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The impact of different COVID-19 containment measures on electricity consumption in Europe

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ABSTRACT

As of March 13, 2020, the director general of the World Health Organization (WHO) considered Europe as the centre of the global COVID-19 outbreak. All countries within Europe had a confirmed case of COVID-19 by March 17. In response to the pandemic, different European countries took different approaches. This paper compares the impact of different containment measures taken by European countries in response to COVID-19 on their electricity consumption profiles. The comparisons are made for Spain, Italy, Belgium and the UK as countries with severe restrictions, and for the Netherlands and Sweden as countries with less restrictive measures. The results show that the consumption profiles reflect the difference in peoples' activities in different countries using various measures.

1. Introduction

Covid-19 was confirmed as a widespread pandemic over Europe as of March 2020, affecting many industrial sectors. The first coronavirus cases were reported in Italy on January 30, 2020. It was also confirmed to have spread to Spain on January 31.

As of June 6, Italy, Spain and the UK had the highest number of cases over Europe [1]. In response, Spain's government placed restrictions under the state of alarm declared on March 14. A series of more strict measures announced on March 29 asked all non-essential workers to stay home. Italy placed an extended national quarantine on March 9, restricting the movement of the population except for necessity, such as essential work or health problems. The lockdown imposed the temporary closure of non-essential shops and businesses. For the UK, the government announced a state of lockdown on March 23 to close all but essential businesses. People were only allowed to go outside for shopping, basic necessities, health reasons, and one form of exercise a day, or work if it was deemed 'essential', such as firefighters, police, electricity provision, etc.

Belgium faced the highest per-capita COVID-19 death rate in Europe [1]. The Belgian government took certain measures on March 12 and ordered the closure of schools, cafes, etc. and the cancellation of all public gatherings. Stricter measures issued on March 17 ordered the closure of non-essential shops, prohibited non-essential travel, and banned all gatherings. In contrast, the Netherlands adopted less-restrictive measures to get the virus under control as much as possible. All large-scale public events and gatherings were banned, schools and day care centres were closed, and people were required to self-distance and to work from home wherever possible. Unlike many other countries however, Sweden did not impose a lockdown. The measures were limited to recommendations for people with symptoms of respiratory infection and people over 70 to isolate themselves.

This paper shows how different containment measures taken by European countries in response to COVID-19 reshaped the electricity consumption profile in these countries. The results show that the change in peoples' activities in countries with different approaches is reflected in consumption profiles.

2. Electricity consumption change amid the COVID-19 pandemic

The procedures implemented by the European governments to deal with the COVID-19 emergency have drastically changed peoples' habits and activities at the national level. This change in behaviour is reflected in the electricity systems, in particular in terms of changes in electricity consumption profiles. This is illustrated in Fig. 1 by comparing the electricity consumption profiles of Spain, Italy, Belgium, and the UK, all countries with population containment measures, with the Netherlands as a country with less restrictive measures, and Sweden which did not impose a lockdown.

The comparisons are between a week after the pandemic had been

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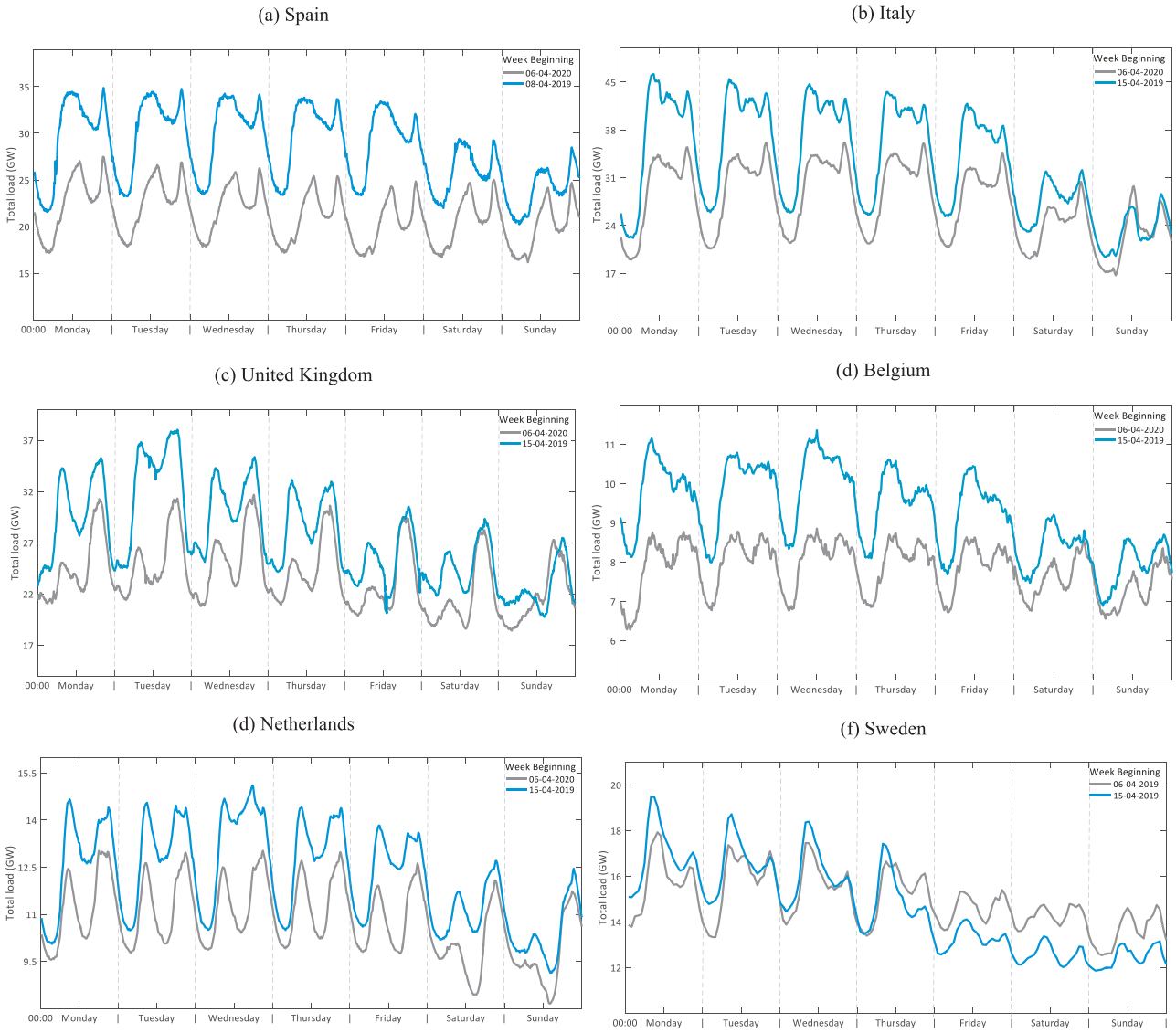

Fig. 1. Weekly load profile comparison for the second week of April 2020 and a reference week in 2019 for (a) Peninsular Spain [3], (b) Italy [4], (c) the UK [5], (d) Belgium [6], (e) Netherlands [7], and (f) Sweden [7]

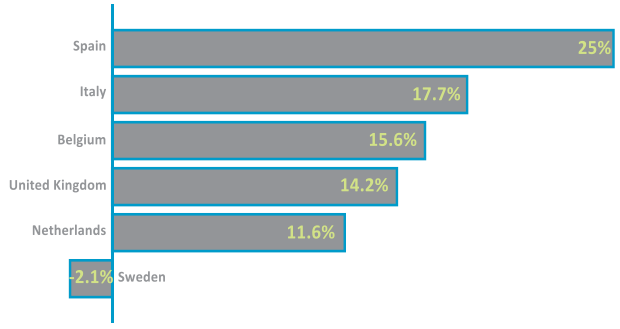

Fig. 2. Demand Variation Index (*DVI*) for Spain, Italy, the UK, Belgium, Netherlands, and Sweden for the periods reported in Fig. 1.

announced, and a reference week from 2019. The electricity demand is not only influenced by the day of the week and the time of the day, but it is also affected by weather changes. Therefore, the reference week in 2019 was chosen at a similar point in the year with a comparable daily average temperature. However, there are other factors which affect the demand, hence the comparisons cannot be perfect.

In Fig. 1, the grey line shows the trend in total national electricity demand for the second week of April (i.e. 6–13 April 2020) and the blue line shows the demand for a reference week in 2019. A comparison of consumption profiles clearly shows that for all countries except Sweden, the national demand was reduced after the pandemic was declared. The state of alarm decreed by the governments and the gradual restriction on activities to deal with the COVID-19 pandemic have led to a considerable reduction in electricity demand. For Spain, Italy, Belgium and the UK, the reductions are more noticeable. This is a direct consequence of population containment measures, and the closure of public and industrial centres as a means to curb the pandemic.

During the lockdown, there has been an increase in domestic demand as people have been spending more time at home. However, as businesses have been shrinking their activities, the reduction in commercial and industrial demand has been far greater than the increase in domestic demand. In the case of Belgium, Elia, the Belgian transmission system operator, reported that the drop was more noticeable for consumers connected to the distribution grid compared to Elia's 149 industrial customers connected directly to the high-voltage grid [2].

For Netherlands, remote working, the ban on public events and gatherings, and reduced activities have lowered the daily consumption. The case for Sweden is particularly interesting. For the period from

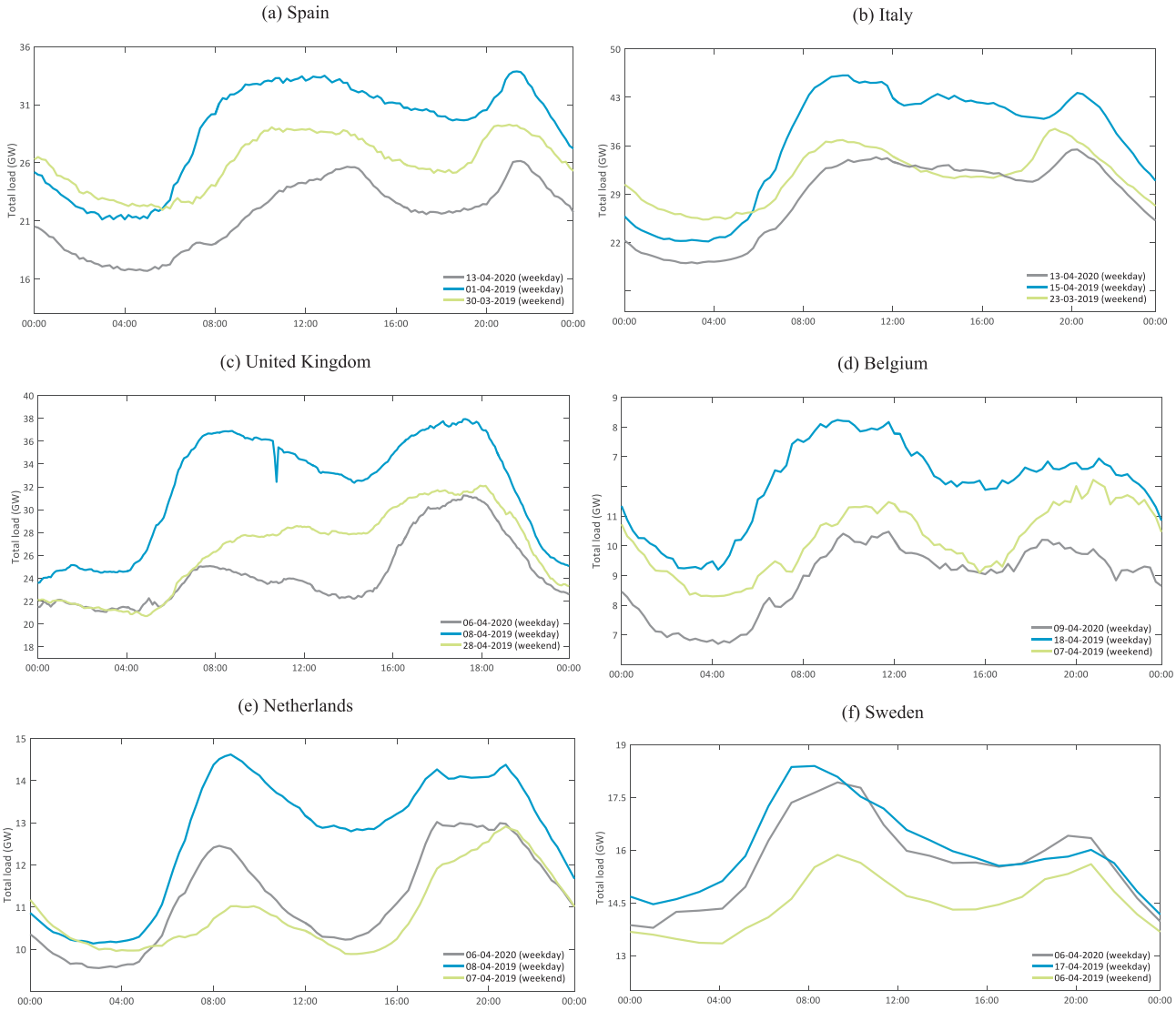

Fig. 3. Daily load profile comparison for a weekday of April 2020, a reference weekday and a weekend in 2019 for (a) Peninsular Spain [3], (b) Italy [4], (c) the UK [5], (d) Belgium [6], (e) Netherlands [7], and (f) Sweden [7]

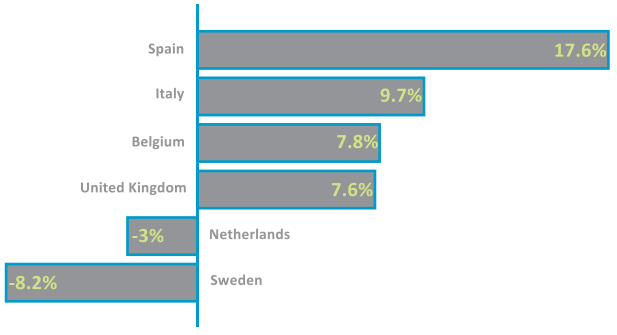

Fig. 4. Demand Variation Index (DVI) between a weekday after the pandemic and a weekend of 2019 for Spain, Italy, the UK, Belgium, Netherlands, and Sweden.

Monday to Thursday, the morning peak demand was reduced. However, the usual evening peak remained, indicating that normal evening activities were still going on. For Thursday evening and the subsequent long weekend, the consumption was even greater than for the reference week of 2019.

To better compare the change in demand for the countries considered, a Demand Variation Index (*DVI*) is defined as follows, which presents the average reduction of demand compared to a reference period:

$$DVI = \frac{\sum_{i=1}^{n} (P_{t_i}^{old} - P_{t_i}^{new})}{(n \times \bar{P}^{old})} \times 100 \quad (1)$$

where $P_{t_i}^{new}$ is the demand for time t_i, $P_{t_i}^{old}$ is the demand for the same time of a previous reference period, n is the number of recorded demands, and $\bar{P}^{old}$ is the average demand during the previous reference period.

Fig. 2 shows the *DVI* for the countries considered and for the periods represented in Fig. 1. As shown, Spain experienced the highest reduction in demand followed by Italy, Belgium and the UK. For the Netherlands, the reduction was lower as a consequence of the less-restrictive measures imposed on the population. For Sweden however, the *DVI* was negative, which implies that the consumption actually increased.

In Fig. 1, the case of Spain is particularly interesting, because it not only experienced an even greater reduction in electricity demand, but it also followed a different trend. For Belgium, Italy, and the UK, with schools, universities and most offices closed or under severe restrictions during the pandemic, the demand profile for weekdays during the pandemic were similar to weekends of the reference week in 2019. This

is also true for the Netherlands. However, for Spain, weekday demand was even less than the reference weekend demand, probably as a result of the closure of large commercial and industrial centres that were active during the weekends.

To make a closer comparison, Fig. 3 shows the daily demand for a weekday during the pandemic with a reference weekday and a reference weekend from 2019. The grey line shows the trend in total electricity demand for a weekday in April 2020, the blue line shows the demand for a similar weekday in 2019, and the green line is for a weekend in 2019, all with a comparable daily average temperature. The *DVI* index in Fig. 4 presents the overall variation between the weekday after the pandemic and the reference weekend in 2019.

Overall, for the UK, Belgium and Italy, it can be seen that after the pandemic, the weekday demand was not dissimilar, though slightly lower, when compared to consumption during the weekend in 2019. Particularly, post-pandemic weekday mornings were similar to weekends in 2019, lacking the typical morning peak as many people were now working from home and the schools were shut. This means that the typical morning electricity peak for transportation, kettles and lights was either dramatically reduced or spread over a longer period of time. The UK experiences a lower electricity consumption level during the post-pandemic day, even when compared to 2019 weekend electricity use. Belgium and Italy had lower demand during the evenings and earlier part of the night-time as clubs, cafes and restaurants were closed.

For the Netherlands, the similarity of the pandemic weekday demand and pre-pandemic weekend demand holds. However, the *DVI* is negative, which means that the week-day consumption was not less than that for pre-pandemic weekends. Moreover, the Netherlands still retained its morning peak for energy consumption. For Spain, the trend of weekdays during the pandemic has been similar to 2019 pre-pandemic weekends, except that the morning peak demand was delayed by a few hours. However, while the trend was similar, there was a considerable and almost constant drop in 2020 weekday demand compared to 2019 pre-pandemic weekends, probably due to the shedding of commercial and industrial loads that existed during pre-pandemic weekends.

For Sweden, as shown in Fig. 3, the consumption profiles of weekdays during the pandemic, were very similar to the profile of the reference pre-pandemic weekdays in 2019. Therefore, the *DVI* between the weekday after the pandemic had been declared and the reference weekend in 2019 was large and negative, which implies that the pandemic weekday demand was dissimilar and appreciably greater than pre-pandemic weekends, which clearly reflects the different approach Sweden took.

This paper discussed the impacts of the pandemic amids the weeks the containment measures were in place. As the European countries start to ease their lockdowns and restrictions, it can be predicted that the electricity consumption profiles will gradually return to their normal trajectory. However, the countries hit more severely, may experience a reduced demand for a long-term period. Moreover, probability of hitting a second wave of outbreak would prolong the low consumption behaviour of the electricity demand.

3. Conclusion

Widespread occurrence of an infectious disease may affect electricity consumption, production, maintenance, operational activities, development plans, and etc. In particular, this paper compared the effect of different containment measures taken by various European countries in response to the COVID-19 pandemic on their electricity consumption profiles. The results show that different lockdown measures in European countries and their effects on population activities have considerably changed the consumption profiles. For countries like Spain, Italy, Belgium and the UK with severe restrictions, the weekday consumption was considerably reduced and energy consumption profiles are similar to pre-pandemic weekend profiles for the same period in 2019. However, for countries with less restrictive measures, the decrease in power consumption was lower. In fact, for Sweden which did not impose a lockdown, the consumption even increased at certain points in time when compared to the same time period in 2019.

These interesting outcomes imply that while lockdown measures change the consumption profiles on one hand, on the other hand, these profile changes can also be a reflection of the effects of different approaches to dealing with the pandemic on people's activities.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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