condition for a secure supply, and thus high energy security. This partial indicator is defined numerically depending on the energy sector observed. Within the natural gas and electricity sector, the level of energy availability is expressed using the (N-1) system availability index. For the coal sector Availability of energy can be defined as the ratio of proven reserves to total resources. In the case of oil, Availability of energy can be declared through the ratio of the total quantities of oil available for free sale on the market and the total oil needs. On the example of natural gas and electricity, the partial indicator Availability of energy can be declared as:

$$N-1=\frac{TCG+CNG+MDSG+MDLPG-MSC}{MAX\ D} * 100\ [\%]$$

where:
TCG - technical capacity of the gas pipeline, ie. the maximum amount of gas that can be delivered through the existing pipeline [million m^3 per day],
CNG - amount of gas produced in the country [million m^3 per day],
MDSG - maximum delivery from natural gas storage [million m^3 per day],
MDLPG - maximum delivery from LPG terminals [million m^3 per day],
MAX D - total daily natural gas demand on the day of the highest natural gas demand, which statistically occurs once in 20 years,
MSC - maximum supply capacity = max (TCG, CNG, MDSG, MDLPG) [million m^3 per day].
Figure 2 shows the appearance of the fuzzy sets with linguistic variables which define the partial indicator Availability of energy in more detail. The linguistic variable "very low" describes a situation of high import dependence and a limited number of suppliers, with a low share of domestic production. The very low availability is also characterized by the impossibility of storing energy. The value of the linguistic variable "low" describes the situation of a slight reduction in import dependence, a small number of suppliers and low energy storage capacities. The value of the linguistic variable "moderate" defines the state of more increase in storage capacity and stabilization of domestic production with a decrease in import dependence. The linguistic variable "high" describes the increase of supply capacities, with the modernization of domestic production and the increase of storage capacities. The linguistic variable "very high" describes extremely developed production, low import dependence or higher import dependence, which is accompanied by a larger number of potential sources of supply.

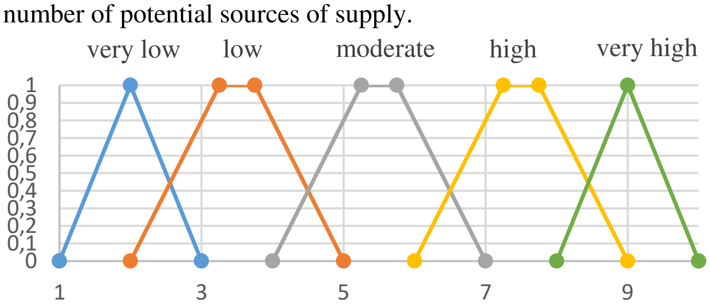

Figure 2. Fuzzy sets with adequate linguistic variables for the partial indicator Availability of energy (S1)

In the case of the natural gas or electricity sector, the partial indicator Availability of energy specifically defines the description of each linguistic variable as follows:

- N-1 <0.35 - value of linguistic variable "very low",
- 0.36 <N-1 <0.7 - value of the linguistic variable "low",
- 0.71 <N-1 <1.05 - value of the linguistic variable "moderate",
- 1.06 <N-1 <1.4 - value of the linguistic variable "high",
- N-1> 1.41 - value of the linguistic variable "very high".

B. Partial indicator Diversification of sources and routes (S2)

Diversification of sources and routes is a partial indicator that indicates the number of sources of the observed energy source and the different directions through which it can reach the energy entity. The increased number of sources, as well as supply routes, raises the level of security of supply and energy security in terms of ensuring uninterrupted supply of energy. At the same time, the possibility of using different locally available energy sources to perform the same function also contributes to raising the level of security of supply and energy security. In this way, the potential lack of many different sources of a certain energy source is bridged. As an example, we can take the use of a locally available renewable energy source, which raises the level of energy independence at the local level through the creation of a new energy source, which contributes to raising the level of energy security. The parameter Diversification of sources and routes is given numerically through the measure of diversification of import supply routes based on the capacity of the observed energy source available for supply. Diversification of sources and routes for imported energy products can be expressed with the help of the IDUPS index of diversification of imported supply routes [15].
On the example of natural gas, the index gives a measure of diversification of import supply routes based on the natural gas capacity available for supply. The index is calculated as the sum of the squares of the percentage share of individual interconnections and deliveries from the LPG terminal [15]:

$$\text{IDUPS} = \sum_{i}^{\text{border X}} \left(\sum_{c}^{\text{TI}} \%\text{TI}_c \text{border X}_i \right)^2 + \sum_{m} (\%\text{LNG terminal})^2$$

where:
% TIc border X - percentage share of technical capacity at the point of interconnection X which belongs to the border crossing with the state and, in relation to the total import capacity,
% LNG terminal - percentage share of technical capacity of LPG terminal *m* in relation to total import capacity.
Figure 3 shows the appearance of the fuzzy sets with linguistic variables by which the partial indicator Diversification of sources and routes is more closely defined.

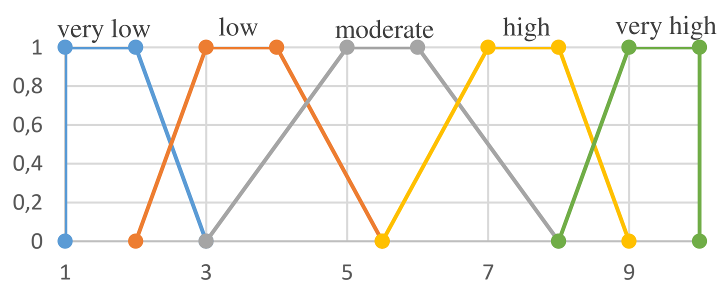

Figure 3. Fuzzy sets with adequate linguistic variables for the partial indicator Diversification of sources and routes (S2)

The linguistic variable "very low" describes the situation of the existence of one import route and only one source of supply through that route, as well as the almost non-existent modern technical capacities of storage and production. The energy entity is very vulnerable in the context of energy security due to the inability or reduced ability to procure energy. The value of the linguistic variable "low" describes the situation of one import route and the increase of technical capacities in relation to the total import capacity. Within this linguistic variable, the energy subject is also vulnerable in the context of energy security, but to a lesser extent. The value of the linguistic variable "moderate" defines the state of existence of another totally independent import route with a new source of supply and an additional increase in technical storage capacities. Linguistic variable "high" defines an increased number of import routes, as well as an increase in storage capacity. The linguistic variable "very high" describes a multifarious diversification profile in terms of multiple sources and supply routes. This case describes an energy entity that has an extremely favourable situation from the aspect of energy security. At the same time, this linguistic variable defines the expressed possibility that the energy entity has several different sources of supply, as well as alternative directions by which the energy source can reach.

For the natural gas sector, the partial indicator Diversification of sources and routes specifically defines the description of each linguistic variable as follows:

- IDUPS> 10000 - value of the linguistic variable "very low",
- 9999> IDUPS> 7500 - value of linguistic variable "low",
- 7499> IDUPS> 5500 - value of the linguistic variable "moderate",
- 5499> IDUPS> 3500 - value of the linguistic variable "high",
- IDUPS <3499 - value of the linguistic variable "very high".

C. Partial indicator Infrastructure development (S3)

Infrastructure development shows the state of infrastructural preconditions for the use of a certain energy source. It refers to the construction of capacities to produce primary forms of energy, the development of production plants for energy transformations, the construction of storage capacities, transport, and distribution networks (depending on the type of energy source). All these are preconditions for intensifying the use and development of the domestic market of a certain energy source. Each development of energy infrastructure contributes to increasing the security of supply of energy entities with energy necessary for the process, and thus to raising the level of overall energy security. Infrastructure development can also be seen through the level of implementation of planned infrastructure projects (PIP). In this context, the relationship between the realized and the total capacity of a certain energy source envisaged by a specific infrastructural projection of development is observed:

$$\text{PIP} = \frac{\text{Realized capacity}}{\text{The total anticipated capacity}}$$

Figure 4 shows the appearance of the fuzzy sets with adequate linguistic variables which define the partial indicator of Infrastructure Development more closely.

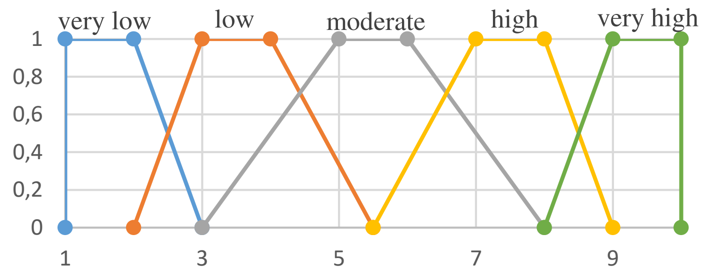

Figure 4. Fuzzy sets with adequate linguistic variables for the partial indicator Infrastructure development (S3)

As far as the share is concerned, the partial Infrastructure Development indicator specifically defines the description of each linguistic variable as follows:

- 0 <PIP <0.20 - value of linguistic variable "very low",
- 0.21 <PIP <0.40 - value of the linguistic variable "low",
- 0.41 <PIP <0.60 - value of the linguistic variable "moderate",
- 0.61 <PIP <0.80 - value of the linguistic variable "high",
- 0.81 <PIP <1 - value of the linguistic variable "very high".

D. Synthesis of Security of supply

The Security of supply synthesis indicator is more closely defined by three partial indicators. Synthesis of this indicator is related to the composition of Energy availability (S1), Diversification of sources and directions (S2) and Infrastructure development (S3) into SECURITY OF SUPPLY (S). 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.

$$\mathbf{M = S;\ P1 = S1, P2 = S2, P3 = S3}$$

This has been done by tailoring the model in several steps (Figure 5).

During the process, data are collected that can be performed at the statistical level (based on calculations, projections, statistical processing, software model results, etc.) or based on expert analysis, i.e., judgment of the report. The partial indicators within this synthesis indicator are entered the model itself in one way. F, All three are measurable and they are entering the model through numerical data that are the result of active monitoring.

The data are then classified and put into the analysis model itself in an adequate form. Such data are entered the synthesis model by the procedure called proposition. They are further classified and defined as the input data of the fuzzy set. Next, procedure of ranking has been performed based on the application of the AHP (Analytic Hierarchy Process) method. It can be done by several different methods. After that, ranking data is used as input to the fuzzy set and analysed in the fuzzy composition process. As a result of the fuzzy composition, an energy security of supply assessment is generated in a fuzzy form.

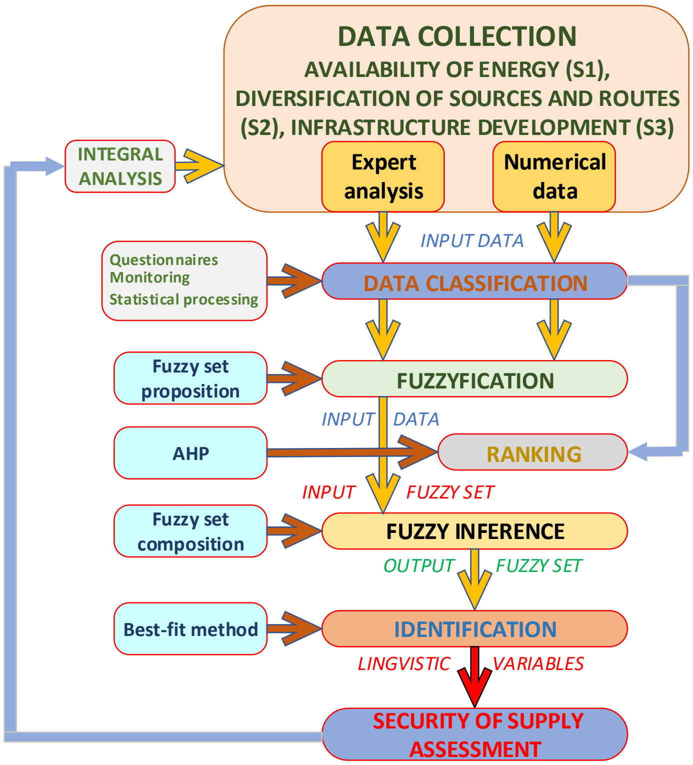

Figure 5. Schematic diagram of a model for energy security of supply assessment

The output of this fuzzy set is identified in almost last step. At the end, the results of model make quantifications of Energy security of supply indicator.

IV. Scenario development and results

A. Natural gas sector of Republic of Serbia

After coal and oil, natural gas is the third most used primary source of energy in the Republic of Serbia. Its share in total primary energy consumption in 2020 was 13.25% [16]. The total consumption of natural gas in 2020 amounted to 2.481 million m^3, which is 4% less than in 2019 [16]. The trend of growth of natural gas consumption in final consumption, which was noticeable after 2014 (the energy balance of natural gas for the period 2010-2020. are shown in Table 1), was temporarily stopped in 2018. This is primarily due to the reduction of gas consumption for non-energy purposes, which continued in 2019 and 2020. The structure of natural gas supply and consumption in 2020 is shown in Figure 6.

Natural gas transmission system of the Republic of Serbia is a linear system with two inputs and two outputs with other natural gas pipelines systems [16]. Main gas pipeline system connects all domestic gas fields with consumers and enables gas import from Russia. Main technical characteristics of transmission system are presented in Table 2. The main shortcoming and weakness of the transmission system in the previous period was only one entry point on the transmission system, which provided the import of the necessary quantities of natural gas. This shortcoming has been overcome by building an interconnection pipeline from the Bulgarian-Serbian border to the Serbian-Hungarian border. During 2020, this gas pipeline was mostly completed, connected to the transport system in Bulgaria and the transport system of Transportgas in Serbia. The first quantities of gas for the market in Serbia were delivered from the direction of Bulgaria through this gas pipeline at the beginning of 2021, and it becomes fully operated in October 2021.

The Republic of Serbia has four interconnections with other gas pipeline systems:

- Hungary - Republic of Serbia (Kishkundorozhma, entry point) - Republic of Serbia - BiH (Zvornik, exit point);
- Bulgaria - Republic of Serbia (near Zajecar, entry point) - Republic of Serbia - Hungary (near Horgos, exit point).

The first two interconnections are part of the Transprotgas Serbia transport system, the other two belong to the Gastrans transport system, while the Yugorosgas-Transport transmission system does not have gas pipelines connected to the transport systems of neighbouring countries.

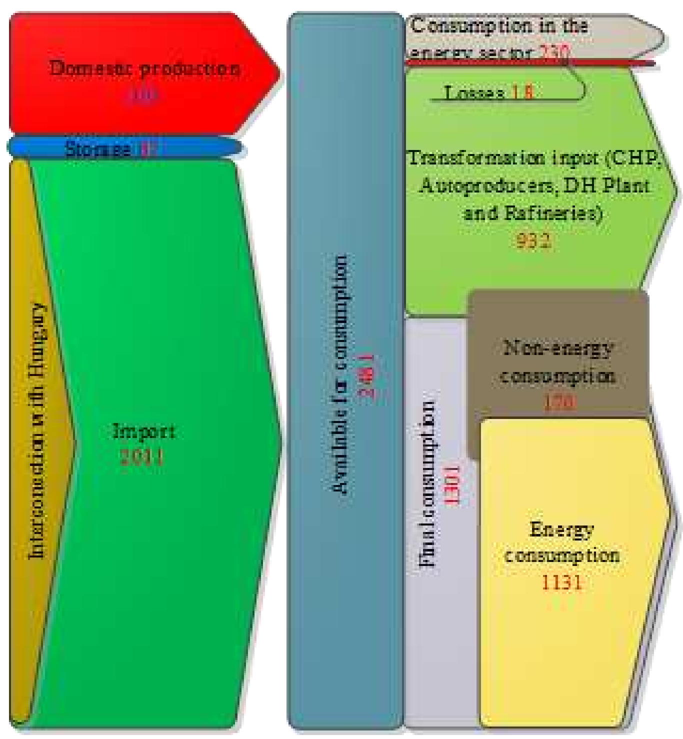

Figure 6. Structure of natural gas supply and consumption in 2020, in millions of Sm^3 [17]

B. Natural gas energy scenario development

In order to demonstrate the impact of energy supply on energy security, through the Indicator of Security of supply, the scenario of development of the natural gas sector of the Republic of Serbia [7] will be considered through the model. Regarding gas consumption, different projections can be made with different assumptions (e.g., real GDP growth, degree of implementation of energy efficiency measures, degree of increase in gas use for electricity production, etc.). For analysis in this case study, two characteristic projections of natural gas consumption were identified.

Table 1. Energy balance of natural gas for the period 2010-2020., in millions of Sm^3 [18]

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Production	387.183	508.161	533.511	531.188	557.17	572.502	523.229	489.085	449.567	438.615	402.723
Import	1967.753	1747.520	1789.756	1887.480	1394.6	1740.221	1795.226	2182.632	2153.385	2262.610	2011.390
Storage	0	133.729	-216.108	-74.500	68.795	-114.511	56.850	-12.800	29.458	-197.967	66.836
International Storage	-27.343	0	0	0	0	0	0	0	0	0	0
Available for consumption	**2327.59**	**2389.41**	**2107.15**	**2344.168**	**2020.6**	**2198.212**	**2375.305**	**2658.917**	**2632.410**	**2503.258**	**2480.948**
Transformation input	**805.480**	**904.808**	**826.160**	**774.997**	**856.098**	**885.174**	**886.884**	**920.464**	**942.349**	**953.057**	**932.319**
CHP	95.173	153.786	146.795	70.436	27.391	20.064	46.582	94.992	115.978	149.637	76.804
Autoproducer	203.910	184.245	132.134	205.803	216.38	164.998	144.646	136.587	149.740	166.099	166.760
DH Plants	506.397	566.777	547.231	498.758	480.84	563.451	566.640	565.657	536.915	497.046	534.960
Refineries	-		-	-	131.47	136.661	129.016	123.228	139.716	140.275	153.795
Consumption in the energy sector	**60.274**	**54.242**	**93.736**	**159.932**	**183.56**	**209.707**	**180.986**	**202.241**	**197.345**	**210.465**	**229.857**
Losses	**20.943**	**5.746**	**11.847**	**16.328**	**18.194**	**11.433**	**22.544**	**36.101**	**36.705**	**20.570**	**17.801**
Final Consumption	**1440.89**	**1424.61**	**1175.40**	**1392.911**	**962.98**	**1091.89**	**1284.89**	**1500.111**	**1456.011**	**1319.166**	**1300.972**
Final Non-Energy consumption	**271.435**	**283.532**	**21.496**	**13.4365**	**114.25**	**157.658**	**292.077**	**425.526**	**197.386**	**169.746**	**169.746**
Final Energy consumption	**1169.46**	**1141.08**	**1153.90**	**1258.546**	**848.72**	**934.240**	**992.814**	**1074.585**	**1258.625**	**1149.420**	**1131.226**
Industry	759.313	732.730	760.460	88.9452	485.88	543.083	550.089	578.938	720.005	622.175	612.237
Transport	12.623	14.054	4.459	9.486	8.833	11.204	6.502	5.309	21.001	13.532	13.318
Households	270.412	266.653	244.232	218.528	179.00	189.822	210.678	240.938	243.982	255.165	251.126
Agriculture	18.330	17.448	20.670	19.543	32.207	20.713	28.953	22.564	23.506	24.488	24.100
Public and Commerciale sector	108.783	110.197	124.088	121.537	142.80	169.418	196.592	226.836	250.131	234.060	230.360

Table 2. Main technical characteristics of transmission system [18]

Main technical characteristics	**Transportgas Serbia**	**Yugorosgaz-Transport**	**Gastrans**
Capacity (mill. m^3/day)	≈ 18	≈ 2.2	34
Pressure (bar)	16–75	16–55	74
Length (km)	2414	125	402
Nominal diameters (mm)	DN 150–DN 750	DN 168–DN 530	DN 1200
Compressor station	1	-	1 (near Velika Plana)
Compressor station power (MW)	4.4	-	24
Entry in transmission system	13	1	1
1. from other transmission system	4 (Horgos,Karadjordjevo brdo, Pancevo, Gospodjinci)	1	1 (near Zajecar)
2. from production field	9	-	-
3. from underground storage	1	-	-
Number of exits from the transport system	241	6	3
Measuring and regulating stations at the exit from the transport system	238	6	3
Handover stations	2	-	4
Exit to the Yugorosgaz-Transport system	1	-	-
Exit to the Transportgas Serbia transport system	-	-	3
Interconnector to BiH	1	-	-
Interconnector to Hungary	-	-	1 (near Horgos)
Natural gas storage	1	-	-

Table 3 lists the projections of natural gas consumption [7, 17].

Table 3. Natural gas consumption projection, million m^3 [7]

Scenario	**Reference**		**Intensive consumption**	
Purpose	2025	2030	2025	2030
Transformation input	907.980	973.285	1027.286	1113.940
Final energy consumption	2073.410	2430.072	2255.508	2622.217
Losses	42.699	48.978	46.466	54.002
Total	3024.089	3452.334	3329.261	3790.158

In terms of infrastructure development, according to [17] three characteristic scenarios were selected for further consideration (Table 4):

- The pessimistic scenario of natural gas infrastructure development (PES) assumes a lack of investment in new infrastructure projects and maintaining the existing level of infrastructure development [17];
- The Reference Scenario (BAU) point out the development of gas sector infrastructure in accordance with the planed strategic documents [17];
- The optimistic scenario for the development of natural gas infrastructure (OPT) is more forceful and indicate the introduction of two additional supply corridors bond to BAU and the construction of considerable additional underground storage facilities. This scenario is in line with the objectives of the Energy Community in the SEE region [19].

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 2030. These futures are designed to approach security of supply, considering various supply options as well as different needs.

C. Results and discussion

Security of natural gas supply refers to the provision and timely delivery of the required quantities of natural gas to consumers. Security of supply is improved by diversifying sources and supply routes and building gas storage facilities. In infrastructure's term the security of supply in gas pipeline system is satisfactory if the capacity of the entrance to the transmission system can meet the total needs for natural gas and in case of interruption high needs for natural gas that statistically occur once every 20 years. This corresponds to values (N-1) of indicators greater than 100%. According to [18] the calculated N-1 index is 33.8% for 2020.

Intensive changes happened in 2021, because the gas interconnector from the Bulgarian-Serbian border to the Serbian-Hungarian border has been in operation from October and that the technical capacity of this pipeline is 12.66 billion m^3 [18]. The indicator (N-1) now has a much higher value (N-1=114%) and now this standard of infrastructure supply is finally met [18].

All three partial indicator (S1, S2, S3) has been considered in those various scenario's combination.

The gas interconnector (Balkan Stream - Gastrans operator) for the transport of natural gas, which has been operational since 2021 and whose route passes through the territory of the Republic of Serbia and crosses the state border of the Republic of Serbia, to connect with neighboring transport systems in Bulgaria and Hungary has greatly influenced the values of security of supply indicators through two partial indicators - Availability of energy (S1) and Diversification of sources and routes (S2). Only the realization of this project achieves the infrastructure standard of N-1 supply in the Republic of Serbia would be met, because it is now amount to 114% [17, 18] (Figure 7).

Table 4. Scenarios for gas infrastructure development [16]

Scenarios	Interconnections	UGS	Available quantities of natural gas and effects of realization
BAU	Hungary (existing) Gastrans- Balkan Stream (Bulgaria) (existing) Bulgaria	The capacity of the "Banatski Dvor" underground storage is increased to 800 mcm.	*Interconnection with Bulgaria (MG 10)* Capacity: 4.93 mcm per day [17]. Possible connection to Turkish Stream (supply from Russia) and TAP (supply from Azerbaijan) *UGS* capacity: 9.96mcm per day [17].
PES	Hungary (existing) Gastrans- Balkan Stream (Bulgaria) (existing)	The capacity of the "Banatski Dvor" UGS remains 450 mcm.	*Interconnection with Hungary* – Same as for BAU *UGS* capacity: 4.95mcm per day [17].
OPT	Hungary (existing) Gastrans- Balkan Stream (Bulgaria) (existing) Bulgaria Croatia Romania	The capacity of the "Banatski Dvor" underground storage is increased to 1000 mcm.	*Interconnection with Bulgaria*–Same as for BAU *Interconnection with Romania (gas producer)* Capacity: 4.38 mcm per day [17]. *Interconnection with Croatia (*gas supply from Algeria through Italy) Capacity: 4.1 mcm per day [17]. These 3 interconnections together bring 13.39 mcm per day (availability of natural gas from imports increase by 70%). *UGS* – Same as for BAU

Gas interconnection project Republic of Serbia - Bulgaria, main gas pipeline MG-10 Nis - Dimitrovgrad (border with Bulgaria) would make more possibility for different gas sources and new route of connection (possibility for the supply of natural gas from Russia and other supply routes: the so-called. Southern Corridor (Azerbaijan, liquefied natural gas from terminals in Greece, etc.) [16]. The realization of this project increases the security of natural gas supply (N 1) = 135.5%) (Figure 7) [17, 18].

Gas interconnection project with Croatia would increases the security of natural gas supply more than interconnector with

Bulgaria (N-1) = 137.5%) (Figure 7) [17, 18]. This interconnector also creates the possibility to make new sources of natural gas supply from North Africa from Italy to Croatia or from the planned liquefied natural gas terminal in Croatia [16].

Gas interconnection project Republic of Serbia – Romania would be additional input of natural gas into the network increases security of supply ((N-1) = 139%). It would also represent reliability of system operation and opens the possibility of purchasing natural gas from other sources (Romanian or gas from one of the planned transcontinental supply routes). Also, this project significantly affects the relief of the main gas magistral in country Horgos- Belgrade (Batajnica) [16].

Project of expansion of the underground gas storage (exUGS) envisages the expansion of the underground natural gas storage in Banatski Dvor from the current capacity to 800 million to 1 billion m3, with a maximum technical production capacity of 9.96 million m^3/day (415000 m^3/h) and a maximum technical injection capacity of 5.52 million m^3/day (230000 m^3/h) [16, 18]. The project significantly increases the available quantities of natural gas in the periods of maximum daily consumption ((N-1) = 142%) (Figure 7) [17, 18]. According to the Program [17], this expansion should be realized in 2023-2025. A special advantage and pronounced impact that the expansion of the underground gas storage capacity has on the security of natural gas supply is the increase of the system's resistance to longer, complete interruptions in the supply of natural gas from other transport systems [16].

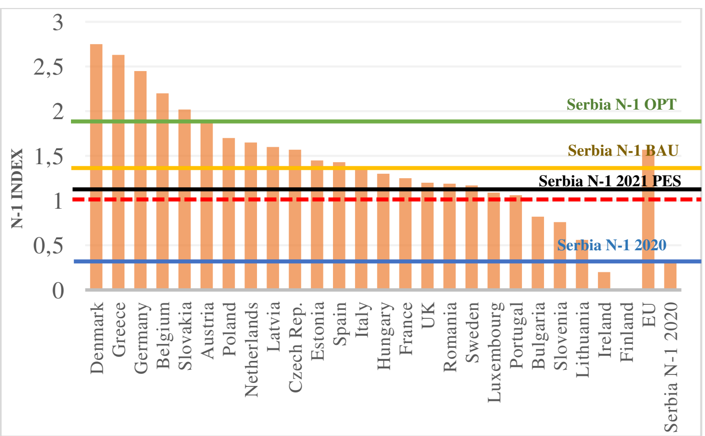

Figure 7. Partial Indicator S1 for different project realization

Establishing new interconnections is crucial to improve the diversification of sources and supply routes, and thus the more positive values of IDUPS. Table 5 shows the values of the index in the case of the implementation of planned projects for interconnections with the gas pipeline systems of Bulgaria, Romania, and Croatia.

Table 5. Partial Indicator S2 for different scenarios

Partial Indic. S2	Old station	Current station	New interconnection			All Intercon. + exUGS
	Hungary	Balkan Stream + Hungary	Bulgaria	Croatia	Romania	Complete Realisation
IDUPS	10000	6007	5424	5224	5348	2282

In this way, IDUPS would make significant progress. Should there be a connection with other possible routes of natural gas supply (South Corridor, LPG terminals in Greece and Croatia), they would have new supply routes (other incoming routes of Russian gas, connection with Azerbaijan and the Caspian region, the possibility of gas supply from North Africa via Italy, as well as from LPG terminals from Greece and Croatia).

Based on the data from [17], the value of the planed infrastructure projects (PIP) for combined development scenarios is determined, which is quantification of partial indicator of Infrastructure development (S3) (Table 6). The PIP is obtained considering the relationship between the achieved expansion of capacity proposed by the development projection and the total possible expansion of capacity predict by the implementation of all infrastructure projects. New interconnections with Bulgaria (daily capacity 4.93 million m^3), Croatia (daily capacity 4.1 million m^3) and Romania (daily capacity 4.38 million m^3), with the expansion of PSG Banatski Dvor's capacity to the planned 800 million m^3 to 1 billion m^3 (daily capacity 9.96 million m3), provide possibilities of increasing the daily availability of natural gas from interconnections by 71%, ie. increase in total daily gas availability by 77% (interconnections and underground storage).

Table 6. Partial Indicator S3 for different level of development

Partial Indicator S3	SC 1	SC 2	SC 3	SC 4	SC 5	SC 6
PIP	0.443	0.539	0.835	1	0.238	0

In the case of the implementation of all planned infrastructure projects, the maximum daily capacity of natural gas from all available sources of supply would be 42.35 million m^3, compared to the current 23.95 million m^3.

When forming the outcome of the composition for each combination, the outcome is determined by the AHP criterion analysis. The matrix of comparison of elements, as well as the values of the degree of consistency and weighting coefficients for partial and synthetic indicators are shown in Table 7.

Table 7. Comparison of the influence of partial on the synthetic indicator, degree of consistency and weighting coefficients for S1, S2, S3 partial indicators

Security of supply (S)		S1	S2	S3	CR	0,033375	Wi %
	S1	1	0,33	0,2			10,62
	S2	3	1	0,33			26,05
	S3	5	3	1			63,33

Partial indicators in the process of composition of the synthetic indicator Security of supply were treated using Satie's AHP scale, which allows emphasizing the impact of a particular partial indicator in the description of the synthetic indicator and minimizing the subjective influence of the model.

Using specific fuzzy sets that define partial indicators, in the operation of synthesis, indicators of Security of supply (S) is defined by the composition of previously described partial indicators. Each of the six combined scenarios was analyzed through a mathematical model in order to compare different projections of natural gas consumption and infrastructure development. Results of combined scenario of OPT scenario of infrastructure development with Reference consumption scenario is presented. Table 8 and Figure 8 shows the affiliation of Security of supply indicator for OPT-Reference scenario which is characterized by intensive infrastructural development combined with expected consumption following the current trend.

Table 8. Quantified estimates of partial indicators in the propositional phase

S	1	2	3	4	5	6	7	8	9	10
S1	0	0	0	0	0	0	0	0	1	1
S2	0	0	0	0.15	0.29	0.53	0.85	0.70	0	0
S3	0	0	0	0	0	0.17	0,51	0.51	0.49	0.49

Figure 8 points out the dominant result of security of supply.

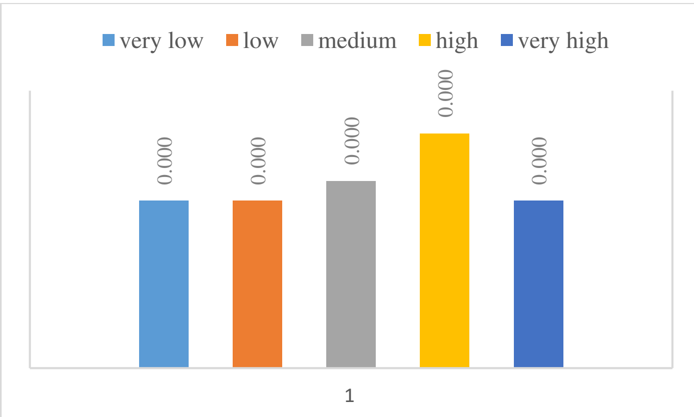

Figure 8. Security of supply indicator for OPT-Reference scenario

Figure 9 shows the impact partial indicators S1, S2, S3 on Security of supply synthesis indicator S for OPT-Reference scenario.

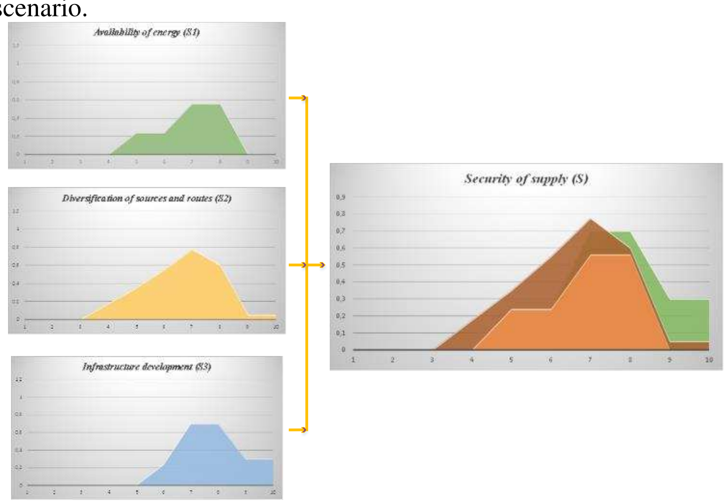

Figure 9. Impact of partial indicators on Security of supply synthesis indicator for OPT-Reference scenario

As expected, one of the highest results of energy security was achieved through this scenario, and it is especially pronounced within the synthetic indicator of Security of Supply, where the development of infrastructure is obvious with the increase of available sources and routes for natural gas supply.

V. 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 security of supply gives results on energy security. Security of energy supply indicator can be a tool for security at all, environmental protection, economy prosperity, market stability, etc.

In this paper, the analysis was concentrated on energy security, especially on security of supply and partial indicators related to the natural gas sector in the Republic of Serbia. Number of interconnections in Republic of Serbia are two and, according to plan of development, it is expected to be increased. It was shown that the rising of number of energy sources and routes leads to energy security growth and have a significant, positive effect on energy availability, comfort, and energy costs.

The model shows that the higher Energy security rating, the Security of supply indicator shows values that are more acceptable. It is also noticeable that in each combination with the Pessimistic scenario of infrastructure development the value of the Security of supply indicator is lower. In each combination with Reference scenario of consumption, the Indicator of Security of supply has higher results, same as in OPT scenario of infrastructure development.

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AUTORI/AUTHORS

Aleksandar Madžarević – assistant professor, Faculty of Mining and Geology, University of Belgrade, aleksandar.madzarevic@rgf.bg.ac.rs, ORCID 0000-0002-8997-1393

Miroslav Crnogorac - assistant professor, Faculty of Mining and Geology, University of Belgrade, miroslav.crnogorac@rgf.bg.ac.rs, ORCID 0000-0002-8078-2684