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Impact of COVID-19 Response Measures on Electricity Sector in Jordan

Salaheddin Malkawi [1,*], Suhil Kiwan [2] and Sajedah Alzghoul [2]

[1] Department of Nuclear Engineering, Jordan University of Science & Technology, P.O. Box 3030, Irbid 22110, Jordan
[2] Department of Mechanical Engineering, Jordan University of Science & Technology, P.O. Box 3030, Irbid 22110, Jordan; kiwan@just.edu.jo (S.K.); sajedhzghoul@gmail.com (S.A.)
* Correspondence: salahm@just.edu.jo

Abstract: With the wide spread of new variants of coronavirus that cause the infectious disease COVID-19, governments around the world typically respond by imposing restrictions on people's activities that range from partial to full lockdowns. This has severe implications on all economic activities, which is manifested by the changes in energy demand. In this study, the impact of COVID-19 on the electricity sector in Jordan is analysed through quantifying the strictness of the government response measures to contain the spread of the pandemic, as calculated by the stringency index, with the electricity demand by the different sectors. Results showed that the minimum peak load in 2020 decreased by 13% as compared to that of 2019. The most affected sectors were the domestic sector, whose share in consumption increased by 8%, and the commercial and hotel sector, whose share decreased by 19%. The concept of an energy-weighted stringency index was introduced to account for the impact of government response measures on the different sectors. The analysis was applied for all Jordan as well as for the three electricity distribution regions. Results also showed that despite measures taken to contain spread of the pandemic, the share of electricity generation by renewables increased from 15% in 2019 to 24% in 2020.

Keywords: COVID-19; electricity generation; electricity demand; peak load; stringency index

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1. Introduction

COVID-19 is an infectious disease caused by the newly discovered coronavirus SARS-CoV-2, which has caused a worldwide pandemic of respiratory illness to most infected people [1]. The first case of the novel coronavirus was reported in December 2019 in Wuhan, China [2]. In early 2020, the World Health Organization (WHO) officially entitled this novel virus as a coronavirus, and the number of confirmed cases increased rapidly by human-to-human contact [3]. As of January 2022, more than 308 million people have been infected, and more than five million people are known to have died following their infection [4]. Countries worldwide reacted to the fast spread of COVID-19 by imposing measures that included the following: social distancing, short working hours and partial to full lockdown of the public life. This led to severe implications for people's life worldwide, which varied depending on the government's measures taken to deal with the pandemic [5]. The energy sector was one of the main sectors affected by the containment measures, not only during the pandemic but also for years to come [6–9]. Electricity, which is a major energy carrier, was significantly affected by the governments' containment measures [10,11]. For example, the measures and emergency plans taken by affected countries in the European Union (EU) and states in the United States of America (USA) led to a decrease in the electricity consumption of 3–12% in the first five months of 2020, then most of them returned to their baseline consumption by the end of July 2020 [12,13]. On the other hand, the reduction in electricity demand had a positive impact on the environment, as it was mostly accompanied by a reduction in the carbon emissions at a level that depends on

the generation technology [14]. However, with new waves of COVID-19, mainly arising from the new variants of the virus, countries are re-imposing measures to contain the spread of the pandemic and consequently affecting the energy consumption. The effects of response measures on electricity sector does not only affect the amount of electricity consumption but also the pattern of consumption. This, in turn, will have a long-term impact on electricity consumption, electricity production, energy mix and progress of sustainable development [15–19]. Therefore, it is of paramount to investigate the policy implications for any future containment measures on the electricity sector.

The work presented in this paper aims at analysing the impact of the stringency in the government policies to contain the spread of COVID-19 pandemic on the electricity sector in Jordan during the year 2020. The adopted approach was to compare the change in electricity consumption in all sectors between 2019 and 2020 and correlate it with the calculated stringency index of the measures taken by the government to contain the spread of the virus. An energy-weighted stringency index was introduced, which gives a relative weight to each containment measure depending on its share of electricity consumption in Jordan as a country and in each region of electricity distribution, since the electricity consumption varies between the different regions. This is vital for future policy implications on the containment measures for energy security and the sustainability of all sectors in the country including healthcare, industry, and the economy, in general.

2. Materials and Methods

The aim of this work is to assess the impact of measures taken by the government to contain the spread of COVID-19 on the electricity sector in Jordan, which is vital for the sustainability of all aspects of life. Electricity is a high-grade energy carrier that is consumed by the different sectors and produced in Jordan from several sources including fossil fuel and renewable energy [20]. As the electricity consumption and consequently generation are directly affected by the measures taken by the government to contain the spread of COVID-19, they will therefore be analysed and correlated to the government response stringency index, to be discussed in the following subsections.

2.1. Government Response Stringency Index

The impact of COVID-19 on energy and other sectors is mainly dominated by the measures taken by governments to prevent and contain the spread of the pandemic through quarantines, travel restrictions, bans on public events, closure of schools, lockdowns and other restrictions on people's public life.

The Oxford COVID-19 Coronavirus Government Response Tracker (OxCGRT), proposed by Hale et al., was created to track and compare governments' policies around the world across a standardized series of indicators. Each indicator is given a value between 0 and 100 depending on the policy adopted by the government, such as school closures, ban on international travel, closure of public transport, stay-at-home orders and other restrictions on people's public life. The value of the stringency index (SX) on any day is the average of sub-indices of policy indicators, as given in Equation (1) [21].

$$SX = \frac{1}{\text{number of indicators (n)}} \sum_{j=1}^{n} SX_j \quad (1)$$

A high value of SX would indicate stringent measures taken by governments to contain the spread of COVID-19, whereas a lower value indicates lower stringency measures. It must be noted that the stringency index does not necessarily reflect how effective the government response to the containment of COVID-19, but rather indicates the strictness of the policy of the government.

The OxCGRT was applied to Jordan on daily basis from March to December 2020 with an objective to find the impact of the government response on the electricity sector. However, due to the large variation in the energy consumption between the different

sectors affected by the government response policies, in this work, we proposed the energy-weighted stringency index to account for the variation in energy consumption between the different sectors.

2.2. Energy-Weighted Stringency Index (EWSX)

The energy-weighted stringency index (EWSX) uses the same principle as the OxCGRT but with a weighting factor that is proportional to the share of electricity consumption in that sector. Table 1 gives a breakdown of the sectors and how they are correlated with COVID-19 government response policy indicators. Based on this categorization, the electricity consumption by sector in Jordan for the year 2018 is shown in Figure 1. It is worth mentioning that this categorization is slightly different from that published by National Electric Power Company (NEPCO) annual report, which combines domestic with governmental and other public buildings in one sector [22]. In this work, the analysis was carried out by both the OxCGRT stringency index (SX) and the energy-weighted-stringency index (EWSX).

Table 1. Correlation between electricity consumption sectors and government response indicators.

Electricity Sector	Response Policy Indicator
Domestic	Stay at home order
Governmental, Ordinary, Banks, public buildings, Telecommunication, Private hospitals, etc.)	School closing, workplace closing, close public transport, and public information camping
Commercial and Hotels	Restriction on gathering, Cancel Public events, and international travel
Industrial	Workplace closing and international travel
Agriculture and Water pumping	Stay at home requirement
Street lighting	Restriction on internal movement and restriction on international travel

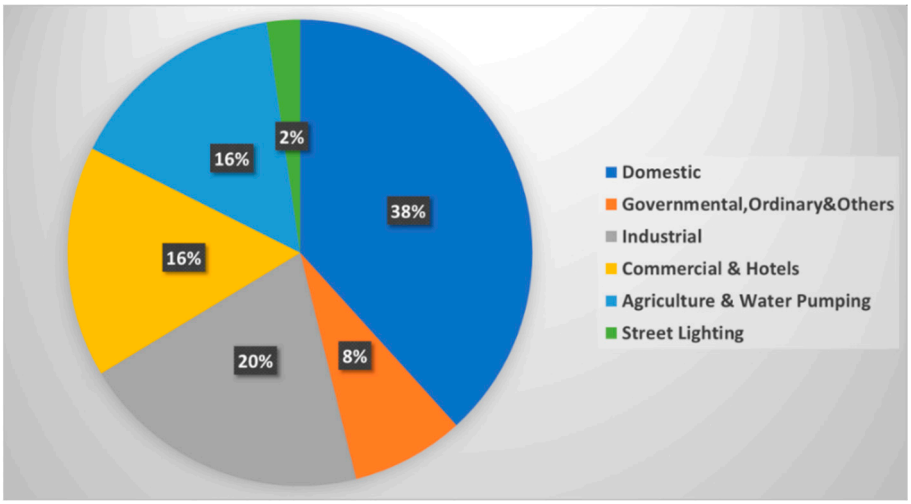


Figure 1. Electricity consumption by sector in Jordan (2018).

2.3. Data Collection and Analysis

Data on electricity generation, consumption, and the variation of load with lockdown orders were collected from the relevant sources that included, but not limited to, Ministry of Energy and Mineral Resources (MEMR), National Electric Power Company (NEPCO), Energy and Minerals Regulatory Commission (EMRC), Electricity generation and distribution companies, Amman Chamber of Industry, and other relevant organizations. The

data was analysed in-depth to provide a timely and accurate update on the electricity sector during the pandemic and how it was affected by the stringency of the government response. The analysis was carried out for the years 2019 and 2020. Data was compared on weekly and quarterly bases to account for the variation in weather, seasonal cycles and other yearly effects.

For analysis purposes, the country was divided into three main regions according to the electricity distribution companies. The northern part of Jordan is covered by Irbid District Electricity Company (IDECO), the central part by Jordan Electric Power Company (JEPCO) and southern part by Electricity Distribution Company (EDCO), as depicted in Figure 2. Moreover, the government response measures were mostly different in the three regions depending on the time and rate of increase in the number of COVID-19 cases in each region.

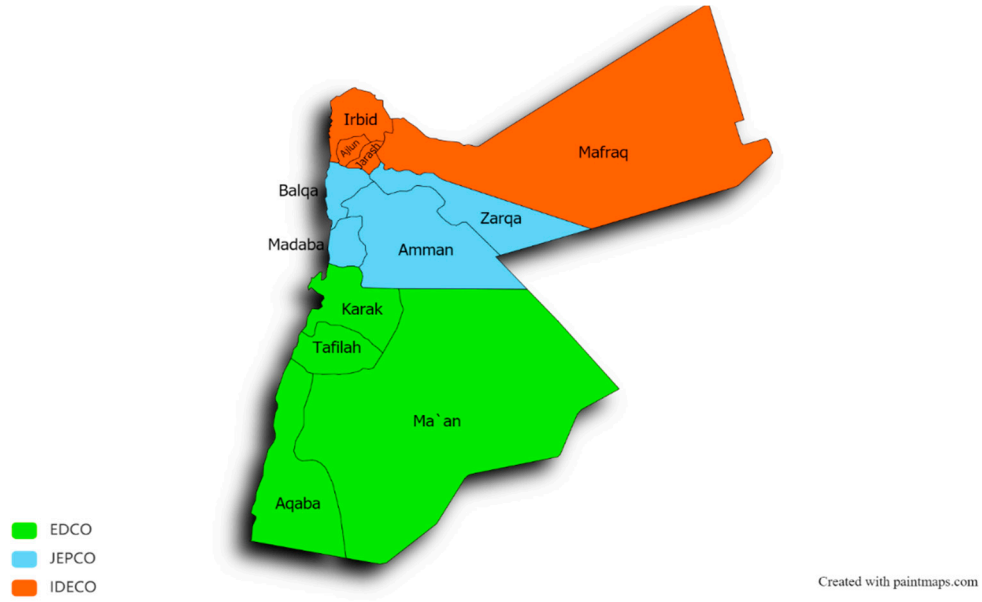


Figure 2. Electricity distribution companies in Jordan.

The data for 2019 was used as the baseline for the period of the "as usual" scenario in which there was no pandemic, where electricity load and demand by different sectors during the pandemic was compared to it. The 2020 data were also compared with their forecasted values from the previous year to find out the relationship between the change in daily electrical load and the outbreak caused by COVID-19.

3. Results and Discussion

3.1. Impact on Electrical Power Demand

Figure 3 shows the peak load for the electrical interconnected system for the years 2013 to 2020 with an average growth rate around 3.1%. In 2020, the minimum peak load decreased by 13% and reached a value of around 1 GW, as compared to a decrease of 7% between the years 2019 and 2018. On the other hand, the evening peak load was higher than the previous year by 7%, while the morning peak load increased by 8%, as compared to an increase of around 5% between the years 2019 and 2018 [23]. Figure 4 illustrates the changes in peak load between the years 2019 and 2020. This variation in the trend from previous years is mainly attributed to the lockdown measures taken by the government to contain the spread of COVID-19, particularly when a full lockdown was imposed during the months March to May 2020 and the evening lockdown, which continued for the rest of the year.

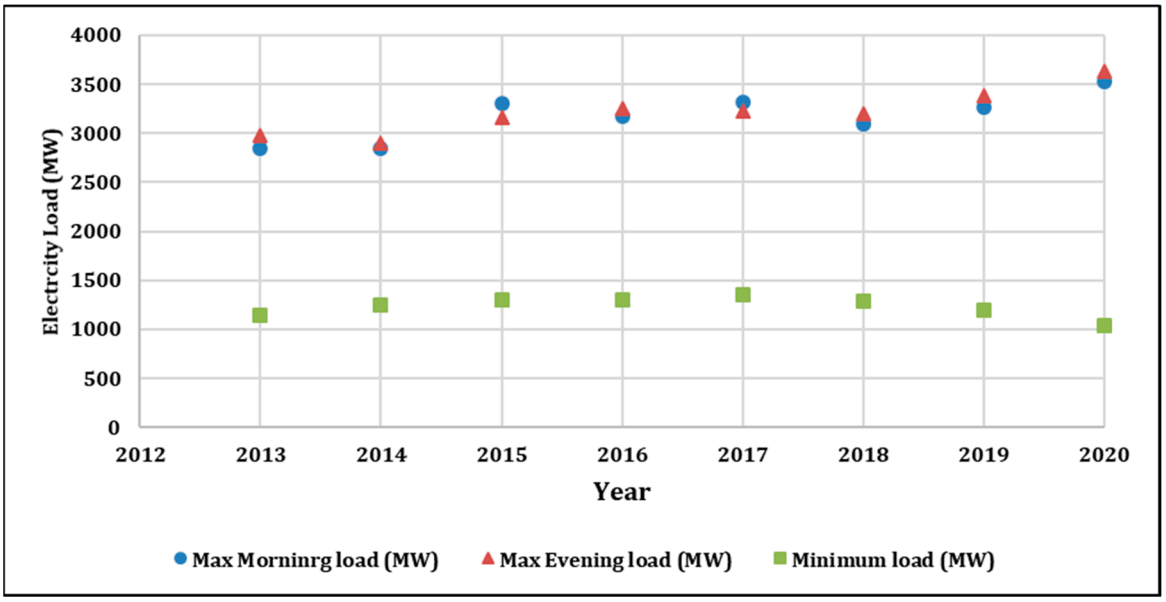


Figure 3. Peak load of the interconnected system (2013–2020).

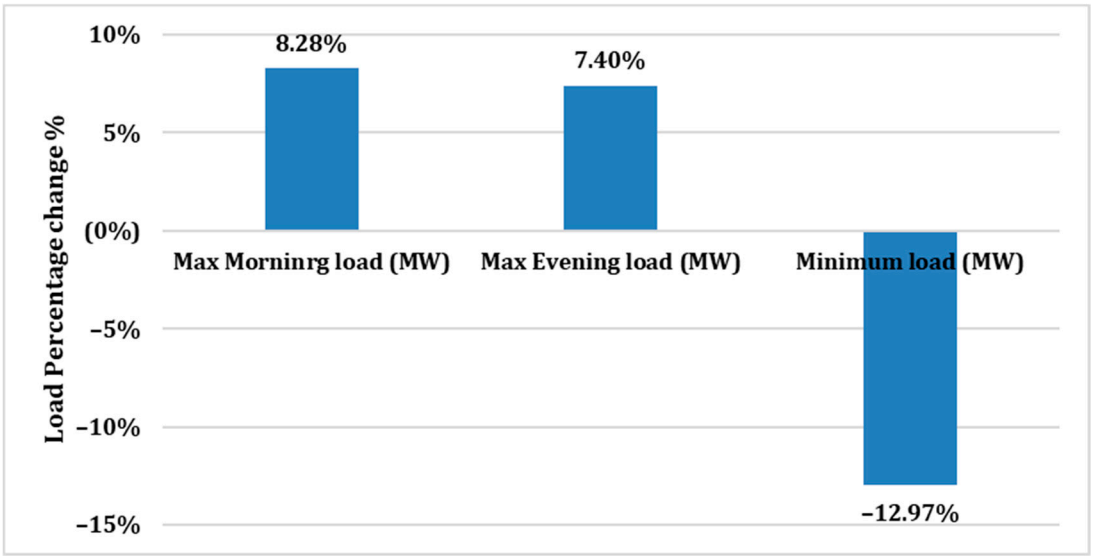


Figure 4. Percentage change in peak load between 2019 and 2020.

The daily electricity consumption for the year 2020 along with the stringency index are shown in Figure 5. As can be seen from the figure there is a strong correlation between the stringency index and the electricity consumption. When the stringency index was 100, the daily consumption reached a minimum value of around 38 GWh, while when the index was 50, the consumption increased to around 68 GWh. This is due to the fact that when the value of the index is at its maximum many of the sectors are closed and therefore less electricity is consumed. On the other hand, when the policies are more relaxed, as reflected by a lower stringency index, more economic sectors are open, and people could resume their activities at levels that varies based on the stringency index.

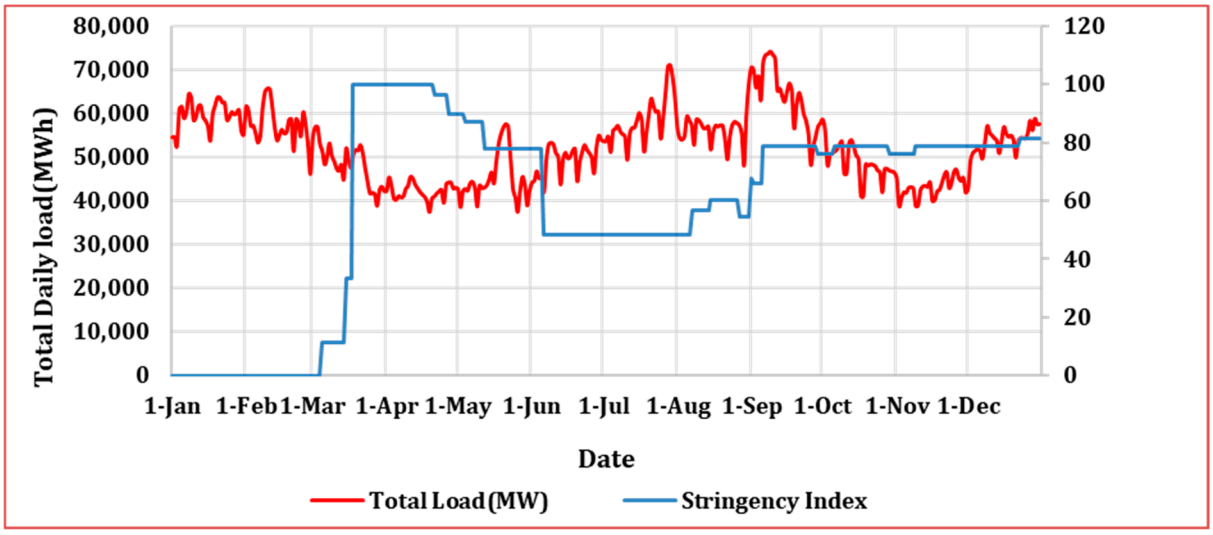


Figure 5. Daily electricity consumption with SX for the year 2020.

The variation of the electrical load with critical date, which is the date at which the change in stringency index entered into force, is shown in Figure 6. It is clear from the figure that there is a sudden change in the electricity demand that coincides with the critical date when the changes in the government policies enter into force. It is also clear from the figure that there is a general inverse relationship between the electricity demand and the calculated value of the stringency index.

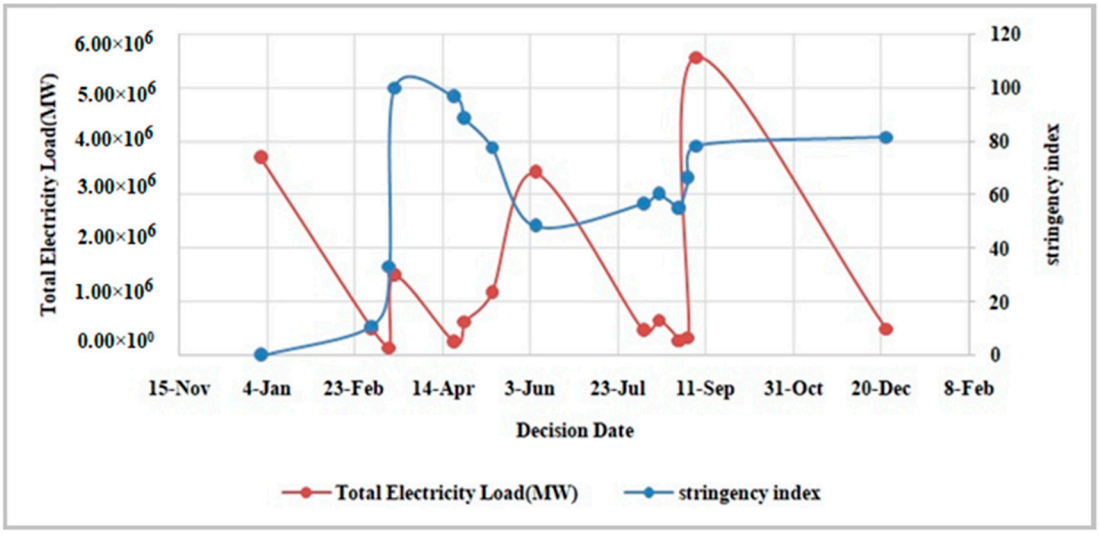
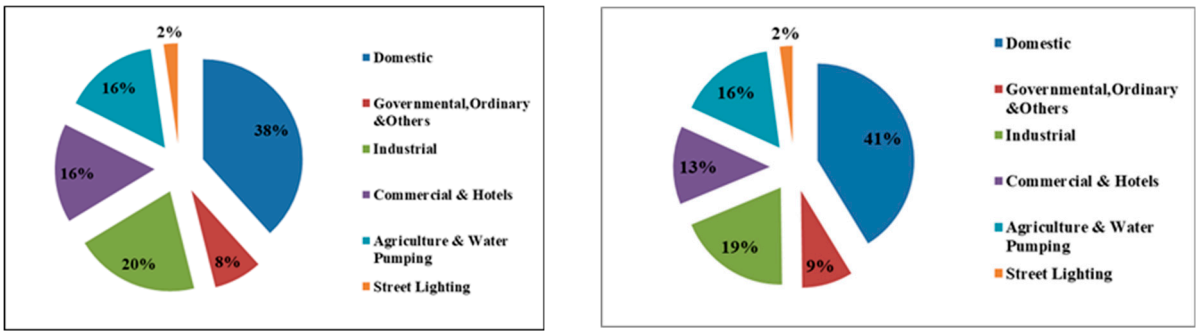


Figure 6. Change in electricity load by the critical decision date for 2020.

Figure 7a,b show the electricity consumption by sector in 2019 and 2020, respectively [24]. The main changes between the two years are in the domestic sector, which increased from 38% to 41% and the commercial and hotel sector, which decreased from 16% to 13%. These changes are mainly attributed to the stay home orders and the restrictions imposed on international travel. Figure 8 shows the change in the share of electricity consumption by each sector between 2019 and 2020 along with the energy-weighted stringency index (EWSX). Results show that the most affected sectors were the domestic, whose share increased by 6% for an EWSX of 39, and the commercial and hotel sector, which decreased by 19% for an EWSX of 53. It must be pointed out that the decrease in street lighting

consumption is not attributed to COVID-19 containment measures but mainly due to the widespread use of street lighting energy saving systems.



(**a**) (**b**)

Figure 7. Electricity consumption by sector in (**a**) 2019 and (**b**) 2020.

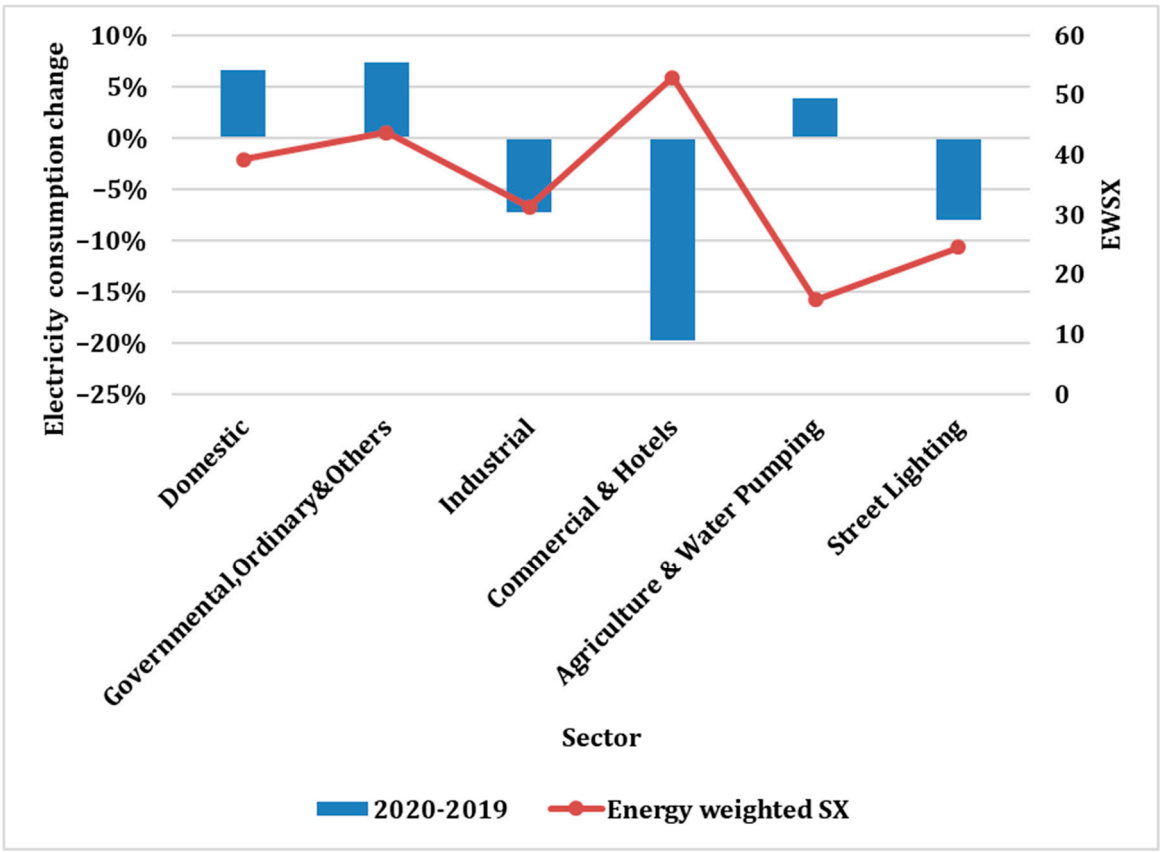


Figure 8. Change in electricity consumption by sector for 2019 and 2020 with energy-weighted stringency index.

3.2. Electricity Consumption by Region

3.2.1. Jordan Electric Power Company (JEPCO)

As illustrated in Figure 2, JEPCO is responsible for electricity distribution in the central part of Jordan. The monthly percentage change in electricity demand between 2019 and 2020 along with the stringency index are shown in Figure 9. The change in the demand during the months March to June 2020 was negative, with the lowest change at −17.4% in April 2020 when the stringency index was at its highest value of 100. The changes for the rest of the year were positive, since the stringency index was lower and hence more

sectors were allowed to return to work. To account for the seasonal changes in electricity consumption, the changes were plotted per quarter, as depicted in Figure 10. As can be seen from the figure, in the domestic sector, due to full lockdown orders imposed from 20th March until end of May 2022, there was an increase in electricity consumption of 16% in the second quarter and an increase of 10% in the third and fourth quarters due to the evening lockdowns, which were imposed for the rest of the year. Similarly, there was a large increase in electricity consumption by governmental, ordinary, and other sectors in the first quarter, due to the pressure on public services to respond to the pandemic.

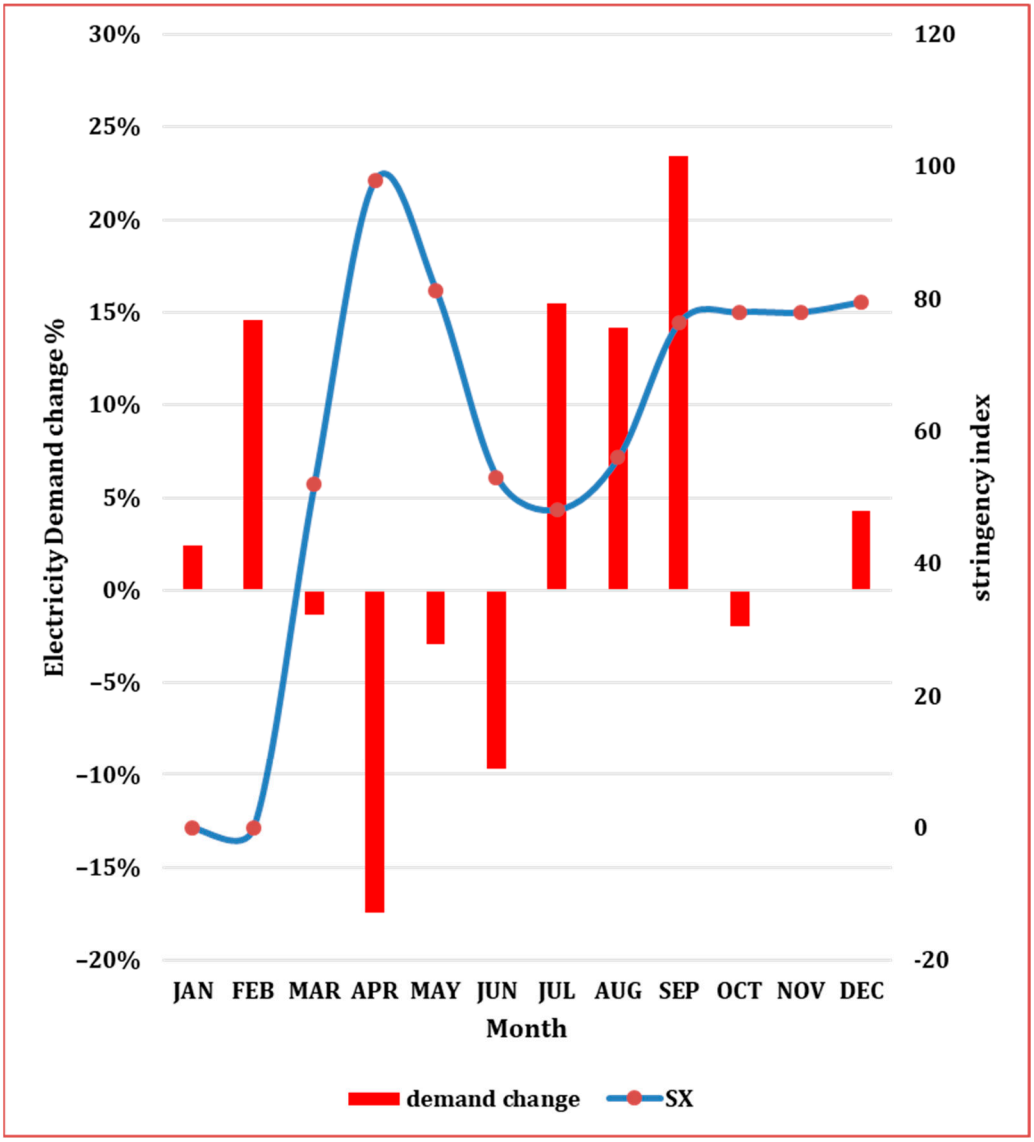


Figure 9. Monthly change in electricity demand between 2019 and 2020 at JEPCO's area with the variation in stringency index.

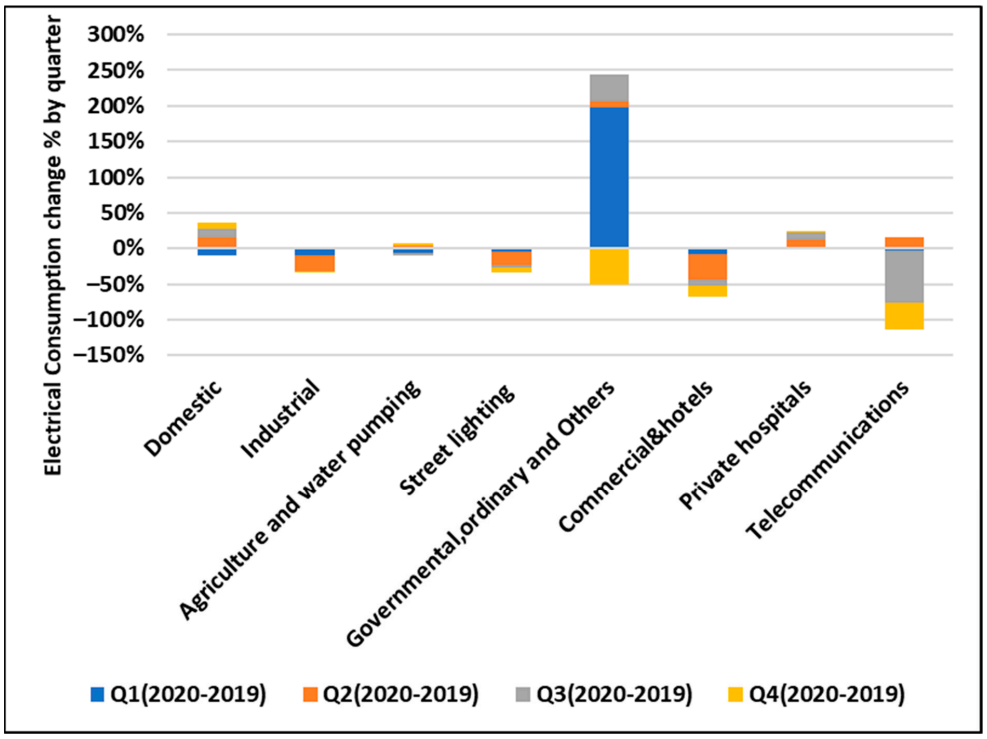
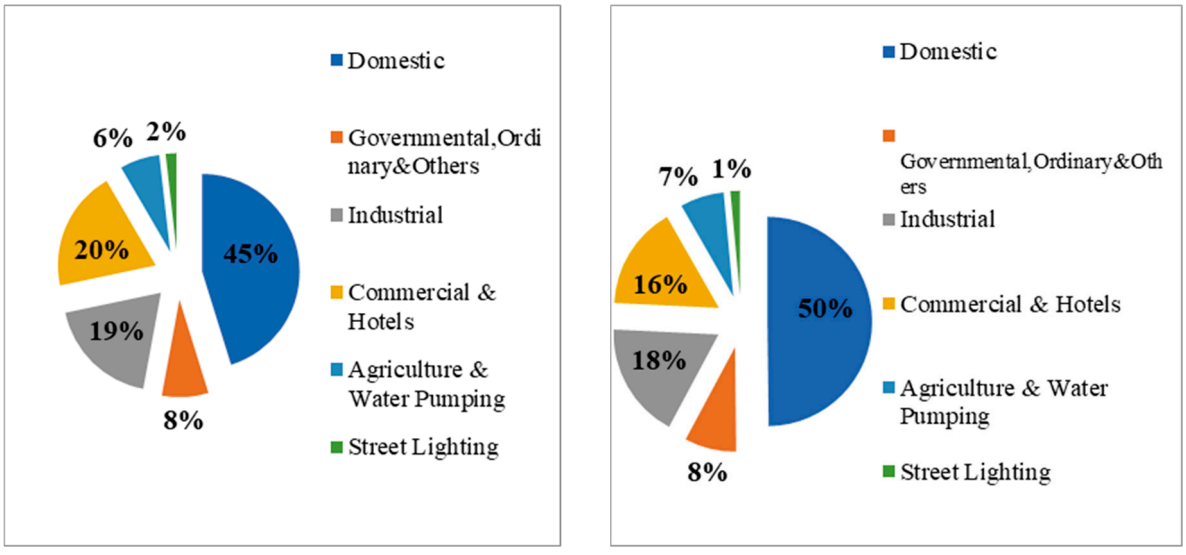


Figure 10. Change in electricity consumption in JEPCO's region by quarter between 2019 and 2020.

Figure 11a,b show the electricity consumption by sector at JEPCO's area for the years 2019 and 2020, respectively. JEPCO covers the central part of Jordan, which is mostly occupied by residential, commercial and hotels sectors. This is reflected on the change in electricity consumption. In 2020, the consumption by the domestic sector increased by 6% in comparison to 2019 due to the stay-at-home orders, the pressure put on hospitals and the need for them to operate at their full capacity. The other major change was in the commercial and hotel sector, which dropped from 20% to 16%, as it is one of the sectors that were most affected by the response measures taken to contain the spread of COVID-19.



(**a**) (**b**)

Figure 11. Electricity consumption by sector at JEPCO's area. (**a**) 2019, (**b**) 2020.

Figure 12 shows the percentage change between 2019 and 2020 in the consumption share by each sector along with the EWSX. It can be seen from the figure that when the EWSX was 47, this resulted in an increase in the electricity consumption by the domestic sector of 6%. On the other hand, for the industrial sector, the consumption decreased by 8% when the EWSX was 25.15, with similar behaviour for the other sectors. It must be emphasized that this applies for JEPCO's area, since other regions have different electricity consumptions distributions.

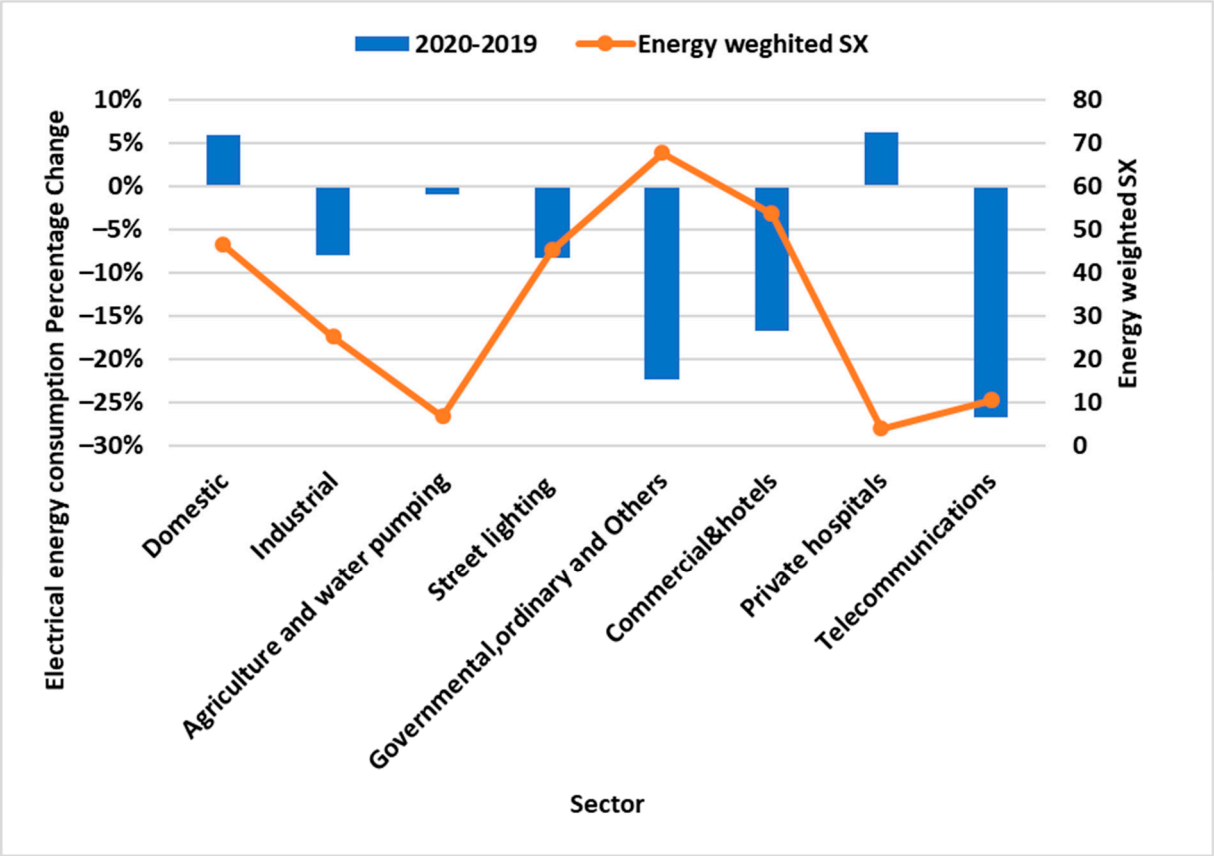


Figure 12. Change in electricity consumption at JEPCO's region between 2019 and 2020 for the different sectors with EWSX.

3.2.2. Irbid District Electricity Company (IDECO)

The northern part of Jordan, which is mostly covered by agricultural area, is supplied with electricity by IDECO. This is apparent from the electricity consumption by sector for the years 2019 and 2020, as shown in Figure 13a,b, respectively. As can be seen from the chart, the increase in the domestic sector was from 49% to 53%, which follows the same trend as in the central region of Jordan supplied by JEPCO and for the same reasons explained above. On the other hand, the agricultural sector, which consumes around 20%, remained almost the same, as it is one of the essential sectors for the sustainability of life, and therefore was exempted from many of the government's strict response measures. The remaining sectors consumed less share of electricity and followed the same trend as in JEPCO's area.

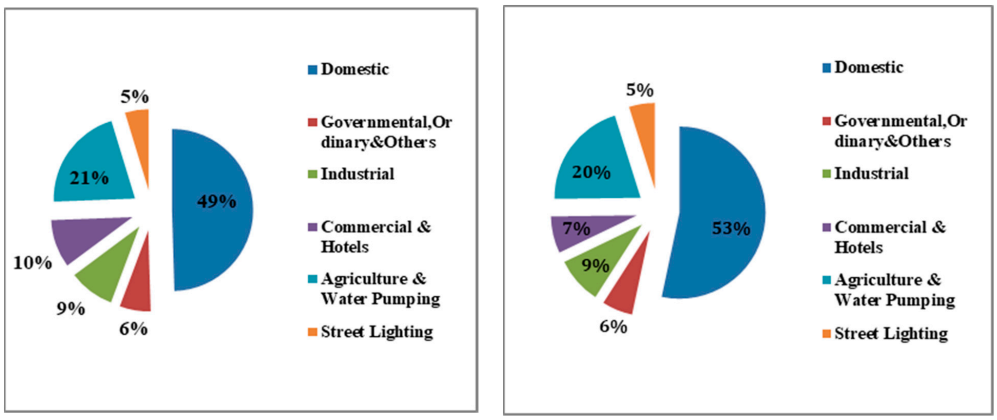


Figure 13. Electricity consumption by sector in IDECO's area. (**a**) 2019, (**b**) 2020.

The monthly percentage change in electricity consumption between 2019 and 2020 along with the stringency index in IDECO's region is shown in Figure 14. As can be seen from the figure, there was a large decrease in the demand in the months of March and April, since the first cases were discovered in Irbid and a major lockdown was imposed in the Irbid region. This maximum decrease is correlated with the stringency index, which was at 100. The demand in May 2020 exceeded its value by 5% during 2019; this is due to the recovery of several economic activities that had raised their activity to recover their losses during the lockdown, and the calculated stringency index was 80. In June 2020, the energy demand decreased in comparison to the previous month in the same year and showed an 8% lower energy demand in comparison to the demand in June 2019. In the second half of 2020. The demand for electrical energy in the IDECO's area gradually increased until it exceeded its values in 2019. In general, the change in electricity demand followed the same inverse relationship with the stringency index.

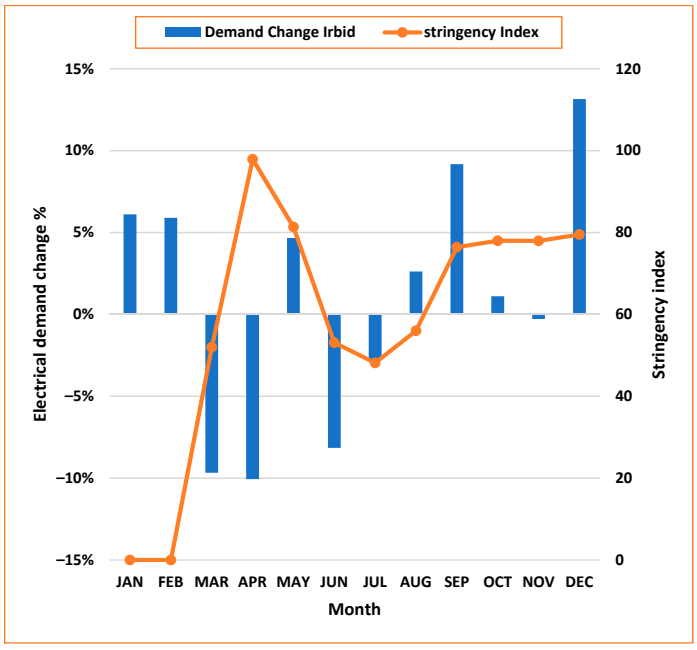


Figure 14. Monthly change in electricity demand between 2019 and 2020 at IDECO's area with the variation in stringency index.

To account for seasonal variations, the change in consumption by each sector between 2019 and 2020 per quarter was plotted, as shown in Figure 15. Results show that most of

the change in consumption was in the first quarter, which corresponds to the full lockdown that was imposed following the start of a rise in the number of cases that started in the Irbid region.

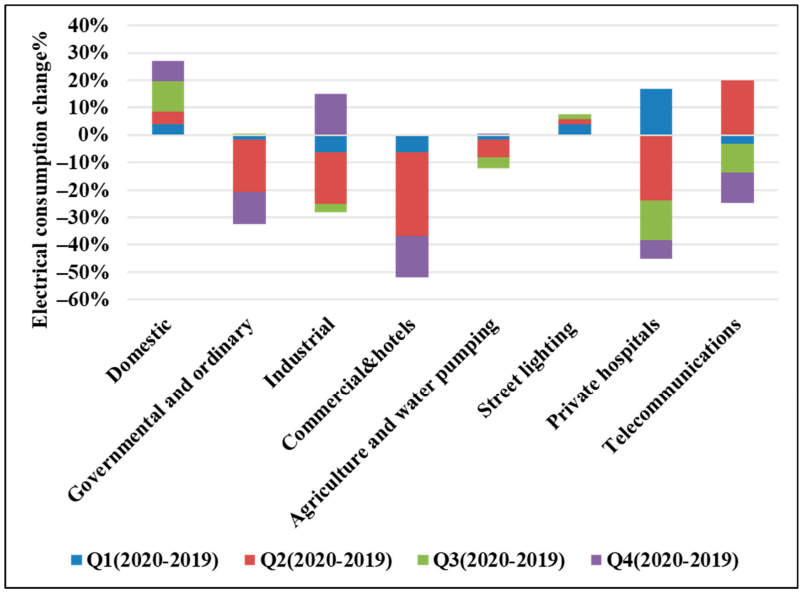


Figure 15. Change in electricity consumption in IDECO's region by quarter between 2019 and 2020.

Figure 16 shows the percentage change in electricity consumption by sector from 2019 to 2020 along with the energy-weighted stringency index (EWSX). It can be seen from the figure that the governmental response measures led to reduction in electricity consumption by commercial and hotel sectors by 11.3% for an EWSX of 44. On the other hand, the consumption by the domestic sector increased by 6% for an EWSX of 38. Other sectors showed slightly negative change in their consumption, decreasing by 3%, despite the measures taken to contain the spread of COVID-19.

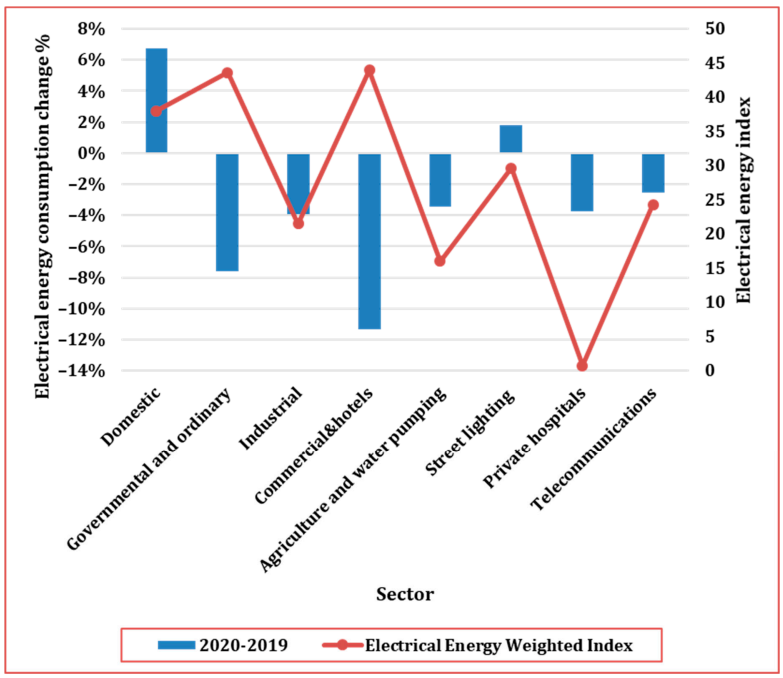
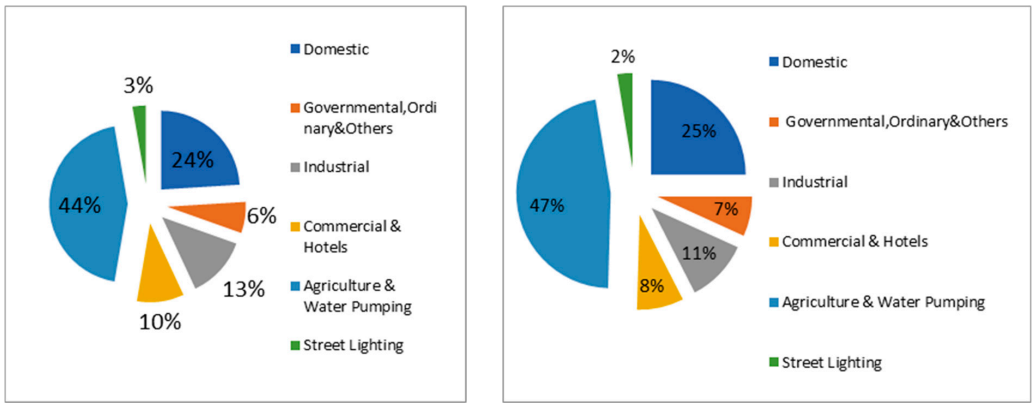


Figure 16. Change in electricity consumption at IDECO's region between 2019 and 2020 for the different sectors with EWSX.

3.2.3. Electricity Distribution Company (EDCO)

Electricity Distribution Company (EDCO), as illustrated in Figure 2, covers the electricity distribution in the southern part of Jordan. Figure 17a,b show the electricity consumption by sector for the years 2019 and 2020, respectively. The largest share of the consumed electricity in 2019 was by the agriculture and water pumping sector with 44% followed by the domestic sector by 24%. This distribution by sector is different from that of JEPCO and IDECO, due to the fact that EDCO covers a very large area with a lower population density and it supplies the northern part of Jordan by part of its water, in addition to agriculture. The same pattern remained in 2020 with a slight increase in both sectors, as shown in the chart.



(**a**) (**b**)

Figure 17. EDCO's electricity consumption by sector. (**a**) 2019, (**b**) 2020.

The percentage change in the monthly demand at EDCO's area between 2019 and 2020 along with the stringency index is shown in Figure 18. As can be seen from the figure, there was a decrease in the range of 7% to 10% in the months of April to June of 2020, when the stringency index was between 50 and 100. The consumption of electricity gradually increased during July until September 2020 and exceeded the demand in 2019. At a stringency index of 80, the electricity consumption decreased by 8%, and the demand for electrical energy returned to its normal values by the end of 2020.

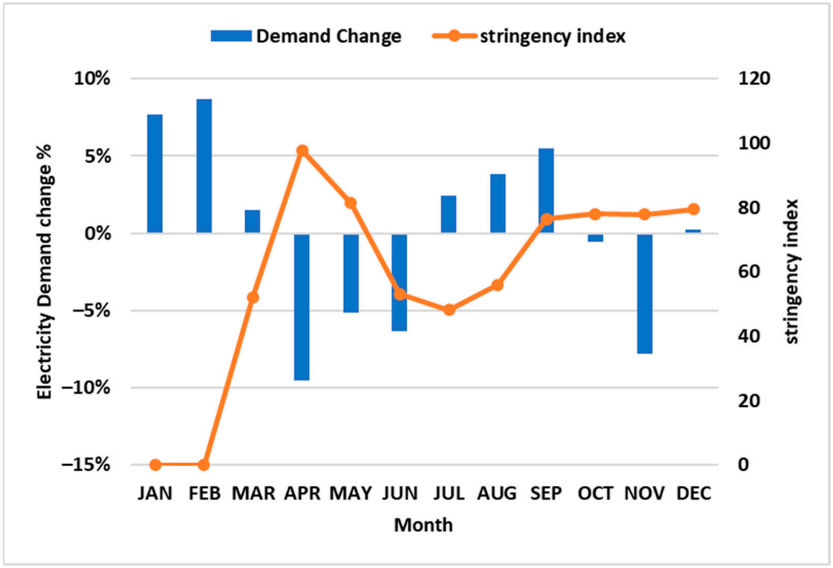


Figure 18. Monthly change in electricity demand between 2019 and 2020 in EDCO's area with the variation in stringency index.

To account for the seasonal variations in demand, the change in consumption between 2019 and 2020 by quarter is plotted in Figure 19. As can be seen from the figure that the most affected sector was the commercial and hotel sector in the second quarter, which can be attributed to the measures taken to contain the spread of COVID-19 as the southern part of Jordan receives many tourists in that part of the year.

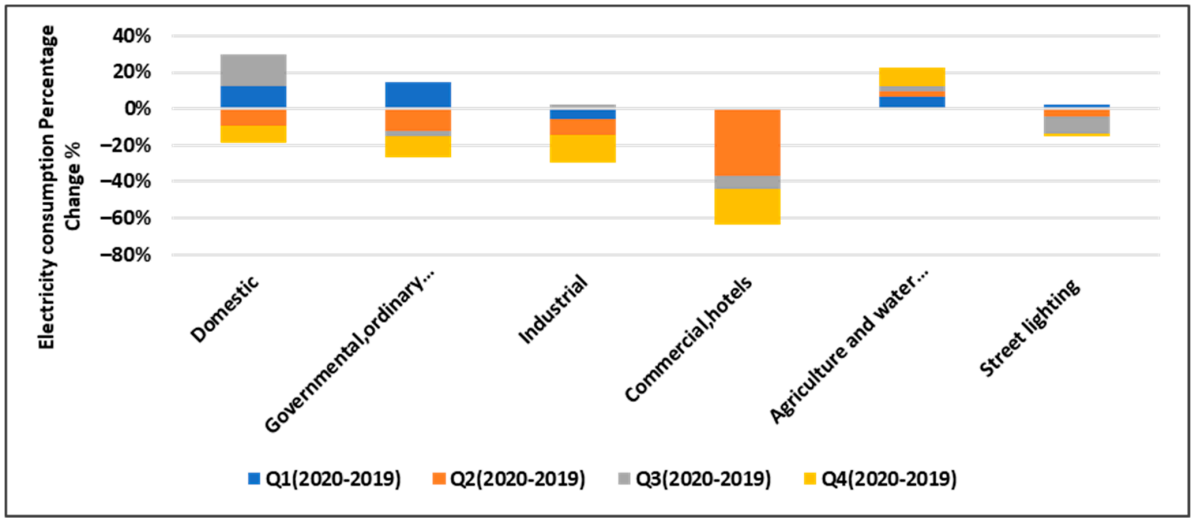


Figure 19. Change in electricity consumption in EDCO's region by quarter between 2019 and 2020.

Figure 20 shows the percentage change in electricity consumption by sector from 2019 to 2020 along with the energy-weighted stringency index (EWSX). It can be seen from the figure that the sectors most affected by the government response measures were the commercial and hotels sector, by 16% at 36 EWSX, and the telecommunication sector, by 31% at 21 EWSX. The change in the commercial and hotels sector is discussed above, whereas the change in the telecommunication sector is mainly due to the fast transfer to the online systems in most aspects of life.

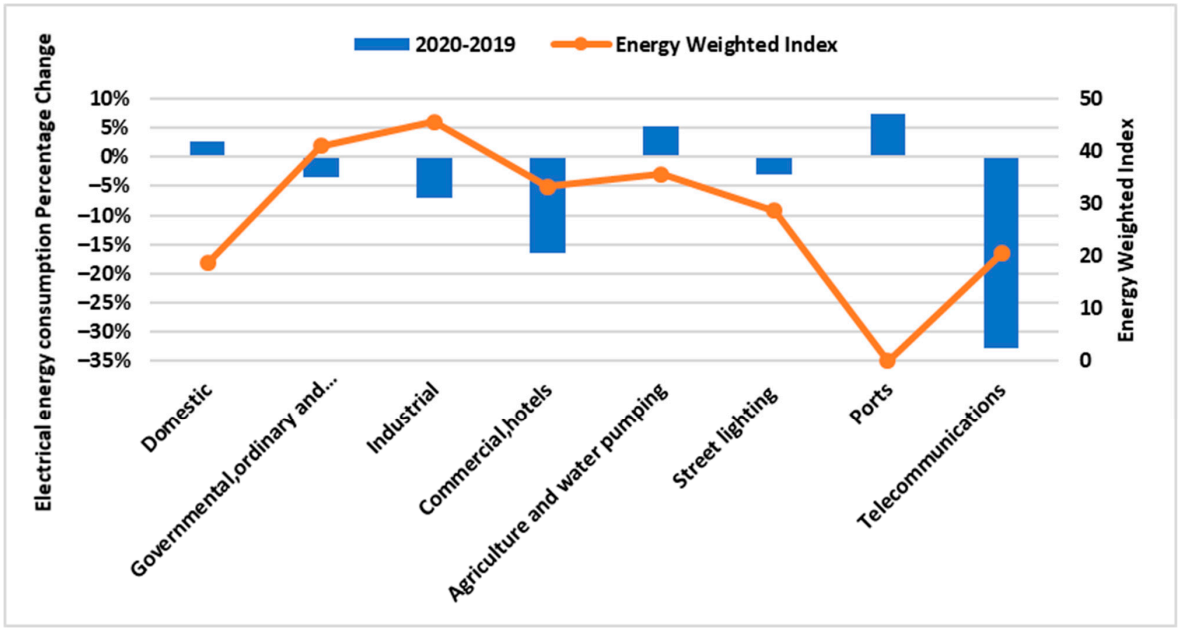


Figure 20. Change in electricity consumption at EDCO's region between 2019 and 2020 for the different sectors with EWSX.

3.3. Electricity Generation

Jordan has a diverse energy mix for electricity generation that utilizes renewable and fossil fuel energy resources, in addition to minor imports of electrical energy through the interconnected system, mainly from Egypt, that account for 1 to 2% of the annual consumed electricity. The overall reduction in electricity consumption due to the COVID-19 pandemic was reflected in the electrical energy purchased by the National Electric Power Company (NEPCO), which decreased by 0.4% from 19.27 TWh in 2019 to 19.19 TWh in 2020 as compared to an increase by 2.8% from 2018 to 2019. This can be seen from Figure 21, which shows the change in the generated and imported electricity for the years 2010–2020. Figure 22a,b show the contribution of fossil fuel and renewable energy in the generation of electricity for the years 2019 and 2020, respectively. Despite the strict measures taken to contain the spread of COVID-19, there was an increase in the share of renewable energy from 15% in 2019 to 24% in 2020, which demonstrates Jordan's commitment to the reduction in greenhouse gas emissions through the shift from fossil fuel in electricity generation to renewable energy [23,25].

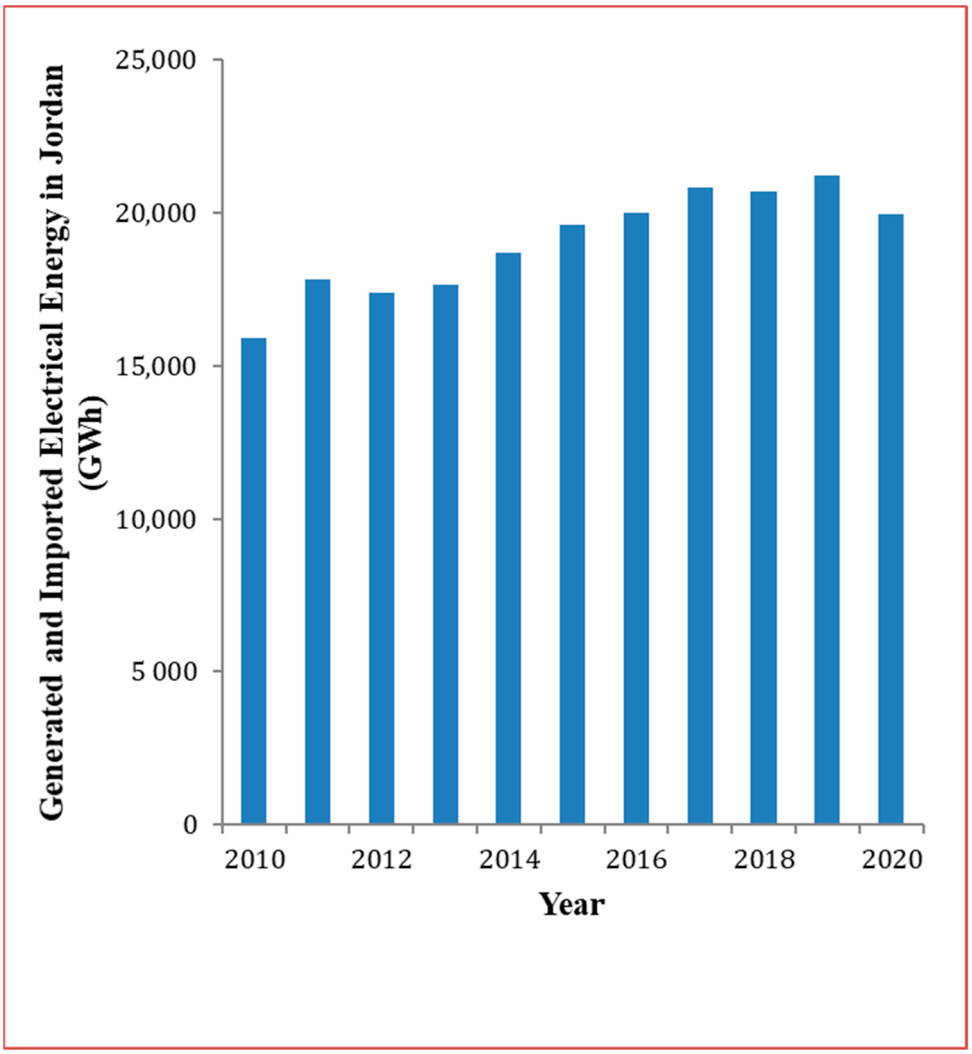
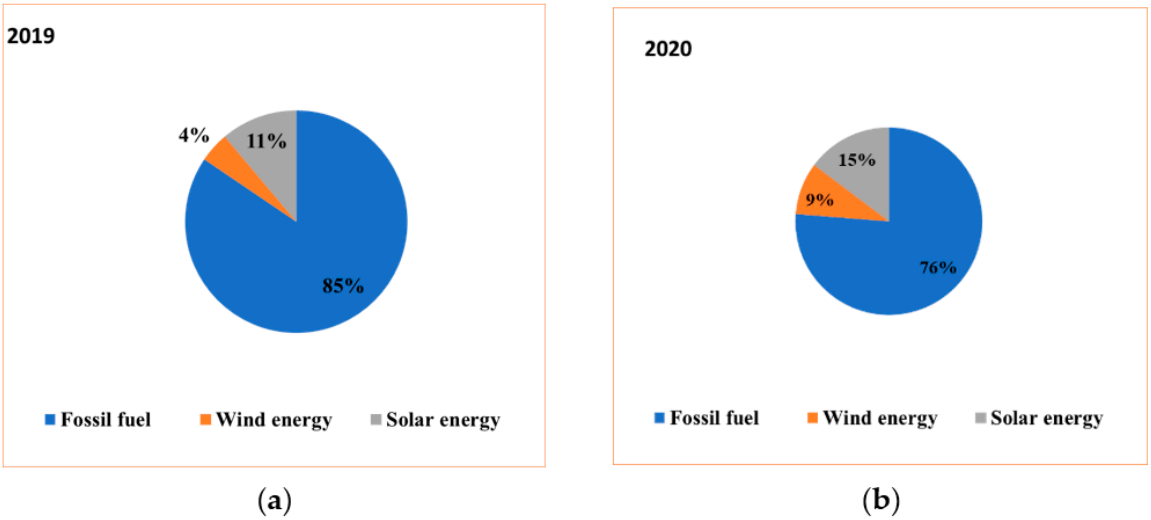


Figure 21. Generated and imported electrical energy 2010–2020.



(**a**) (**b**)

Figure 22. Contribution of fossil foil and renewable energy in electricity generation. (**a**) 2019, (**b**) 2020.

4. Conclusions and Policy Implications

In this study, several conclusions related to the electricity sector in Jordan are presented including the change in minimum peak load, electricity demand, and impact on the consumption by the different sectors as related to the stringency in the government response measures to contain the spread of COVID-19 pandemic.

In 2020, and as a result of the containment measures, the minimum peak load dropped by 13% as compared to that of 2019. On the other hand, the maximum morning load and the maximum evening load increased by 8% and 7%, respectively. The reduction in electricity consumption was reflected on the electrical energy purchased by the National Electric Power Company (NEPCO), which decreased by 0.4% from 19.27 TWh in 2019 to 19.19 TWh in 2020 as compared to an increase by 2.8% from 2018 to 2019. This is mainly attributed to the measures taken to contain the spread of COVID-19.

A comparison of the impact of COVID-19 containment measures on the three electricity distribution regions, central (JEPCO), northern (IDECO) and southern (EDCO) showed some differences, which is mainly due to the difference in the electricity consumption shares between the three regions. The most affected sectors in the central region were the governmental, ordinary and others sector, with a drop in consumption of 22% in 2020 as compared to 2019. In the northern and southern regions, the most affected sector was the commercial and hotels sector, whose consumption dropped by 11% and 16%, respectively. On the other hand, there was an increase of around 6% in the domestic sector in the central and northern regions, whereas the increase was around 2% in the southern region.

There is an overall inverse relationship between the stringency in the government response measures, as calculated by the stringency index and the electricity consumption. This varies between the different sectors depending on the importance of the sector in the sustainability of life.

The energy-weighted stringency index was introduced to account for the degree of the change in the electricity consumption by the different sectors, which can be utilized in the evaluation of the impact of any response measures on the energy sector before actually implementing the measures.

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