SALES OF ELECTRICITY FROM COGENERATION PLANTS ON ORGANIZED MARKETS IN SOUTHEAST EUROPE

by

Zorana M. BOŽIĆ[a*] and Dušan P. DOBROMIROV[b]

[a] PowerMart ApS, Aarhus, Denmark
[b] Faculty of Technical Sciences, University of Novi Sad, Novi Sad, Serbia

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Volatile energy prices in the past period, force countries and their market participants to find alternative and cheaper sources of electricity production, while respecting defined environmental principles. Serbia is one of the rare European countries that uses its reserves of dissolved gas in the heat and electricity production. Combined heat and power plants, although in an almost negligible amount, contribute to the diversification of Serbia's production mix. With the presence of organized markets and local power exchanges, sale of electricity from combined heat and power plants is guaranteed for all producers who do not meet the conditions for acquiring the right to feed-in tariffs. The aim of this paper is to analyze the most profitable sale on the power exchanges of the domestic market and the region, specifically the markets of Serbia, Croatia, Hungary, Romania, and Bulgaria. The calculation methodology itself implies the use of average monthly price value for the observed markets, in the period of the past three years and nine months. In addition to the aforementioned, the costs of cross-border capacities were considered. In order to have a clearer overview of the results and the possibility of applying the methodology, the amount for calculation is 1 MWh. Costs and revenues related to negative and positive balance energy deviations are excluded from the analysis. Results showed that sale of electricity is most profitable on Serbian power exchange.

Key words: *cogeneration plants, Southeast European power markets, power exchanges*

Introduction

Demand for electrical energy increased drastically due to the exponential growth of the world population, therefore, great efforts are required to make more renewable energy resources available [1]. Set of proposals to make the EU's climate, energy, transport and taxation policies fit for reducing net greenhouse gas emissions are adopted by the European Commission with aim of reduction for at least 55% by 2030. However, the current geopolitical events in Europe between Russia and Ukraine, have led to an increase in energy prices, primarily fuel and gas, and consequently electricity. In addition, the rise in energy prices was preceded by the crisis caused by the Corona virus pandemic. In order to ease the increased energy prices, EU requires exceptional electricity demand reduction measures of at least 5% during peak hours and overall 10% by end of March 2023 [2].

* Corresponding author, e-mail: zoranabozic3@gmail.com

Climate commitments under the European Green Deal, enchase the energy efficiency as a key element in energy and climate goals by 2050. This can be partially mitigated by exploring new energy technologies and advancing conventional energy technologies, such as combined heat and power (CHP) plants. Regarding rational energy use, it primarily concerns the modernization of technologies in economic activities by introducing state-of-the-art energy technologies with markedly higher energy efficiency in transforming primary forms of energy into final, is profitable given that any transformation of energy inevitably causes losses which modern technologies are able to cut down even by half [3].

Conventional power plants in the US throw away heat energy, while only one third of the fuel energy going into the plant is converted into electricity. Capturing this waste heat contributes to the reduction of the thermal needs in households and industry. Additional advantage in CHP is a use of municipal waste and biomass in production of heat and power. Such plants cover majority of the heat demand in winter period in Denmark, while in summer months the plants do not operate as much. This process is operated by CHP in Sweden and most of the Scandinavia.

Energy efficiency in Serbia and the Region

It is estimated that the Balkan energy sector needs up to 60 billion euros in investments by 2030 [4], implying that cooperation among the countries of this region is bound to intensify.

The Energy Efficiency Policy is essentially a program for reshaping the market, which entails strategic decisions to help make permanent alterations in the market structure or function for all energy-efficient products/services/stakeholders [5]. It is vital for energy efficiency to be seen as savings in profit, because only thus can it become appealing to investors.

However, Serbia is energy dependent on imports as 30% of its energy demand is met by purchasing from foreign markets, a reason sound enough to direct more investments into energy efficiency increase [6]. Serbia's thermal power plants are among the biggest polluters in Europe and the only question remaining is how to stimulate the substitution of these plants by new ones which produce electricity from renewable sources [7]. New Energy law passed in 2021 in the Republic of Serbia, for the first time actively emphasizes the importance of renewable energy sources, by introducing the role of prosumers. Also, during 2022, the price of feed-in tariffs increased, which has a positive effect on the development of future projects.

Literature review

The literature is extensive in works dealing with cogeneration issues from a variety of perspectives and aspects. Cho *et al.* [8] provided an extensive review on the current status and the trends in the combined cooling, heating and power systems. Rinne and Syri [9] studied the role that combined heat and power units, along with increased heat storage, could have on balancing the variable wind power generation in Finland, also quantifying the impacts on CO_2 emissions evolution. The impact of short-term uncertainty on energy investments, due to intermittent RES, has been also investigated by Seljom and Tomasgard [10]. Jensen and Meibom [11] investigated the prospects for new investments in a combined heat and power gas turbine in the Nordic power system for investors, with or without existing portfolios, also highlighting the effects of competition on the profitability of these investments. Rong and Lahdelma [12] developed a stochastic optimization approach for a CHP producer to optimally determine the production and CO_2 emissions trading planning. Sorknaes *et al.* [13] presented an analysis to assess the economic feasibility of the CHP units' provision of balancing ser-

vices to electricity system. Their findings suggest that there is high uncertainty depending on the specific conditions of each country and examined plant, as well as on the available electricity markets. Koltsaklis *et al.* [14] developed a mixed integer linear programming model in order to optimally determine the design and production scheduling of energy systems based on CHP units and taking also into account the existence of a possible external heat source. Kumbartzky *et al.* [15] developed a mixed-integer linear programming model to determine the optimal operation of a CHP plant with heat storage, when taking part in electricity markets trading under uncertainty in power prices. Bjelić and Rajaković [16] made use of the HOMER simulation tool to determine the optimal distributed generation micro-grid design at a municipal level under a wide range of CO_2 emissions reduction targets.

A series of works have focused on the techno-economic and/or environmental assessment regarding the potential installation of CHP units. Comodi and Rossi [17] investigated the operating ranges of CHP units in which they achieve both energy and cost savings, also highlighting the vital importance that the ratio between the costs of commodities has on the CHP units' profitability. Vogelin *et al.* [18] presented an analysis in order to investigate the factors (electricity and fuel prices) that can influence the optimal design of a CHP plant in residential and industrial heat demand profiles. Sevencan *et al.* [19] investigated the economic feasibility of a fuel cell-based combined cooling, heating and power system for the demand satisfaction of a data center, highlighting also the influence of the energy price levels. Hawkes and Leach [20] compared three possible operating strategies of residential micro-combined heat and power technologies, highlighting possible contradictions between minimum cost and environmental impact, as well as the sensitivity to electricity buy-back prices. Papamarcou and Kalogirou [21] examined the economic feasibility of a possible installation of a CHP unit in a hotel in Cyprus. Božić *et al.* [22] presented an economic feasibility analysis of the cost effectiveness of implementing a combined heat and power system at oil and gas fields in Serbia.

Streimikiene and Siksnelyte [23] provided an analysis to indicate the factors, associated with electricity market regulation, that have influenced the generating technologies investments in the power sector. Kavvadias [24] developed a theoretical indicator with the aim of providing insights on the CHP investments, considering the relationship between electricity and fuel prices, technical characteristics of CHP units and conventional generation equipment, as well as economic return. Zhang *et al.* [25] made use of the ENERGYPLUS software to investigate the economic attractiveness of specific CHP incentive policies in the US, including capital cost rebate, tax credits, low tax loan, and utility credits for the installation of CHP units in given building types, also indicating their interdependence with the technical characteristics of each specific CHP technology.

The cited literature is mainly focused on the technical contribution of cogeneration, their cost-effectiveness, while little attention is paid to the sale of electricity from cogeneration plants on the power exchanges. The aim of this paper is to determine which power exchange is most profitable for electricity sale from CHP. In addition, the analysis of price comparisons in the period before and during the coronavirus pandemic, provides insight into market reactions to global pandemic trends. To the best of author's knowledge, no previous work has been done to cover sale of electricity on Serbian and neighboring power exchanges of SEE region. This paper fulfills that gap.

Materials and methods

Some power markets in Southeast Europe are young. Power exchanges in Serbia, Bulgaria and Croatia are operating less than seven years, while Romanian and Hungarian

markets are more mature. During its development, newly formed markets have reached an enviable level of traded volumes, attracting the active participation of producers and traders.

According to the report of the Energy Agency, the production of electricity from CHP by licensed independent producers in Serbia, reaches 12 MW of installed capacity [26]. In addition to the mentioned mini power plants, input fuels can also be biomass, biogas, waste, gas from wastewater, *etc.* To gain the possibility of applying the methodology of this analysis to power plants with other input fuels, the total production is not included in the analysis, but instead the authors use a unit of 1 MWh.

In this paper, data on the prices of spot products from four electricity exchanges were used. Period of three years was observed, namely 2019-2021, as well as the first nine months of 2022. Stated period includes the year before the beginning of global corona virus pandemic, as well as the period after the start of the military operation in Ukraine, with the aim of showing the trend of price movements in normal and emergency conditions. This is particularly important since CHP are mostly designed to have a lifespan of 12 to 15 years.

Spot products represent hourly contracts with [€ per MWh] value and volume in [MWh] [27]. Prices from power exchanges in Serbia, Romania, Bulgaria, Hungary, and Croatia are available on the official power exchange websites shown in tab. 1. Number of data points covers 1.369 days, and 131.408 hourly day-ahead prices in [€ per MWh]. Also, in order to achieve the most accurate data on the most profitable market, hourly price data are averaged on a daily basis, and their value is reduced by the cross-border capacity allocation price, as presented in tab. 2.

Table 1. Websites for power markets

Market	Short name	Power prices websites	Capacity auctions websites
Serbia	SEEPEX	http://www.seepex-spot.com/en/	–
Croatia	CROPEX	https://www.cropex.hr/en/	https://www.jao.eu/auctions#/
Bulgaria	IBEX	https://ibex.bg/en/	https://www.jao.eu/auctions#/
Romania	OPCOM	https://www.opcom.ro/pp/home.php	https://www.transelectrica.ro/web/tel/licitatii-atc?type=2&year=2020&month=0
Hungary	HUPX	https://hupx.hu/en/	http://kapar.mavir.hu/kapar/lt-publication.jsp?locale=en_GB

In addition to the market clearing prices that are representing income, the cost of cross-border transmission capacity was also included in the analysis. The authors use data on capacities from the monthly auctions organized by the JAO auction house for the Serbian--Croatian and Serbian-Bulgarian cross-borders, as well as the transmission system operators of the Serbian-Hungarian and Serbian-Romanian markets. Data on auction results are available on the websites listed in tab 1. Cross-border capacity allocation auction results for multiple periods within a month, are averaged on monthly basis for the Romanian market. As for Serbian market, Serbian CHP produces do not need to bid for capacity when selling electricity on South-East European Energy Exchange (SEEPEX).

Details of the cost on power exchanges entrance, may vary depending on the terms of special business arrangements, but approximately they are around 35.000 €, with cca 40% being the entrance fee, while the rest goes to technical and annual fees. In addition, balancing costs were not considered.

Table 2. Average monthly power prices in [€ per MWh], with cross-border capacity costs

		Bulgaria	Hungary	Romania	Croatia	Serbia
2019	January	67.11	72.76	74.98	69.09	75.99
	February	39.36	49.20	48.57	49.46	49.94
	March	34.93	39.14	38.46	39.09	38.25
	April	41.11	45.95	44.82	45.21	46.62
	May	40.47	41.61	40.04	41.08	41.97
	June	40.22	40.89	38.53	39.93	41.50
	July	55.01	54.69	55.26	52.70	53.95
	August	51.81	58.47	60.14	55.66	58.97
	September	55.16	55.54	60.41	55.36	56.80
	October	55.03	56.81	56.96	55.30	58.22
	November	41.21	43.77	42.52	45.07	43.14
	December	42.04	40.96	40.48	40.01	41.19
2020	January	53.89	52.84	52.14	51.13	53.87
	February	40.20	39.64	40.00	39.42	39.96
	March	26.93	29.45	29.37	29.25	29.85
	April	23.45	25.12	25.18	23.84	25.09
	May	22.57	23.42	24.43	22.37	23.99
	June	28.79	29.87	29.15	28.71	29.79
	July	35.68	36.50	35.62	35.37	36.63
	August	37.07	37.43	37.46	38.04	37.24
	September	45.54	45.59	45.63	45.80	45.54
	October	42.01	39.29	41.41	38.55	39.39
	November	47.31	48.63	48.22	47.05	48.63
	December	55.94	58.06	58.00	55.43	57.95
2021	January	52.65	56.14	55.33	53.80	53.74
	February	46.27	50.16	47.83	50.11	46.86
	March	51.18	53.82	54.05	54.27	54.02
	April	61.04	62.34	62.57	63.66	63.59
	May	59.18	59.68	58.48	59.27	59.90
	June	76.92	77.09	76.77	77.93	78.63
	July	94.50	94.87	93.71	93.42	95.35
	August	111.00	108.84	112.60	105.10	109.65
	September	124.30	134.92	133.76	138.28	135.08
	October	188.34	197.25	192.27	202.38	201.56

→

Table 2. Continuation

		Bulgaria	Hungary	Romania	Croatia	Serbia
	November	208.14	215.58	212.28	215.62	218.30
	December	219.45	245.44	229.77	251.58	246.43
2022	January	190.78	201.53	191.70	205.17	209.46
	February	187.49	194.34	188.30	193.90	198.77
	March	248.76	286.43	273.69	292.87	292.22
	April	173.46	189.73	173.70	191.72	191.56
	May	201.22	205.10	201.76	201.04	205.79
	June	222.22	237.90	229.87	244.36	242.29
	July	322.90	372.74	366.92	374.70	384.25
	August	432.35	445.39	489.68	490.93	491.96
	September	375.76	391.62	378.59	391.13	396.03

To achieve the defined goals of the paper, the authors use methods of descriptive statistics. The analysis of data is presented with a graphical comparison of the obtained values. Also, exchanges are compared by using the correlation matrix presented in [28]. Correlation measures the strength and direction of the linear relationship between two average prices and provides an overview of how price trends of one power market affect others.

Results

Based on the defined data and methods of analysis, the following results are obtained.

The SEEPEX recorded the highest prices in 2019 – January, February, April, May, June, and October as presented in fig. 1. The next most profitable power exchange for CHP producers from Serbia is Croatian CROPEX. The lowest prices are recorded in Bulgarian IBEX during eight months for the observed period.

On the other hand, fig. 2 shows results in 2020, where Bulgarian IBEX had the greatest number of months with the highest price values, primarily in January, February, March, and October. And the lowest prices were recorded at the Croatian CROPEX during the second and fourth quarters.

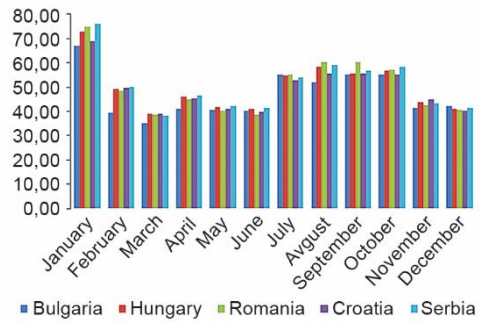

Figure 1. Average power prices with cross--border capacities [€ per MWh] in 2019

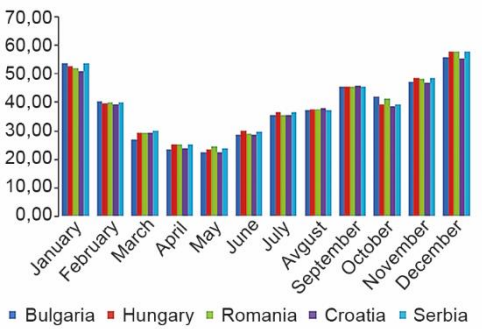

Figure 2. Average power prices with cross--border capacities in [€ per MWh] in 2020

In 2021, SEEPEX again recorded the highest prices in May and June, and additionally in July and November. Almost identical to 2019, IBEX recorded the lowest prices in the same months, also including December.

First nine months of the 2022 are presented in fig. 4. All power exchanges had higher prices than the previous year. Again, SEEPEX is leading in number of months with highest prices in January, February, May, July, August and September. IBEX had lowest prices in almost all months, according to the results presented in fig. 3.

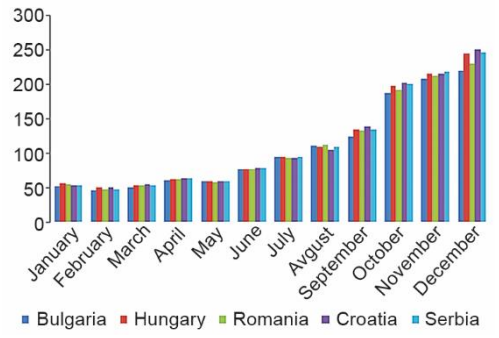

Figure 3. Average power prices with cross--border capacities in [€ per MWh] in 2021

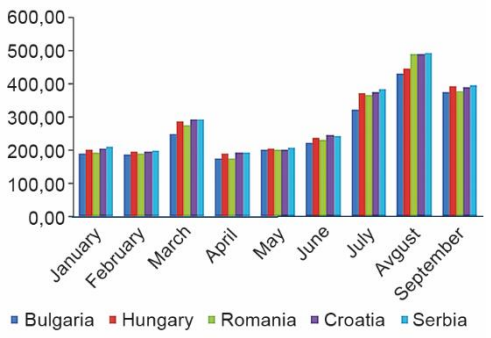

Figure 4. Average power prices with cross--border capacities in [€ per MWh] in 2022

The rise in prices during the Covid pandemic and after the start of the special military operation in Ukraine can be seen in fig. 5. Serbian and Croatian markets have the highest growth in August 2022.

The correlation method determined by the tab. 3 shows the lowest correlation between the territorially distant countries of Bulgaria and Croatia, while the highest values of market correlation were recorded in geographically related countries between Serbia, Croatia, and Hungary.

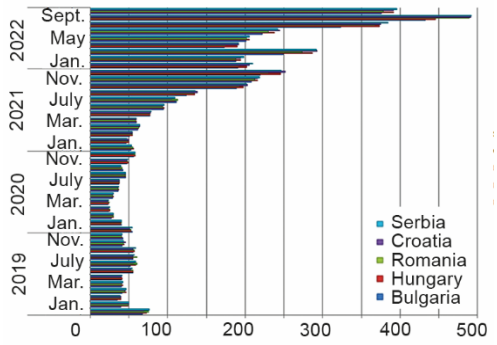

Figure 5. Average power prices in [€ per MWh] for period January 1, 2019 to September 30, 2022

Table 3. Correlation matrix

	Bulgaria	Hungary	Romania	Croatia	Serbia
Bulgaria	1				
Hungary	0.983	1			
Romania	0.986	0.993	1		
Croatia	0.981	0.995	0.991	1	
Serbia	0.982	0.994	0.991	0.995	1

Conclusions

Considering the results of the analysis, it is possible to conclude that, in terms of the number of months with the highest average monthly prices, Serbian SEEPEX is in the first place. In the total observed period of 45 months, for 18 months, SEEPEX is the market with highest prices. It is interesting to note that the trend of the highest and lowest prices for the winter period, marks the related months from December to February at one single market. Accordingly at the turn between 2019 and 2020, Bulgaria had the highest prices and Croatia the lowest, but the opposite occurred at the turn between 2021 and 2022. The smallest correlation between these two markets testifies to that. Then, at the turn of 2020 and 2021, the highest prices were in Hungary, and the lowest in the Bulgarian market.

By analyzing the obtained results, it can also be concluded that prices in the last quarter of 2021 are on average 4-5 times higher than in the same quarter of the previous year, and twice as high as in the previous quarter of the same year. Also, prices in August 2022 are four times higher than the prices in the same month previous year. The cause of this jump in prices is reflected in the consequences of the Covid pandemic and rising prices of other energy sources, primarily gas.

The presentation of the obtained results leads to the conclusion that for the producer of electricity from mini cogeneration plants, it is most profitable to place electricity on the Serbian SEEPEX, and the least profitable on the Bulgarian and Hungarian markets. Sales can also be profitable in late summer on CROPEX and during the winter on HUPX or IBEX.

In addition to the above results, it is also necessary to mention that the average monthly prices on power market in Serbia are less than the set feed-in tariffs, until August 2021. Incentive prices defined by the state were, on average, twice the market prices. However, with the increase in market clearing prices on power exchange at the beginning of autumn 2021, it is possible to achieve a higher income compared to incentive prices. This certainly represents a positive sign for investors to invest in construction of cogeneration plants.

The directions of further research may include modeling the estimated values of future prices on gas power plant revenues, with the calculation of input energy costs.

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