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Impacts of COVID-19 and distance education on electricity consumption in a university campus: Gümüşhane University example

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ABSTRACT

In March 2020, the World Health Organization announced the Corona Virus Disaase (COVID-19) to be a global pandemic. Then, many countries have implemented some restrictions to decrease mobility and to slow down the spread of the pandemic. Because of the COVID-19 restrictions, some business activities have been suspended, distance education has been adapted instead of face-to-face education and working at home models have been implemented. Thus, these processes have led to impacts on the electricity sector in terms of both generation and consumption. This study investigates the impacts of the COVID-19 pandemic restrictions and distance (online) education on the electricity consumption of Gümüşhane University's main campus (Gümüşhanevî Campus), which is located in the Gümüşhane central province. To show the effects of lockdown and online education, due to the COVID-19 pandemic on energy consumption, the energy consumption data of the campus for January 1st, 2019 to December 31st, 2020 have been analyzed. First, the energy consumption profile of each year has been analyzed monthly to present the similarity of the periods before the COVID-19. Then the lockdown period has been compared with last year's same education period. The analysis results have been interpreted in terms of the reducing of consumption and drawn power profile. The results indicate the dramatic power consumption reduction of the main campus and bring forward to discuss online education options for some courses which can be appropriate through distance education after the COVID-19 pandemic end.

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1. INTRODUCTION

COVID-19, in other words, Coronavirus Disease, has been defined by World Health Organization (WHO) as the Novel Coronavirus 2019 [1]. According to statements of the WHO, which have been declared on January 30, 2020, COVID-19 is a dangerous and threatening disease. Then, the COVID-19 outbreak was declared a pandemic by WHO on March 11, 2020 [2]. As the COVID-19 is a highly contagious disease and its clinical symptoms include difficulty in breathing, fatigue, myalgia, and dyspnea, and would lead to death [3-4], the governments have taken some precautions. These precautions include some restrictions to decrease mobility. Because of the COVID-19 restrictions, some business activities have been suspended, distance education has been adapted instead of face-to-face education, and work at home models have been implemented. Thus, these processes have led to impacts on the electricity sector in terms of both generation and consumption [5-7].

In the literature, the effects of COVID-19 and distance education on the energy consumption of university campuses have been investigated. Gaspar et al. have assessed the impact of the COVID-19 lockdown on the energy consumption of academic buildings at the Polytechnic University of Catalonia- Barcelona Tech (UPC) [14]. They have analyzed the same periods of 2020 and 2021 from an energy consumption point of view. The results indicated that when the buildings were empty between the 16/03/2020 and 17/05/2020 periods, the energy consumption in classrooms, offices, and laboratories decreased by only 53.1%. It means that the academic buildings were used approximately 46.9% of their typical consumption even during the strict lockdown [14]. Filimonau et al. [15] have analyzed the carbon footprint of Bournemouth University in the United Kingdom during the COVID-19 lockdown period (April–June 2020) and they have compared it to the respective period in previous years. Their analysis results reveal that the university's carbon footprint has decreased by around 30% during the lockdown period.

[C]*Initial version of this article was presented in the International Conferences on Engineering and Natural Sciences (IOCENS'21) held on July 5-7, 2021, in Gümüşhane, TURKEY. It was subjected to a peer-review process before its publications.*

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However, the interesting point is that although the overall carbon footprint of the university has decreased during the lockdown period, their evidence claims that blended teaching may be less carbon beneficial than fully online or fully on-campus teaching [15]. Chihib et al. have investigated the impact of the COVID-19 pandemic on energy use at the University of Almeria (Spain) [16]. Their study shows that the presence of students and staff plays a key role in energy consumption. They reported that during the first two months (January and February) both patterns of 2019 and 2020 years were identical until March when the lockdown is due to the COVID-19 outbreak in Spain. Also, their study noted that the energy consumption of the library buildings decreased by 44%, and the teaching and seminary room electricity consumption decreased by 28% during the March-August period in 2020 compared to the same period of 2019 [16]. Doğanşahin and Demirarslan have assessed the natural resources and energy consumption of Artvin Çoruh University (Turkey). They have reported that electricity consumption of the main campus has waned 48.1% for March 2020-February 2021 period compared to the March 2019-February 2020 period [17].

In Turkey on March 12, 2020, after the WHO declared COVID-19 is a pandemic on March 11, 2020, the Turkish Government announced some precautions which include suspending face-to-face teaching and education for three weeks in universities. Then, on March 18, 2020, The Council of Higher Education (YÖK) decided to initiate distance education as of Monday, March 23, 2020 [8]. The timeline of the COVID-19 pandemic and some of the restrictions due to the COVID-19 in Turkey between 11 March 2020 and 31 October 2020 are given in Table 1.

Table 1. Timeline of COVID-19 and some of the restrictions in Turkey between 11 March 2020 and 31 October 2020.

Date	*Events/Restrictions*
1 February 2020	All the flights from China were stopped.
11 March 2020	The first COVID-19 case was recorded.
12 March 2020	It was announced that all educational activities were suspended for three weeks after March 16.
17 March 2020	The first death occurred due to COVID-19 was announced.
21 March 2020	Curfew restrictions were imposed on people aged 65 and over.
23 March 2020	Distance education was started.
3 April 2020	Travel restrictions: entrance and exit by the vehicles were restricted with some exceptions in 30 metropolitans and one province.
3 April 2020	Curfew restrictions were expanded to include people who are under 20 years old.
4 May 2020	It was announced that the return to normal will happen gradually.
1 June 2020	The travel restriction between cities was upheld.

COVID-19 cases were recorded starting from March 11, 2020, and it increased since then yet some periods have peaked. The total number of COVID-19 cases and daily COVID-19 cases in Turkey between 11 March 2020 and 31 October 2020 period are presented in Figure 1 and Figure 2, respectively [9].

After the suspension of face-to-face teaching and education for three weeks at universities in Turkey, most university students went back home including Gümüşhane University students starting from March 13, 2020 [10].

Due to the COVID-19 restrictions for the 2019-2020 spring semester, 2019-2020 summer school, and 2020-2021 fall and spring semesters have been implemented via distance education at Gümüşhane University. In this paper, the impacts of distance education on electricity consumption in the Gümüşhane University campus have been handled by analyzing electricity consumption data of the main campus named Gümüşhanevi Campus. To this goal, firstly, some information including the number of academic buildings and students in the Gümüşhanevi Campus are presented in the following tables and figures. Gümüşhanevi Campus includes academic units, administrative units, buildings, dormitories, dwelling-houses, mosques, social facility buildings, gymnasium buildings, swimming pool, congress center, basketball, football, tennis, and volleyball courts. The map of the campus is presented in Figure 3. The buildings which are given by numbers on the map are listed by classifying in Table 2.

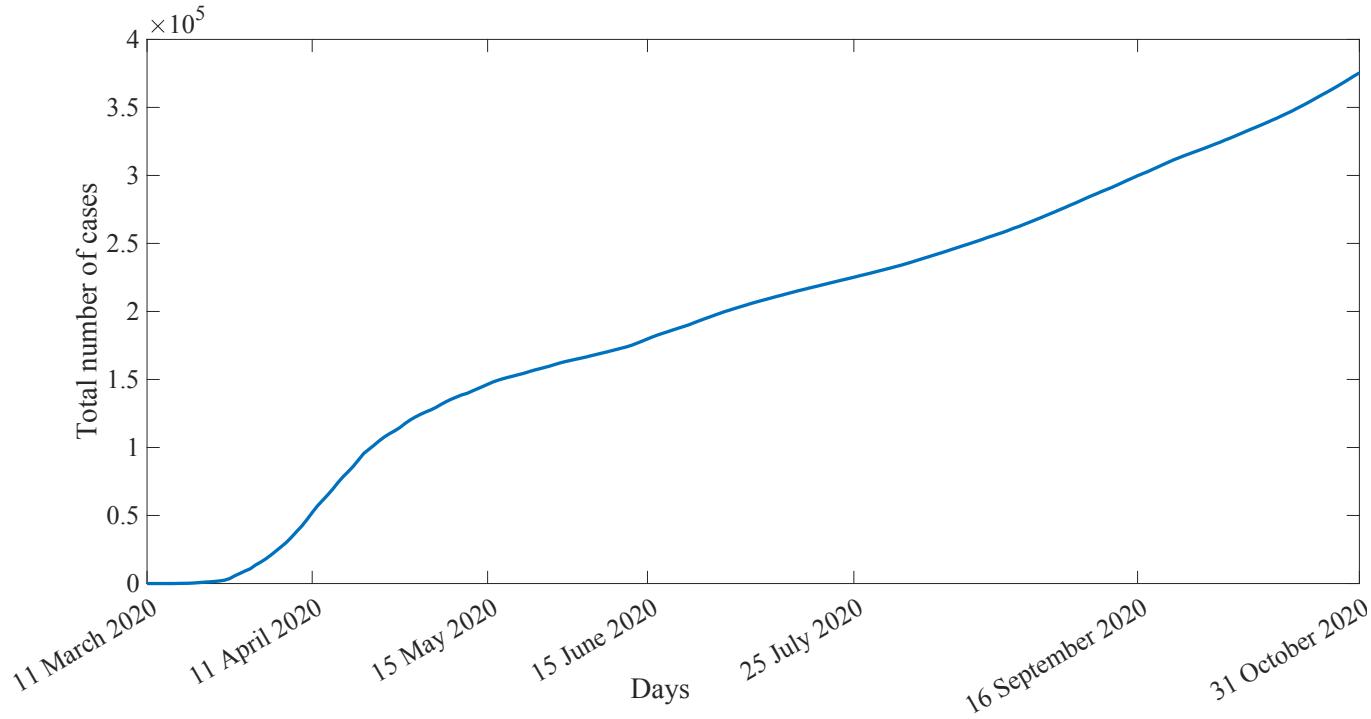


Fig. 1. The cumulative number of COVID-19 cases in Turkey between 11 March 2020 and 31 October 2020.

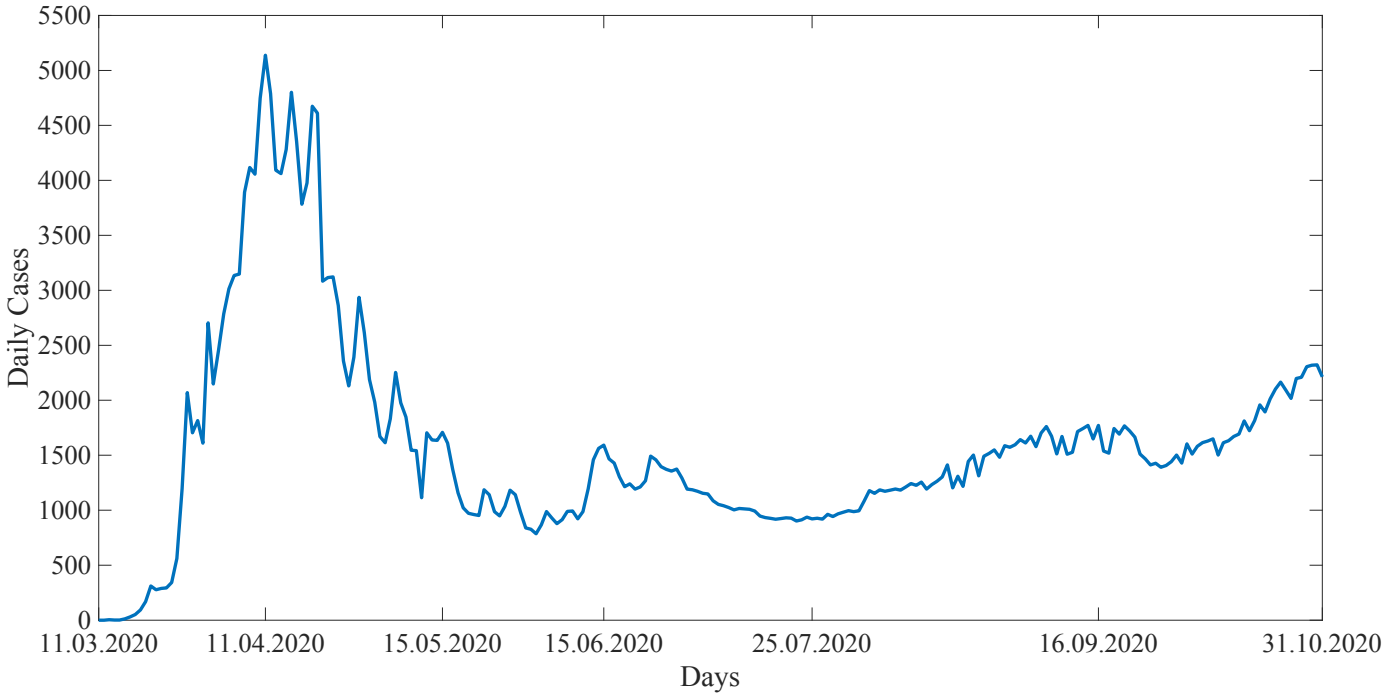


Fig. 2. The daily number of COVID-19 cases in Turkey between 11 March 2020 and 31 October 2020.

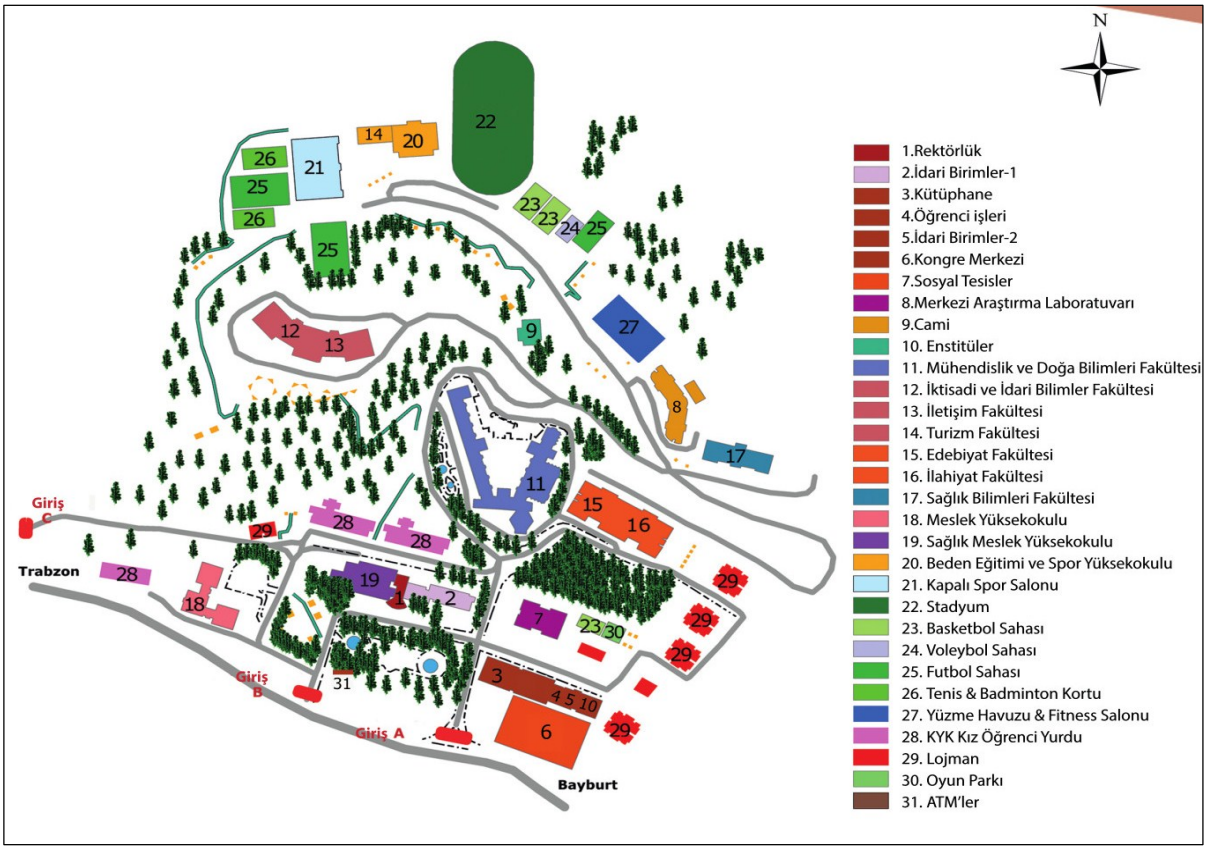


Fig. 3. Gümüşhanevi campus map [11].

Table 2. The buildings which are given by numbers on the campus map are shown in Figure 3.

Numbers	*Building/Structure/Area Names*
1,2,4,5	Administrative buildings
3	Library
6	Congress Center
7	Social Facility Building
8	Laboratories
9	Mosque
10,11,12,13,14,15,16,17,18,19,20	Academic buildings
21	Gymnasium Buildings
22,23,24,25,26,27	Swimming pool, basketball, football, tennis, volleyball courts
28	Dormitories
29	Dwelling-Houses
30	Playground
31	ATMs (Automated Teller Machines)

To analyze the electricity consumption in kWh per student, the total number of the Gümüşhane University students has been taken into account. The total number of registered students was 15,496 and 15,799 at the Gümüşhanevi Campus in 2019 and 2020, respectively [12].

This study presents the effects of distance education on the electricity consumption of the Gümüşhanevi campus. In this regard, 2019 and 2020 electricity consumption are analyzed and compared with each other. In section two materials and methods are introduced. section three presents the analysis results and chapter four involves discussions and a conclusion.

2. MATERIAL AND METHODS

In this study, the effect of distance education due to the COVID-19 pandemic on electricity consumption has been analyzed for the Gümüşhanevi Campus. This campus includes two transformers to provide electricity to the buildings of faculties and schools. Therefore, consumption data of the transformers which are logged by their energy meters have been aggregated. Let P be a vector of hourly consumed power is given in Equation (1).

$$P = [P_1 \ P_2 \ P_3 \ P_4 \ \dots \ P_t], t = 1,2,\dots,24 \quad (1)$$

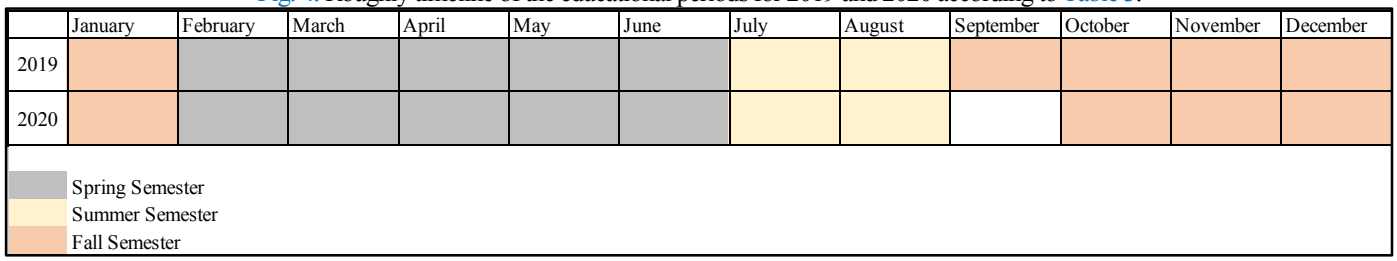
While, $t \in T, T = 1h$ for a single day such that T = {1h, 2h,· · ·, 24h}, the following introduced analyses have been performed.

To compare normal education period and distance education from point of view of electrical energy consumption, Table 3 has been used. When examining the dates of each semester of the year, as in Figure 4, which shows a timeline of the educational periods, can be constituted. The following introduced semester-based analyses have been performed by considering Figure 4. It is noted that all analyses have been performed based on the student numbers.

Table 3. The academic calendar for each semester in 2019 and 2020 [13].

Semester	**Year**	
Spring Semester	*2019*	*2020*
Start of semester courses	4.02.2019	10.02.2020
End of the semester courses	17.05.2019	22.05.2020
End day of the semester exams (include reset exams)	14.06.2019	26.06.2020
End day of the graduation exams	25.06.2019	4.07.2020
Fall Semester		
Start of semester courses	16.09.2019	5.10.2020
End of the semester courses	27.12.2019	15.01.2020
End day of the semester exams (include reset exams)	25.01.2020	13.02.2021
End day of the graduation exams	1.02.2020	20.02.2021
Summer Semester		
Start of semester courses	24.06.2019	24.06.2019
End of the semester courses	9.08.2019	21.08.2020
End day of the semester exams	24.08.2019	28.08.2020
End day of the graduation exams	29.08.2019	4.09.2020

Fig. 4. Roughly timeline of the educational periods for 2019 and 2020 according to Table 3.



2.1. Analysis of Monthly Total Electricity Consumption in kWh per Student

This analysis comprises the monthly total electricity consumption amount of the campus in kWh per student for 2019 and 2020. Because the Turkish electricity tariff system has three different time periods, the energy meter of the transformers records the consumption in those periods, namely daytime (06:00-17:00), peak time (17:00-22:00), and nighttime (22:00-06:00). Hence, this analysis was also performed for these periods. In this context, four indices ($CpS(m)$, $CpS_{dt}(m)$, $CpS_{pt}(m)$, $CpS_{nt}(m)$) have been created and have been calculated by the following equations.

$$C(m) = \sum_{d=1}^{D_m} \sum_{t=1}^{24} P(t).t \quad (2)$$

$$CpS(m) = \frac{C(m)}{sn} \quad (3)$$

$$C(m)_{dt} = \sum_{d=1}^{D_m} \sum_{t=6}^{17} P(t).t \quad (4)$$

$$CpS_{dt}(m) = \frac{C(m)_{dt}}{sn} \quad (5)$$

$$C(m)_{pt} = \sum_{d=1}^{D_m} \sum_{t=17}^{22} P(t).t \quad (6)$$

$$CpS_{pt}(m) = \frac{C(m)_{pt}}{sn} \quad (7)$$

$$C(m)_{nt} = \sum_{d=1}^{D_m} \left(\sum_{t=22}^{24} P(t).t + \sum_{t=0}^{6} P(t).t \right) \quad (8)$$

$$CpS_{nt}(m) = \frac{C(m)_{nt}}{sn} \quad (9)$$

where,

m : Month, m=1,2,…,12
sn : Student number
t : Time (hour) of the day
$P(t)$: Total recorded consumed power at t[th] hour (kW)
d : day of the month
D_m : Total day of the month
$C(m)$: Electricity consumption in the m[th] month as kWh
$CpS(m)$: Monthly total electricity consumption in kWh per student for m[th] month
$C(m)_{dt}$: Electricity consumption during the daytime period in the m[th] month as kWh
$CpS_{dt}(m)$: Monthly total electricity consumption in kWh in the daytime per student for m[th] month
$C(m)_{pt}$: Electricity consumption at the peak period in the m[th] month as kWh
$CpS_{pt}(m)$: Monthly total electricity consumption in kWh at the peak time per student for m[th] month
$C(m)_{nt}$: Electricity consumption at the nighttime period in the m[th] month as kWh
$CpS_{nt}(m)$: Monthly total electricity consumption in kWh at the nighttime per student for m[th] month

The monthly total electricity consumption amount of the campus in kWh per student for each semester has been calculated through Equation (3) by considering the months of the semester.

2.2. Analysis of Yearly Total Electricity Consumption in kWh per Student

To get yearly total electricity consumption in kWh per student following equations have been applied for 2019 and 2020, then the following equations have been used.

$$CpS_{dt} = \sum_{m=1}^{12} CpS_{dt}(m) \quad (10)$$

$$CpS_{pt} = \sum_{m=1}^{12} CpS_{pt}(m) \quad (11)$$

$$CpS_{nt} = \sum_{m=1}^{12} CpS_{nt}(m) \quad (12)$$

$$CpS = CpS_{dt} + CpS_{pt} + CpS_{nt} \quad (13)$$

where,

m : Month, m=1,2,…,12
CpS_{dt} : Total electricity consumption in kWh at the daytime period per student in a year
CpS_{pt} : Total electricity consumption in kWh at the peak period per student in a year
CpS_{nt} : Total electricity consumption in kWh at the nighttime period per student in a year
CpS : Total electricity consumption in kWh per student in a year

2.3. Analysis of Consumption Profile Change When Announced That All Educational Activities Suspended

This analysis presents the electricity consumption profile change when all educational activities were suspended by the government. This analysis shows the electricity consumption of the main campus between March 2, 2020, and March 29, 2020.

3. ANALYSIS OF RESULTS

3.1. Analysis Results of Monthly Total Electricity Consumption in kWh Per Stud

Figure 5 presents the monthly total electricity consumption of the Gümüşhanevi Campus in 2019 and 2020. As is shown from the figure, monthly electricity consumption was decreased dramatically during the lockdown and distance education period when compared to 2019. The changes in electricity consumption as percentages are shown in Table 4. A comparison of the monthly electricity consumption between 2019 and 2020 shows that the consumption was reduced varying from 21% to 51% as shown in Table 4. But the most reduction in consumption occurred in April 2020 by 51% compared to the same month of 2019.

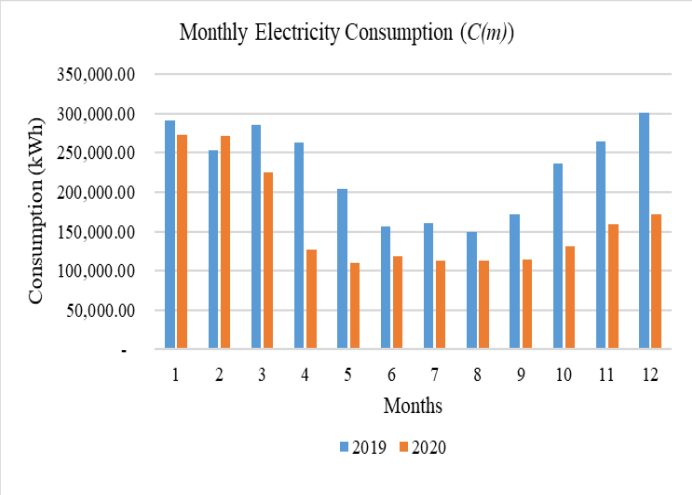


Fig. 5. Monthly total electricity consumption of the campus in 2019 and 2020.

Table 4. The changes in electricity consumption as a percentage during lockdown and distance education period when compared to 2019.

Months of 2020	*% Change in Electricity Consumption*
March	-21
April	-51
May	-46
June	-24
July	-29
August	-25
September	-34
October	-44
November	-40
December	-43

Figure 6 shows the monthly total electricity consumption per student on the campus in 2019 and 2020. As is shown in Figure 6 there is a dramatic decrease in the $CpS(m)$ after distance education. In particular, when compared to 2019, it can be seen from the data given in Figure 6, between the date of 23 March 2020 when distance education started and 1 June 2020 when travel restrictions have been removed, energy consumption per student was reduced by 51% and 46% in April and May, respectively.

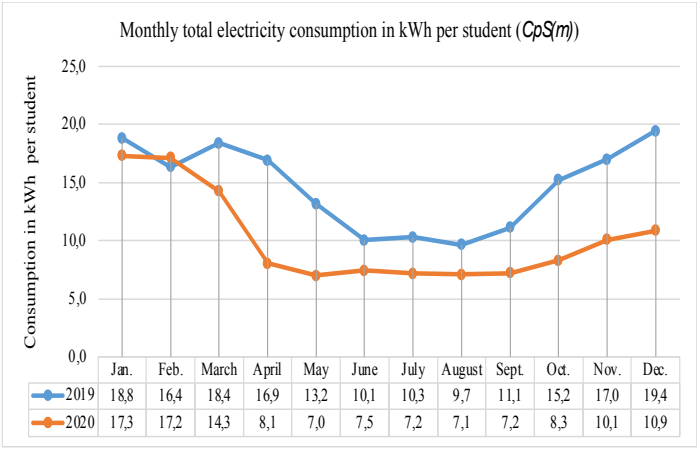


Fig. 6. Monthly total electricity consumption per student of the campus in 2019 and 2020.

The following figures (Figure 7, Figure 8, Figure 9) show the changing of $CpS_{dt}(m)$, $CpS_{pt}(m)$ and $CpS_{nt}(m)$, which are monthly total electricity consumption in kWh per student for $\boldsymbol{m^{th}}$ month at the daytime period, the peak time period, and the nighttime period respectively, in 2019 and 2020. As it can be seen from the data given in Figure 7, there is a significant reduction in electricity consumption per student during the daytime period. Most of the reduction of the consumption per student during the daytime period has occurred in April by 61% compared to 2019. From the data given in the table in Figure 8, it is apparent that there is a significant reduction in electricity consumption per student at the peak period, as well. However, most reduction of the consumption per student during the peak period has happened in April by 56.2 % compared to 2019. Similarly, there is a significant reduction in the electricity consumption per student during the nighttime period for all months of 2020 when compared to 2019 as shown in Figure 9. The most reduction in the consumption per student during the nighttime period has occurred in April by 35.2 % compared to 2019.

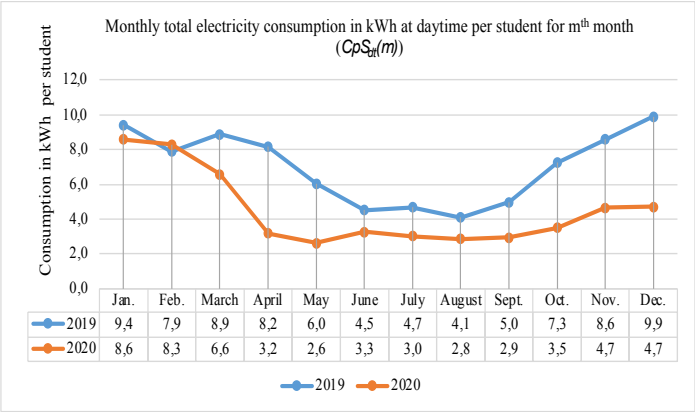


Fig. 7. Monthly electricity consumption aingt the daytime period per student of the campus in 2019 and 2020.

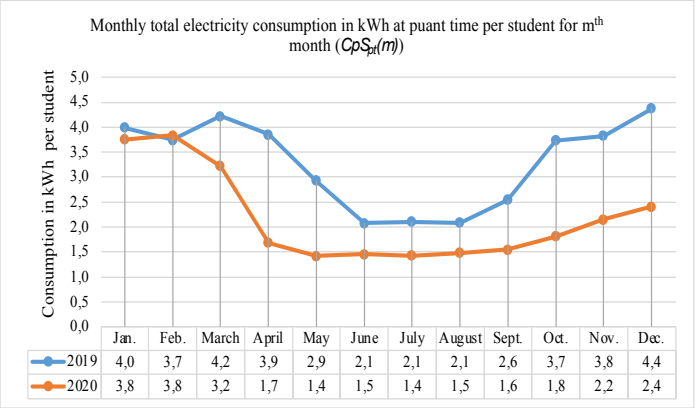


Fig. 8. Monthly electricity consumption at the peak period per student of the campus in 2019 and 2020.

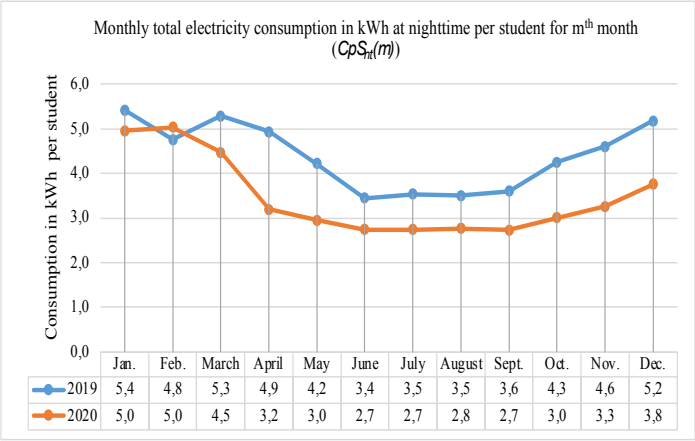


Fig. 9. Monthly electricity consumption dur the nighttime period per student of the campus in 2019 and 2020.

3.2. Analysis Results of Yearly Total Electricity Consumption in kWh per Student

The total electricity consumption in kWh at the daytime period per student in a year (CpS_{dt}), total electricity consumption in kWh at the peak time period per student in a year (CpS_{pt}), total electricity consumption in kWh at the nighttime period per student in a year (CpS_{nt}) and total electricity consumption in kWh per student in a year (CpS) indices have been calculated and tabulated in Table 5. As it can be seen from the Table 5, electricity consumption per student in 2020 was reduced by 35.8%, 33.7%, and 21.1% during the day, the night, and the peak times, respectively, compared to 2019. Total electricity consumption per student has been reduced by 30.9% compared to 2019, as well.

Although there is a significant reduction in the electrical power consumption of the campus, it should be noted that more energy would be consumed in the residences. So, in point of the view of the distribution company the above-mentioned power consumption reduction may cause on the distribution systems a rebound effect. Therefore, this rebound effect must be considered by the distribution system operator to provide stable operation of the electrical grid.

Table 5. CpS_{dt}, CpS_{pt}, CpS_{nt} and CpS indices in 2019 and 2020.

Indices	*Value in kWh per student (kWh/student)*		*Change in 2020 compared with 2019 (percentage)*
	2019	*2020*	
$\boldsymbol{CpS_{dt}}$	84.4	54.2	-35.8
$\boldsymbol{CpS_{pt}}$	39.5	26.2	-33.7
$\boldsymbol{CpS_{nt}}$	52.7	41.6	-21.1
$\boldsymbol{CpS}$	176.62	122.01	-30.9

3.3. Analysis of the Results of Monthly Total Electricity Consumption in kWh per Student for Each Semester

Analysis of the results of monthly total electricity consumption in kWh per student for Spring, Summer, and Fall semesters are presented in Figure 10, Figure 11, and Figure 12 as a bar chart, respectively. From these charts, it can be seen that there is a significant reduction in energy consumption in each semester compared to 2019. However, it can also be noted that the consumption amount profiles (monthly trends) are almost the same for 2019 and 2020 except for the magnitude of the consumption. This can be interpreted that although distance education was implemented during the studied period, the academicians and officers have come to the campus and other electrical demands are the same.

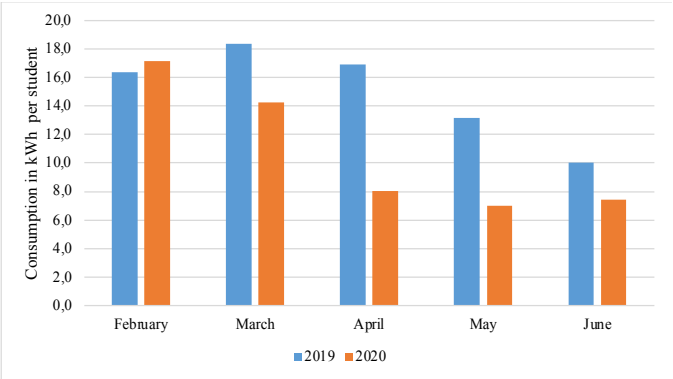


Fig.10. Change of *CpS* in the spring semester.

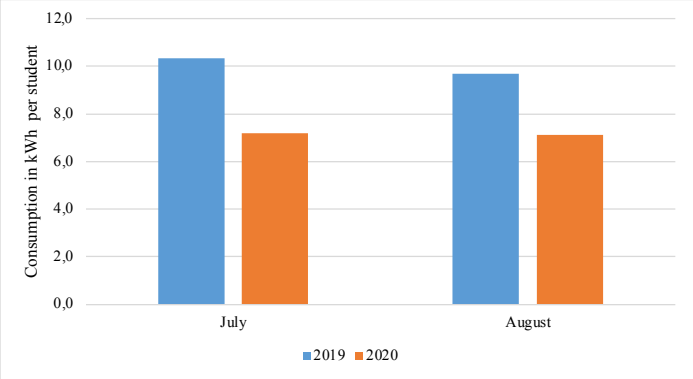


Fig.11. Change of *CpS* in the summer semester.

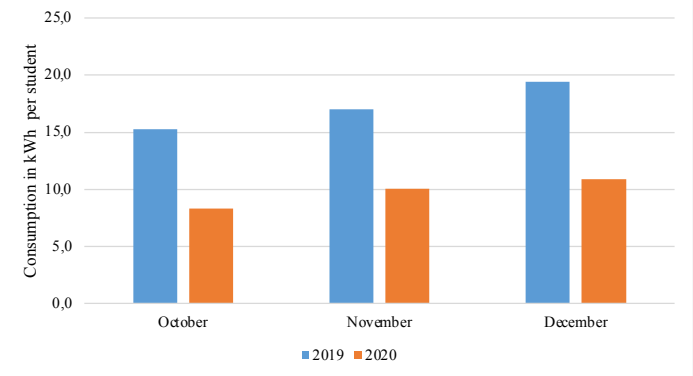


Fig.12. Change of *CpS* in the fall semester.

3.4. The Consumption Profile Change When Announced That All Educational Activities Suspended

In this part, the consumption profile change of the campus due to the suspending educational activities has been exhibited. Figure 13 presents the time series of electricity consumption between March 2, 2020, and March 29, 2020. These dates have been selected particularly to show changes in the time series of the total consumed power of three phases, between two weeks before and two weeks after suspending the face-to-face education announcement. The line graph of the power demand - time series shows the weekly similarity of the demand profile before the announcement which suspends all educational activities. In addition, it can be seen from the graph that there is a gradual decrease in consumption after March 16, 2020.

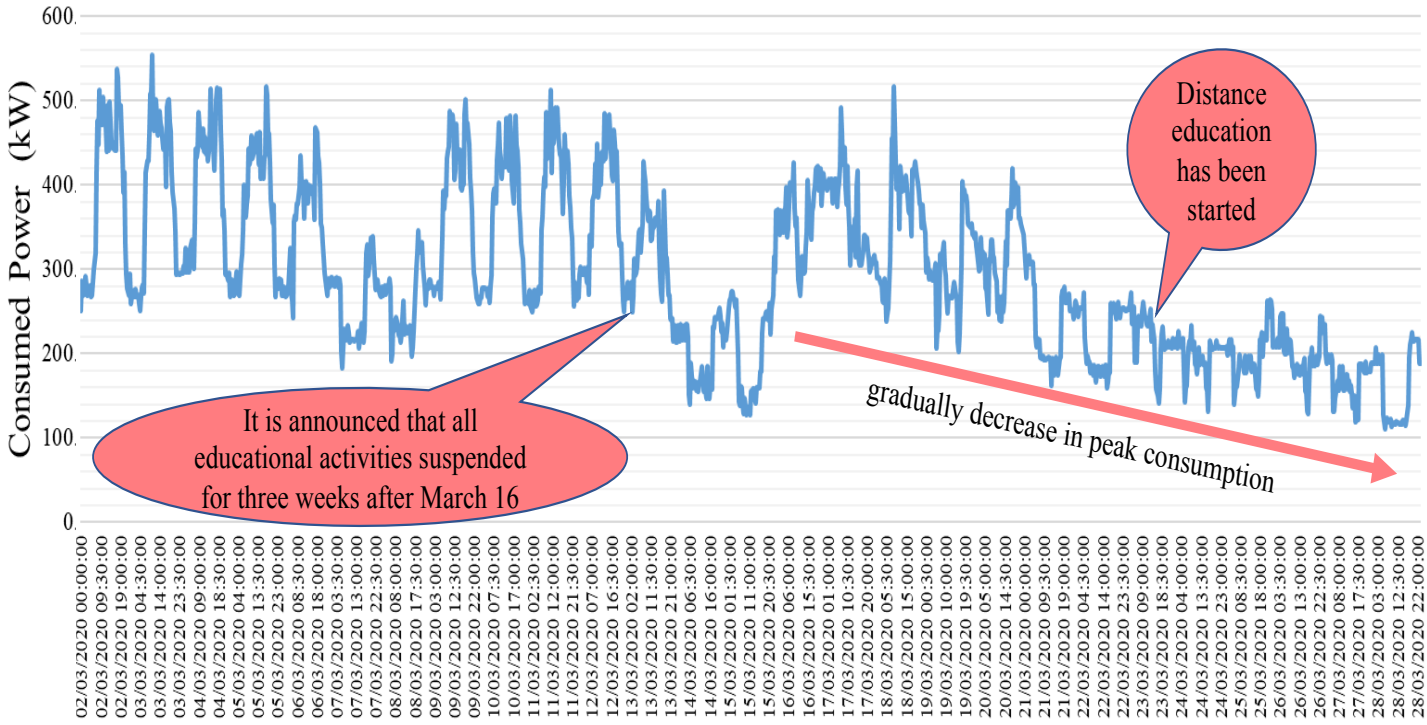


Fig.13. The time series of consumed power between March 2, 2020, and March 29, 2020.

4. CONCLUSION

This study focuses on the effects of distance education due to the COVID-19 pandemic on electrical energy consumption of the Gümüşhanevi Campus, Gümüşhane University, Turkey. To analyze the effects of distance education, electricity consumption data of the campus between January 1st, 2019, and December 31st, 2020, have been utilized. Electricity consumption data have been analyzed through the abovementioned indices. These indices include monthly and yearly consumption data and their calculation per student. As the number of students is almost the same in 2019 and 2020, these results provide a reliable perspective to observe the effects of distance education. In addition, the indices have been investigated during the daytime, the peak time, and the nighttime periods for a detailed analysis thanks to the energy meter recordings. The total consumed power of transformers' three phases, which fed the campus, was logged by an automated energy meter system in fifteen-minute periods. These logged power consumption data have been presented to show changes in the time series of the total consumed power between two weeks before and two weeks after all the educational activities were suspended.

The findings in this study indicate that electricity consumption of the campus decreased dramatically in 2020 compared to 2019 due to distance education and restrictions. These findings also bring forward to discuss online education options for some courses which can be appropriate through distance education after the COVID-19 pandemic end to decrease electrical consumption of the campus. In this regard, blended education which is a combination of online and face-to-face teaching may be considered in upcoming years after the COVID-19 pandemic end, as suggested in the literature [15, 18]. In addition, the daily timeline of education could be redesigned and some of the courses could be taught online during the high-power consumption periods to decrease electricity consumption. So, this might be beneficial for both distribution companies and the universities. As a result, the distribution companies can avoid peak consumptions which negatively affect the distribution grid stability. The universities can prevent high electricity bills since electricity prices are high during the peak consumption period. Also, the obtained results can be utilized to procure some opportunities and ways of reducing the electrical energy demand on campuses in the future. This study also brings forward to analyze the campus electrical system, since even in the strict lockdown there is a considerable consumption on the campus. After the analysis, detected inefficient utilities can be replaced with more efficient ones to provide a sustainable and energy-efficient campus.

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Biography

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