ELECTRICITY CONSUMPTION AND MARKET PRICES IN SERBIA
Impact of the Pandemic of COVID-19

by

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The COVID-19 pandemic has begun in early 2020 and still continues to strongly affect the entire world delivering a significant global, shock, but varying across countries and commodity sectors. The Government of the Republic of Serbia has been adopting different measures to slow down the dissemination of the coronavirus, specifically nationwide lockdown in March and April 2020. Business activities have been reduced. The pandemic situation has changed the lifestyle as people are mostly staying home and working from home. This paper provides a review of unprecedented impacts of COVID-19 pandemic, with restrictions and lockdown in Serbia, on electricity sector at this stage of the crisis. The outcomes offer a contribution to the body of literature because limited research has been conducted on these relationships in case of Serbia. Sets of statistical indicators are used to analyze changes the electricity sector has been facing. Data visualization is used to compare developments during the pandemic with those of previous years. Our research and data-driven analysis of these impacts should improve the understanding of the techno-economic effects of unforeseen events, such as a pandemic, on the power system, scrutinizing if effects could be relatively short-lived or longer-lasting.

Key words: *pandemic COVID-19, electricity consumption, load profiles, day-ahead market, electricity prices*

Introduction

The SARS-CoV-2 coronavirus appeared in the Chinese province of Hubei at the end of 2019. Since then, the phenomenon has turned into a COVID-19 pandemic. In order to slow down the spread of the infection on the territory of the Republic of Serbia, the Government introduced a state of emergency on March 15, 2020 [1], which lasted until May 6 of the same year.

By declaring a state of emergency, the multimillion population was partially or completely banned from leaving their homes, many companies had to reduce production, many employees started working from home, many companies were closed, and students switched to distance learning. Such measure has affected almost all sectors [2].

The driving force of the economy is energy [3]. Some studies have described the influence of level of economic activity on electricity demand [4]. These sudden and comprehensive changes affected electricity consumption, increased the residential electricity demand and

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reduced electricity demand in business and industry, which was also reflected in the diagram of daily consumption and electricity prices in the wholesale market. Certain implications and trends have been identified [5].

Impact of COVID-19 on energy sector was elaborated as a matter of change in energy demand [6, 7], performance of markets [8], electricity generation fuel mix [9], rapid increase in renewable energy share in generation mix [10], GHG emissions [7], politics of sustainable energy transitions [11], energy security [10], transition in energy use [12], government policies [13], *etc.*

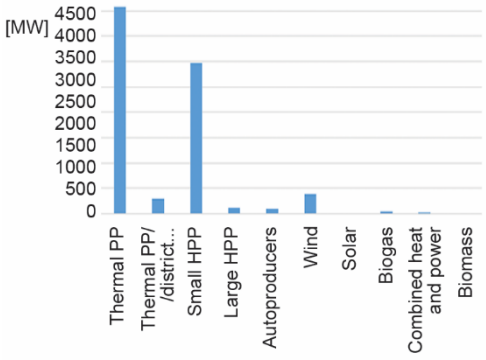

Figure 1. Power plants in Serbia – installed capacity

Before the pandemic, the electricity production in Serbia in 2019 was 34.8 TWh [14], of which thermal power plants – 66% and large hydro power plants – 28%. The total installed net capacity was 8054 MW, of which: thermal power plants 4079 MW, thermal power plants/district heating 297 MW, large hydro power plants 2969 MW, small hydro power plants 114.30 MW, autoproducers 108.267 MW, wind 397.96 MW, solar 10.99 MW, biogas 38.51 MW, combined heat and power 36.82 MW, and biomass 2.38 MW, fig. 1.

The new wind farms are expected [15]. There is a plan to phase out 622 MW (thermal power) units by the end of 2023 [16], but also to construct new plants to replace them [15]. The lignite is considered to be the most important source for decades to come [17].

As a signatory to the Energy Community Treaty (2005), Serbia is obliged to incorporate the EU Directive 2001/80/EC on the limitation of emissions of certain pollutants into the air from large combustion plants (and Directive 2010/75 / EU on industrial emissions) into its national law starting from 2018. There is a transitional period for the electricity sector to harmonize with the standards and define the time schedule for required investments. To this end, National Emission Reduction Plan was adopted in January 2020, according to which all power plants should comply with the obligations (established by Directive 2010/75/EU on industrial emissions) by 2027.

A particularity of electricity consumption in Serbia is the high share of the residential sector in total consumption, which is 47.65% [18], as a consequence of inefficient use of electricity and low energy performance of residential buildings. The local industry is highly energy intensive, the existing power system has a high degree of depreciation, the construction industry is slowly transitioning towards green best practice, the technical and commercial losses in electricity generation and transmission are high, *etc.*

Figure 2 shows the shares in final consumption by sectors in Serbia in 2019 and 2020.

Electricity consumption by sectors in 2019 [18] and 2020 [19] are given in tab. 1.

Serbia has lagged behind in the process of upgrading energy efficiency [20]. Energy efficiency in industry, transport, residential sector and other sectors needs to be increased. For the above reasons, the authorities have adopted several laws and bylaws that govern this area.

These features are reflected in typical hourly load profiles. A typical Serbia load profiles in 2019, for spring (April 17/21), summer (July 10/14), autumn (October 16/20) and

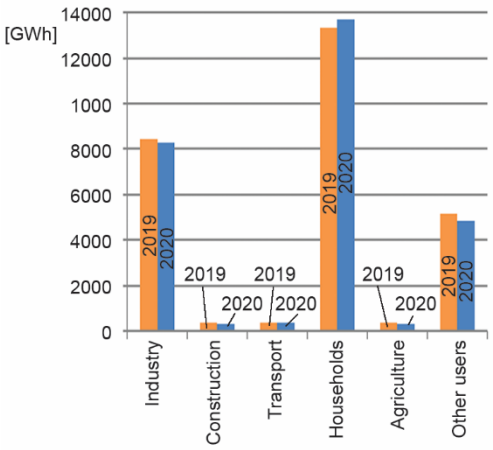

Figure 2. Shares by sectors in final consumption in Serbia

Table 1. Electricity consumption by sectors

Sector/Year	2019	2020
Industry	30.16	29.75
Construction	1.21	1.16
Transport	1.34	1.28
Households	47.65	49.20
Agriculture	1.22	1.19
other users	18.41	17.42

winter (December 25/29), weekdays and weekends, as well as in 2020, for spring (April 15/19), summer (July 08/12), autumn (October 14/18) and winter (December 23/27), are shown in figs. 3-6 [21]. Season and character of the days (weekday or weekend) most influence the electricity demand [22].

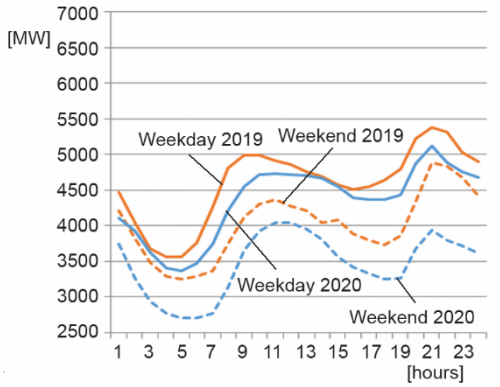

Figure 3. Daily load profile - April 2019/2020

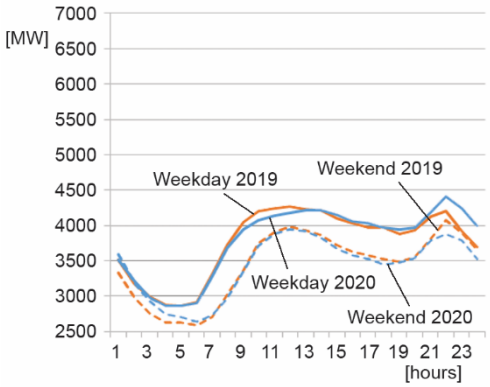

Figure 4. Daily load profile - July 2019/2020

During 2019 (pre-COVID), the maximum system load of approx. 6600 MW was recorded on December 31, and the minimum of approx. 2500 MW on July 14 [21].

The aim of this paper is to present detailed information, discussions on changes caused by COVID-19 and visualization of results, their consequences on the power system, as well as to be the basis for future research on the impact of emergency situations on the power system. It aims to analyze the impact of the pandemic on the electricity consumption, daily load profile and day-ahead prices, and the novelty of this paper is related to the sensitivities of electricity consumption and day-ahead prices to imposed restrictions and the change in the daily load profile. It should improve the consideration of the techno-economic effects of un-foreseen events, such as a pandemic, on the power system. Hopefully this analysis will be a

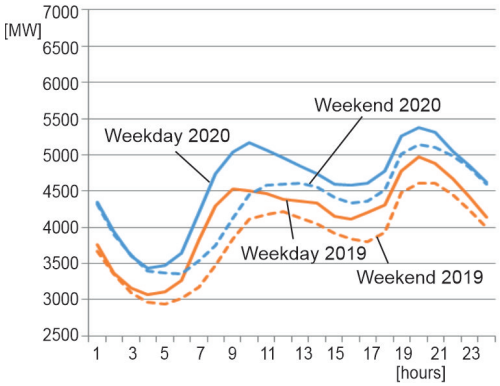

Figure 5. Daily load profile – Oct. 2019/2020

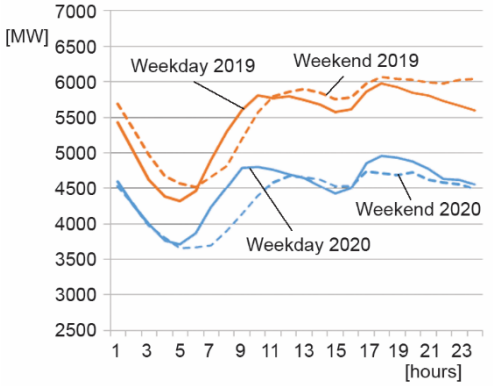

Figure 6. Daily load profile – Dec.2019/2020

valuable contribution for all market participants, highlighting the relevance of impacts, so, as a step further, this data-driven analysis of consumption trend changes due to the COVID-19 pandemic could help us formulate future trends as we can anticipate that more people will opt to work from home in the short-term and long-term future. For that purpose, a research has been done and data have been gathered.

Methodology and data

To carry out this study, we derive data related to the electricity consumption from the ENTSO-E Transparency Platform [23]. The time period that is covered is January 1, 2016 to December 31, 2020. Daily records for 2020 have been downloaded from the website, to be compared with those for the years 2016 to 2019. To determine the values in the previous four years the average load has been calculated for each hour for the years 2016–2019:

$$L_{\mathrm{av},h(2016-2019)} = \frac{\sum_{y=2016}^{2019} L_{h-y}}{4} \tag{1}$$

For this comparison, the Sundays of all years have been made to match, to calculate the difference.

The percentage of change in electricity consumption in 2020 respect the previous four years have been calculated in following way:

$$\mathrm{Change} = \frac{\left[\mathrm{Cons}_{(2020)} - \mathrm{Cons}_{\mathrm{av}(2016-2019)}\right]\cdot 100}{\mathrm{Cons}_{\mathrm{av}(2016-2019)}} \tag{2}$$

The source of the load profiles data is JSC EMS (EMS A.D. – Transmission System Operator in Serbia) Transparency platform [21].

Data corresponding to the electricity exports of Serbia to neighbouring countries have also been downloaded from the ENTSO-E Transparency Platform.

National temperature data is taken from https://www.timeanddate.com/weather/ [24].

Day-ahead power market prices made public by SEEPEX (Electricity Exchange based in Belgrade, Serbia) have been used [25].

Results

Electricity consumption and load profiles

Figure 7 shows the total electricity load in 2020 in relation to the average load in the period 2016-2019, as well as the difference between these values [23].

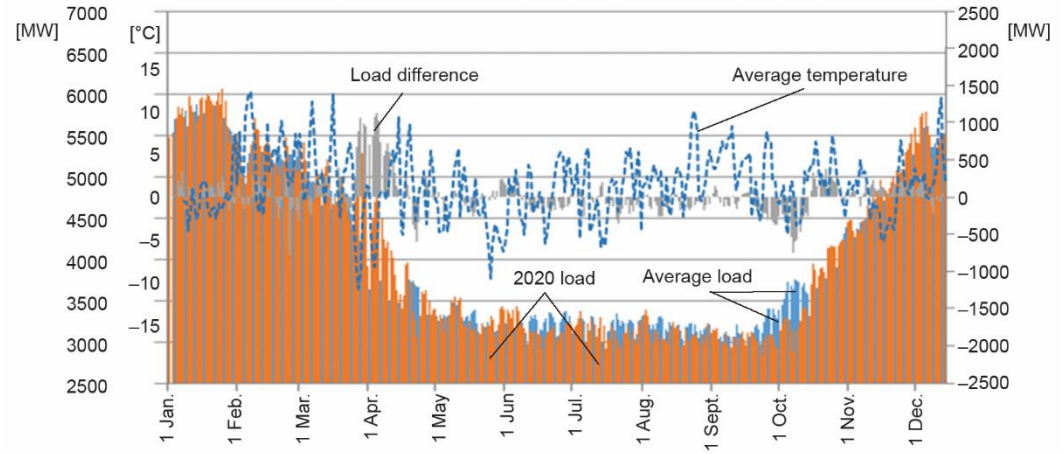

Figure 7. Electricity load in 2020 in relation to the average consumption in the period 2016-2019

The state of emergency in the Republic of Serbia was introduced on March 15, 2020, and lifted on May 6, 2020.

Figure 7 shows that before this period, the consumption curve for 2020 followed the consumption trend in the period 2016-2019. With the introduction of the state of emergency, the consumption curve for 2020 begins to de*via*te significantly from the average consumption in the period 2016-2019.

In order to better notice the phenomenon, fig. 8 compares consumption during the state of emergency in 2020 in relation to the relevant period in 2019 [21]. The Sundays of both years have been made to match, to estimate the difference in consumption for the weekdays and weekends respectively. The dates in the axis of the figure correspond to the year 2020.

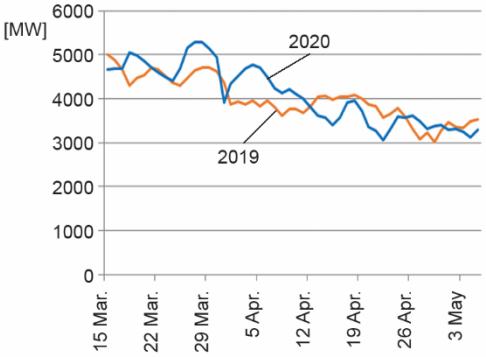

Figure 8. Comparison of electricity load in 2020 and 2019

In the first twenty days of the state of emergency, the average load was 250 MW higher than one in the same period in 2019 (as well as than the average for the same period in 2016-2019), primarily due to the cold period with temperatures lower than the average ones at this time of year. After that period, an almost constant decline in consumption began, compared to 2019 (and the average), of the order of about –200 MW with individual peaks of

–800 MW. As during this period there was a tightening of Government measures and a ban on going out, this decline in consumption is primarily due to the reduction of industrial (as well as other economic) activities. The work of transport companies, restaurants, shops, *etc.* was banned *i. e.* some industries have completely suspended their production during the state of emergency, and most of the economy has reduced its electricity consumption in line with current needs and capabilities.

Analysing the deviation of consumption during the state of emergency in 2020 compared to 2019, fig. 9, these measures led to a drop in electricity consumption in Serbia of about 3% during the state of emergency. There was an increase in consumption of about 3% in March, but during April a drop of about 2% and a drop of about 8% in May.

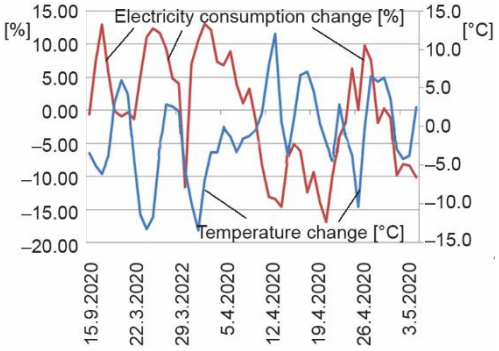

Figure 9. Change in electricity consumption [%] and temperature [°C] during the state of emergency compared to the corresponding period in 2019

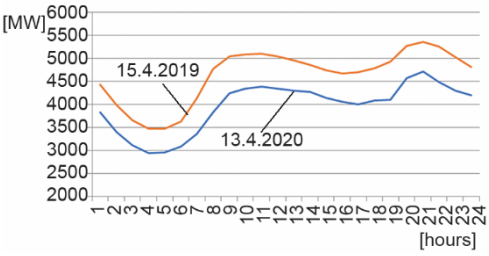

Figure 10. Consumption diagrams for April 15, 2019 and April 13, 2020

Since household consumption dominates (almost half of total electricity consumption in Serbia [18]) and households use 24% of the consumption for heating [26], periods with an increase in consumption are a consequence of low temperatures and the need to heat houses because during most of the day families stay in their households. As electricity covers 14% of the residential sector energy needs for heating (storage heaters, electric heaters, air conditioners [27]), the temperature has a direct effect on electricity demand, as can be seen in fig. 9. The increase in consumption is related to the period characterized by very low temperatures for that time of year.

The maximum drops in consumption were recorded around April 15, 2020 and April 22, 2020, which is related to the period with higher number of new cases of COVID-19 virus infection and probably higher impact on economy production.

It is interesting that the decline in consumption continued even after the lifting of the state of emergency, since the economy was slowly recovering in Serbia, that employees returned to work gradually, and that the virus is still present in the population.

The *shifting* change in the daily load profile has taken place due to the restriction measures. Figure 10 depicts daily load diagrams for April 15, 2019 (Monday) and for April 13, 2020 (Monday) [21]. For this comparison, the Mondays for both years have been made to match.

The reduction in electricity consumption has taken place at all hours of the day, probably due to continuous consumption reduction of closed businesses. Besides, certain changes in electricity consumption patterns can be recognized: morning consumption is growing slowly, evening maximum is shorter and lower than in the relevant period of the previous year.

A histogram of electricity consumption during a morning peak (between 8:00 and 14:00) in the period March 15 to May 06 in 2019, compared to the same period in 2020, is shown in fig. 11 [23]. The most likely values of the electricity consumption were around 4700-5000 MWh in 2019, but 4200 MWh in 2020, with obvious reduction of consumption in this period due to reduced industry activities.

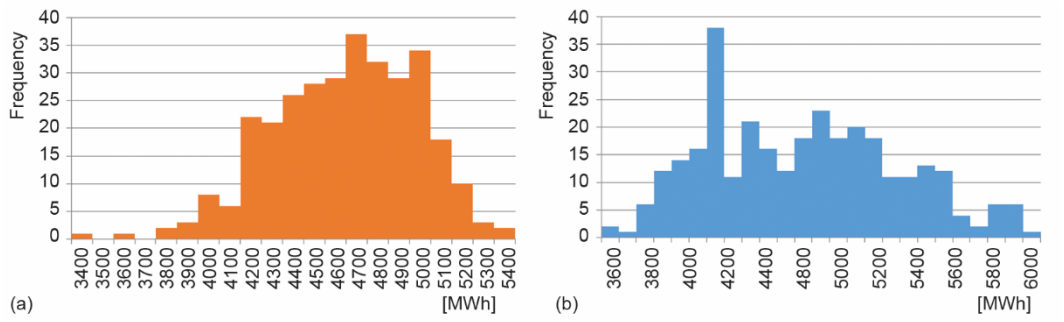

Figure 11. Histograms corresponding to electricity demand, between 8:00 and 14:00 from March 15 to May 06 in 2019 (a) and 2020 (b)

A histogram of electricity consumption during a night-time peak (between 19:00 and 23:00) in the period March 15 to May 06 in 2019, compared to the same period in 2020, is shown in fig. 12 [23]. During a night-time peak the household sector represents a significant part of the demand, and since families spend more time at home in 2020, the distribution of consumption became more even and higher, with obvious increase of consumption in this period.

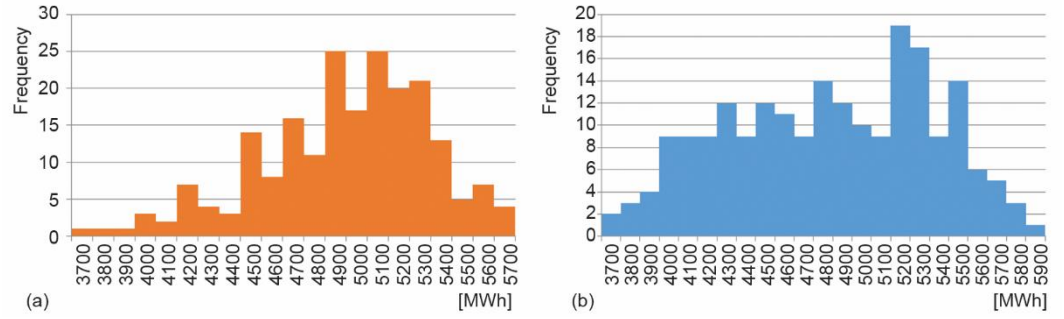

Figure 12. Histograms corresponding to electricity demand, between 19:00 and 23:00 from March 15 to May 06 in 2019 (a) and 2020 (b)

During the spring time, typically electricity is exported from Serbia. However, during the spring of 2020, the export of electricity to neighboring systems decreased by almost 12% compared to the previous year, fig. 13 [21], primarily due to reduced electricity needs in other markets due to the impact of the COVID-19 virus pandemic.

Figures 14(a)-14(d) visualize the electricity exports of Serbia to neighboring countries depending on the electricity price for the period 2017-2020 [21, 23]. There are trend lines with downward trends (negative slopes), for pre-COVID years, when increasing export correlate to decreasing electricity prices, due to lower demand for energy in the region at the time

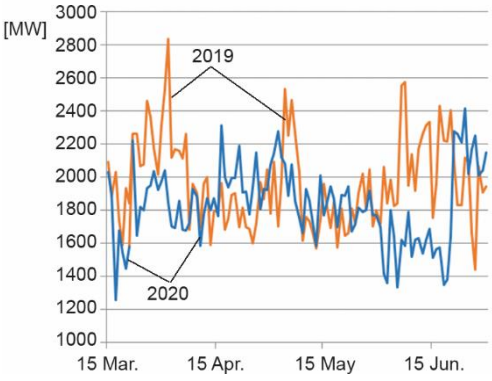

Figure 13. Electricity exports during lockdown in 2020 compared to the corresponding period in 2019

when export was more available. However, 2020 is characterized by an opposite *irregular* trend, with positive correlation coefficient. The increasing export corresponds to increasing electricity prices. Unlike previous years (characterized by dominant exports in usually the cheapest Q2 period) the focus of export activities in 2020 (almost two times higher than import) was between August and October, months with higher electricity prices.

The reduction of electricity consumption in Serbia, as well as the decline in demand for electricity in neighbouring electricity markets, had direct consequences on the reduction of electricity generation in Serbia in that period.

Electricity day-ahead prices

The SEEPEX started operating in 2016, with a day-ahead market. The SEEPEX has brought a market with hourly resolution (where hourly and block products can be traded). The products are standard contracts for the physical delivery within the Serbian power system. This market determines the "system marginal price" at which electricity is traded.

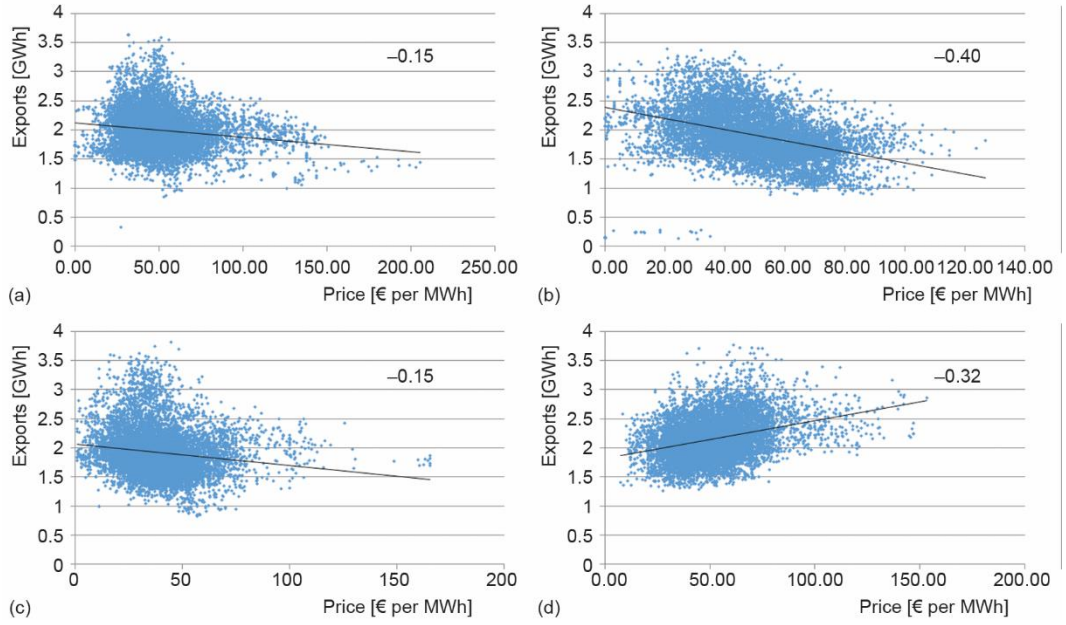

Figure 14. Correlation among total electricity exports of Serbia and electricity prices; (a) 2017, (b) 2018, (c) 2019, and (d) 2020

The volume of energy traded on the day-ahead SEEPEX market in (pre-COVID) 2019 was 2.53 TWh [28]. The share of electricity which was traded on the power exchange in

comparison to the electricity volume which was delivered to all end-users was 8.7% while 18.7% is the power exchange share in comparison to electricity volume delivered to end-users supplied in the open (retail) market. On the wholesale market, the power exchange share amounts to 22.7% and the over-the-counter contracts refer to 77.3%. The wholesale electricity market was mainly based on trade between traders/suppliers (apart from the state-owned power utility, no large independent electricity producers). The traders (including the power utility) optimise their portfolios by trading on the power exchange (offering excess volumes to SEEPEX).

During the COVID-19 pandemic, SEEPEX prices began to fall sharply, both in peak and non-peak hours, fig. 15 [25].

This phenomenon is primarily a consequence of reduced consumption in Serbia. In addition, business issues among Saudi Arabia, USA and Russia related to COVID-19 pandemic had a strong impact on world energy, reducing the demand for oil and natural gas [29]. The price of BRENT oil fell from 60+ $ per barrel to a minimum value of 9.12 $ per barrel on April 21, 2020 [30]. The TTF (a benchmark hub for natural gas prices in Europe) spot price fell to cca 37 € per 1000 m^3, the lowest since the start of the trade on this hub [31]. The combination of local and global effects led to a large drop in electricity prices, which affected prices not only in the short but also in the medium term, fig. 16.

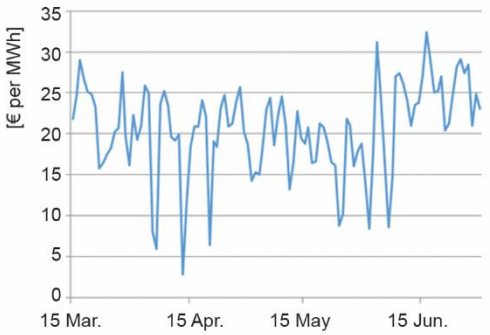

Figure 15. The SEEPEX prices during lockdown

Figure 16 shows the price at SEEPEX 2020 compared to previous years. Especially, on April 13, 2020 there was a decrease in the daily average price of 37 € per MWh compared to the corresponding period of the previous year [25].

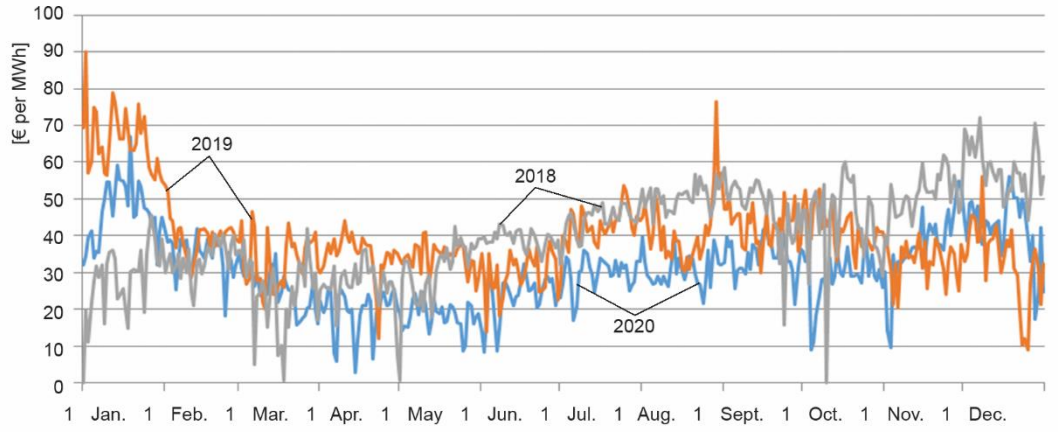

Figure 16. The SEEPEX prices comparison among 2018, 2019 and 2020

During the state of emergency, fig. 17, the average price on SEEPEX fell to an extremely low level: 27.09 € per MWh on weekdays and 20.34 € per MWh on weekends.

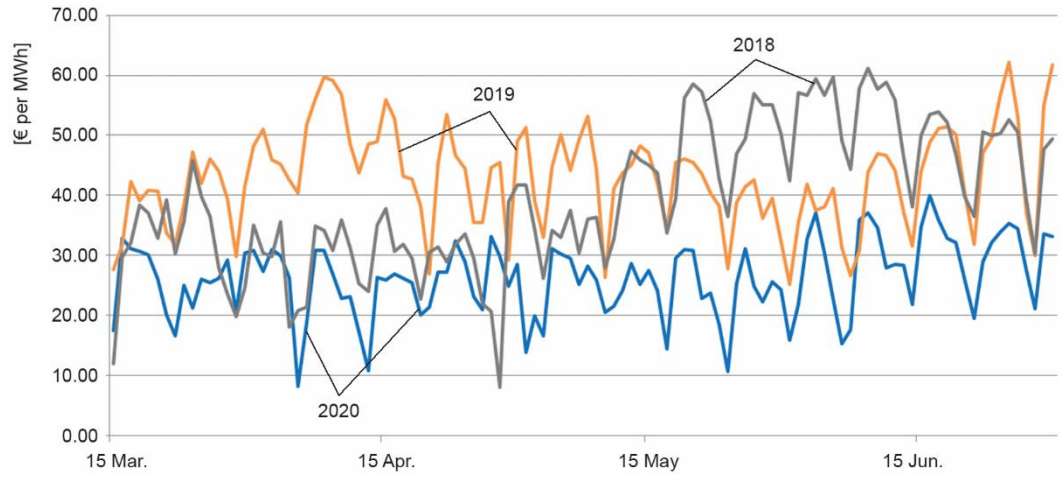

Figure 17. Average daily (baseload) SEEPEX price in 2018, 2019, and 2020

Discussion and conclusions

This paper conducts assessment of the COVID-19 pandemic impact on Serbian electricity consumption and electricity market prices as limited research has been previously conducted on these relationships (in case of Serbia).

The state of emergency and other measures to prevent dissemination of virus led to a drop in electricity consumption in Serbia of approx. 3% during that period (March 15 to May 5, 2020). The consumption first increased 3% in the second half of March due to cold weather, but then dropped 2% during April and up to 8% in a few days of May, due to drop of economy activity. Besides specific measures, consumption was very affected by the weather, which was very cold at the beginning of the state of emergency, but after that the temperature was closer to average. Therefore, consequences of specific measures didn't affect the total consumption very much, as it was the case in some other countries. No major problem was observed in the operation of power system, which demonstrates its ability and readiness to deal with such situations (technical aspects).

In the household category, consumption increased during the state of emergency, but among industrial consumers, some branches had large production downtimes and consumption drop and others without significant production and consumption oscillations. During the state of emergency, a significant drop in the electricity export to the neighboring systems was recorded, primarily due to the drop in demand.

The reduction in electricity consumption, along with global impacts, as well as the reduction in exports in the traditional months, have had direct effects on the day-ahead electricity market. As a consequence, prices on SEEPEX fell approx. 38% during the period March-May 2020 compared to the corresponding period in 2019, reaching a value in some hours of almost 0 € per MWh.

Unlike 2020 when the wholesale electricity prices reached the lowest level, during second half of 2021 they are at an all-time high (baseload spot prices in Serbia and the region have stabilized at around 200 € per MWh [25]). The causes are numerous. Not only renewed demand for energy, but also the rising price of natural gas (reaching a historical maximum), the rising price of CO_2 permits, *etc.* Some reserve coal-fired plants (power and district heating

ones) have been activated, the fossil fuel use implies CO_2 emission permits and EU introduced a reduction in the number of the permits, so their price has been doubled since the end of 2020 (cca 30 € per tCO_2 in December 2020 *vs*. cca 70 € per tCO_2 in January 2021 [32]).

In addition, the price of electricity is affected (through the price of natural gas) by the situation regarding the construction of the "North Stream 2" gas pipeline, which should connect Europe with Russian Federation. Doubts about that issue lead to an increase in the price of natural gas (natural gas futures contracts for 2022 steadied around 560 € per 1000 m^3 in November 2021 [33]). Although it is expected that this issue will be resolved and that the growth of natural gas prices will stop, electricity prices are not expected to fall to the pre-COVID level.

As this is an evolving situation, these findings will need to be updated periodically and could be extended to other countries and/or regions to obtain more comprehensive conclusions.

All crises, including this one caused by the COVID pandemic, inevitably lead to the creation of new circumstances even when the crisis is over. In this respect, the economy recovered fairly quickly, energy demand returned to pre-COVID level, and prices reached unprecedented levels that no one expected (which affect the economy as a whole).

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