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Impact of the COVID-19 pandemic on energy islands: The case of Cape Verde

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A B S T R A C T

The COVID-19 pandemic and its countermeasures radically affected the energy sector. Within a matter of days, whole countries were into lockdown causing the largest energy impact of the last decades. This study explores the pandemic and its effects on the isolated power systems of Cape Verde, a small island-based developing state in Africa. Historical data from 2013 to 2021 is combined with ARIMA-based forecasting to estimate a COVID-free scenario. The results show how the country’s electricity demand suffered a 10% drop distributed among the islands proportionally to GDP per capita. The energy mix was unaffected, but the lower demand motivated 6% less emissions. The reliability of the system improved with respect previous years, but the transmission losses increased by 5% due to energy theft caused by the severe economic crisis suffered in the archipelago. In that sense, the impact on revenue and energy sector workers was quite limited. Furthermore, we also studied the effects of the pandemic in other energy related sectors such as water desalination and transport. The recovery started in the third quarter of 2020 as marked by the increased electricity demand, but also with the rapid growth of passengers and goods in the transport sector.

1. Introduction

Governments around the globe declared different levels of restrictions as a response to the COVID-19 pandemic. While the specific regulations varied from country to country, this measures tended in general to restrict movement by closing airports, harbours, and declaring temporary lockdowns. In general, non-essential services either stopped or adapted to distance working. As a result, industrial and commercial loads decreased while residential loads increased, consumption patterns adapted to distance working. As a result, industrial and commercial loads decreased while residential loads increased, consumption patterns shifted, etc. Hence constituting an extremely interesting study case in the energy sector yet to analyse [1,2].

There are few publications analysing the effects of the pandemic in the electric systems. For instance, demand changes are explored in [1] for Brazil, where the difficulties in forecasting day-ahead load was highlighted along with the wide differences found across regions due to the heterogeneity of the restrictions. Then, the resilience of the Italian power system is analysed in [2] using frequency response as study case. Another example is [3], where the energy use of schools in South Africa is explored in order to recommend energy saving strategies for the post-pandemic future. Regarding mobility and emissions, in [4,5] the authors studied the cases of China and Italy providing a good estimation of the transport sector’s emissions and carbon footprints.

Energy consumption is a marker of the economic health and development of a country [6]. Understanding the fast behavioural changes caused by the pandemic and their subsequent effects on the consumption is key to mitigate disruptions and blackouts [2]. However, the scarce work available focuses on largely industrialized, continental countries. Some of the effects are somewhat predictable, industrial loads are reduced in favour to household level consumption, reliability is strained as generation is lowered and loads more distributed. However, is this the case for less industrialized regions or islands? Are they capable of maintaining the same energy mix? Are system losses altered? How about revenues? How has this affected the energy sector’s workforce? How have these effects propagated to other energy-related sectors? In particular, there is little to no information from developing and insular regions, which are characterized by low industrialization level, and external energy dependency. To fill these gaps we present the case of the archipelago of Cape Verde.

Tourism is the main economic activity of this African developing state, which is conformed by 10 islands with 540,000 inhabitants. Only the grid of the island of Boa Vista is managed by Aguas Energías de Boa Vista, and left out of this study due to the lack of available data. The remaining islands are operated by the System Operator (SO) Electra and stand as the focus of this work. The country presents an extreme external energy dependency on refined oil imports, and an energy access rate of 90%. The government has set targets, on the one hand aiming for 100% energy access before 2025 and, on the other, 50%
and 100% renewable shares by 2030 and 2050, respectively. During the past decade renewable shares have been staggered around 20%, which are provided solely by wind and solar power. A per island summary is depicted in Fig. 1, where the population, and the installed capacity of fossil fuel, wind farms (WF) and photovoltaic (PV) are presented. [7–9] The Cape Verdean government started taking measures against the pandemic on February 2020, being among the first in cancelling all flights from infected countries. Since mid March, children up to 6 years old could not attend school and remote-working was encouraged. By the end of the month, the emergency state had been declared, ships were not allowed to disembark and reunion rights had been limited. In May, restrictions started to be relaxed as the emergency state was lifted, and certain economic activities were slowly restarted such as agriculture. Since June, restaurants were allowed to open, domestic transport restarted, while cultural and sport-related activities had to wait until October. Air and sea traffic were completely restored on December 2020. From June 2021 vaccination sped up which allowed transport restarted, while cultural and sport-related activities had to lift, and certain economic activities were slowly restarted such as agriculture. Since June, restaurants were allowed to open, domestic transport restarted, while cultural and sport-related activities had to wait until October. Air and sea traffic were completely restored on December 2020. From June 2021 vaccination sped up which allowed transport restarted, while cultural and sport-related activities had to wait until October.

The structure of the paper is as follows: first, Section 2 presents the data origin and methodology. Then, Section 3 presents the technical and economical metrics [11–18]. Similarly, Electra, the local SO, includes thorough statistics regarding the energy mix and fuel consumption among others [19–27]. Furthermore, the National Institute of Statistics prepares different reports covering demographics, energy and economic data [28–30]. Particularly, electric demand data was collected as 10 min averages via meters at each power plant’s point of common coupling and using phasor measurement units (PMU) at transmission level. However, the number of measurement points varies from island to island due to their size. The data was then grouped as monthly averages.

In order to quantify the COVID-induced effects and changes in consumption, we employed data since 2013 until 2019 to predict the value expected for 2020 to compare then with the actual recordings. Subsequently, we repeated the same methodology for 2021 once the data was published. Such time series forecasting was approached using auto-regressive integrated moving average (ARIMA) following the Box–Jenkins approach [31]. ARIMA was chosen as it provides a good approximation of the expected value if the pandemic had not taken place using few observations.

3. Effects on the electric system

In this section, the most relevant effects of the COVID-19 pandemic in the Cape Verdean electric system are presented. In general, the overall country is analysed, while in some particular cases, the results of individual islands are highlighted.

Briefly, São Vicente was the least influenced island since its economic activity is quite diverse. While Sal, whose economy relies extremely on tourism presented the largest effects. In that sense, smaller islands such as Brava, Fogo, or Maio, whose demand is focused on household level and agricultural activities, did not see high differences in their consumption patterns.

3.1. Demand

In general, the energy consumption of any given country tends to present a growing tendency. In the particular case of developing countries, the demand increase tends to be fast paced due to the existing positive feedbacks between population, energy access and economic growth. Cape Verde is no exception to this rule as it can be seen in Fig. 2, where the total yearly demand of the country from 2013 is presented along with the ARIMA-based forecasted value for 2020, and 2021.

After the rapid development of the late 90s and early 2000s, demand growth staggered as energy access reached 90%. Nevertheless, between 2013 and 2019, the average yearly growth was an impressive 25%. In fact, the ARIMA-based expected value for 2020 would have kept the growth rate in 23.4%. However, the pandemic forced to close most industries and services, particularly tourism, which was non-existent, causing a drop of 9.7% from the expected value. The consumption decline was not uniformly distributed across the different islands and resulted widely dependent on the strength of anti-COVID measures and the income sources available during the pandemic. This can be seen in Fig. 3, which depicts the relative error between the expected and recorded demand for 2020, and the maximum peak evolution compared to 2019. Both metrics are presented in percentage to avoid scaling problems since Santiago alone represents 55% of the total demand in the country. Note that, the yearly demand and the peak correspond, respectively, to energy and power. Also, those islands with a peak demand increase or with small reductions, the value was recorded outside of the lockdown period, that is January and February or from July to
December. In addition, Fig. 4 presents the relationship existing between GDP per capita and consumption reduction [32]. The regression line achieved a coefficient of determination ($R^2$) of 0.83 and it has been computed considering São Vicente as an outlier. From this graph it is clear that the richest islands, which are also the most touristic, suffered higher demand reductions. Particularly, the island of Sal, was the most affected by the pandemic and its countermeasures. Lastly, the monthly evolution of the generation and its configuration for 2019, 2020, and 2021 is presented in Fig. 5. There, it can be seen how the energy needs drop in April following the lockdown restrictions and do not recover the previous year trend until July, moment in which the normal activity started to recover in most islands. It also shows how 2021 is quite similar to 2019 although the generation remains lower.

### 3.2. Generation

The country has an extremely seasonal renewable resource, with most of its wind and solar power potential concentrated from September to June. This pattern partly explains the renewable shares reduction during the summer months as depicted in Fig. 5. Already before the pandemic, and due to the blackout risk, the SO applies curtailment in order to limit renewable penetration rates around 20%. Therefore, in terms of energy mix, 2020 was not a special year.

Fuel consumption for electricity generation is presented in Fig. 6, along with the CO$_2$ emissions. Fuel usage presents an overall slow growing trend, but uneven regarding the different fuels, which is caused by generator diversity in age, efficiency and fuel employed. In that sense, diesel consumption is roughly steady as it powers most of the small islands, hence having low relative importance. Then, marine distillate oil (MDO) is only marginally used from its inclusion in São Vicente on 2019. While fuel oil 380 (F380) displaces fuel oil 180 (F180) from 2018 due to the replacement of different generators. However, their proportion stays the same during 2020, and 2021 as no modifications were made in terms of installed capacity. Regarding emissions, these have been estimated based on the liters of fuel consumed of each type, as reported by the SO, the average density, and the emissions per kg. This data is summarized in Table 1. The 6.3% emission reduction from the expected value, depicted in Fig. 6, can only be associated to the effects of COVID-19, since the energy mix was not varied and the RES penetration rates stayed in the same range as previous years.

### 3.3. Reliability

Generally speaking, the introduction of RES units in any power grid causes an inertia reduction as synchronous generators are displaced in the energy mix. Cape Verde is no exception to this trend, and has experienced a higher number of blackouts since 2010s due to the increasing RES and operational complexity. Accordingly, the SO has been targeting a series of improvements in maintenance and operation over the last decade in order to improve reliability; which they monitor using the SAIFI and SAIDI indexes. Briefly, SAIFI computes the number of power disruptions to be expected by the average user. While SAIDI monitors the average duration of such disruptions. These indexes present a declining tendency as depicted in Fig. 7. While, they are still far away from European standards, where both values are below 2 [35], they are much better than the rest of Sub-Saharan Africa, where SAIDI and SAIFI average 700 and 170, respectively [36]. During 2020, there was a general reduction in the number and duration of blackouts, except for Santo Antão, Sal and Santiago. On the other hand, Maio and Brava, the smallest islands, present the lowest reliability. Interestingly, SAIDI maintains its descending tendency, while SAIFI worsened in 2021.
3.4. Losses

The SO estimates losses based on the difference between generated and billed energy. In that sense, the archipelago presents high power losses in general, which forced the SO to implement a number of measures over the years in order to lower them. Such actions had effectively caused a yearly decline in losses since 2017. However, this promising tendency was lost with the arrival of the pandemic, as they rose by 8.3% in 2020. Nevertheless, it should be noted that all islands presented 7 to 18% except for Santiago, which reaches 36.3%. The yearly evolution of the losses for the whole country is presented in Fig. 8.

The SO suspects that the main reason for the losses increase is theft. The restrictive measures imposed due to the pandemic damaged extremely the local economies, which forced a lot of people to either connect illegally to the power grid or to alter the metering devices. However, the SO actively fought this situation from September onward and they expected improvements in 2021, which in fact came to happen.

4. Effects on energy economy and workforce

Fig. 9 presents a visual summary of the energy sold distributed by sectors, and the total income as reported by the SO along with the predicted amount for 2020. The largest drop in energy consumed corresponds to industry, which reached 18.6%. Others like the municipalities reduced marginally. While the household level increased 4%. However, we must take into consideration the aforementioned losses increase due to theft. This occurs mostly at household level consumption which suggests that the household level energy use actually increased from 10 to 12%. On the other hand, income reduced by 0.1% with respect to 2019 and 1% respect to the predictions, which would be compensated by the stolen energy.

We faced serious limitations when trying to analyse the effects on the energy sector workforce as the only available data was related to the number of employees, their type of contract and education hours. The latter is far from an arbitrary criteria as the archipelago presents a lack of skilled labourers and requires an increasing number of them. Fig. 10 presents the number of employees divided into those with permanent and temporal positions, along with the amount of hours invested in employees education. There we can see how the effects were quite limited. In general, there is a positive tendency in reducing the number of temporary employees in favour of permanent, which is a symptom of a healthy working environment. However, educational hours were deeply reduced during 2020, as nearly no activities could be conducted due to the pandemic. Then, in 2021, they were compensated by reaching record values. Nevertheless, since data available only spans four years, it is not possible to conclude regarding trends.

5. Effects on other sectors

The effects of the pandemic propagated to other sectors strongly coupled with energy, such as: water and transport. For instance, desalination is the main source of freshwater available in Cape Verde and represents the highest electric load in all islands. Until 2019 the water consumption was growing at a yearly rate of 5.35%. However, it dropped by 3.13% during 2020, which was driven by industry with a 27.9% water consumption reduction. Nevertheless, the pandemic did not slowed down the government plans of strengthening the water infrastructure of the country with new investments [20].

Regarding air transport, there was a 62 and 71% reduction in the number of airport movements and passengers. While imports and exports via airplanes dropped by 42 and 59%, respectively. On the
other hand, maritime transport presented a lower reduction, of 21, 32 and 37% in the number of ships, passengers and tonnes of goods. Nevertheless, there were signs of recovery during the second half of 2021 due to the increasing vaccination rates. Regarding land-based transport, the only available data is regarding public buses, which drove 31% less distance, carrying 32% less users. On a different note, the government also passed a law aiming to gradually substitute all cars for electric vehicles. To that effect, several public and private charging stations will be installed across the islands, and new budgetary provisions have been prepare to support this transition [37].

6. Recovery

Electricity, desalination and transport exemplify the effects of the COVID-19 pandemic. The data shows the struggle of a developing country that got cut out of their main source of income and lost a big proportion of the local industry, ultimately forcing part of the population to incur in electricity theft. However, during 2021 most of the economic pressure was alleviated, due to the re-start of tourism. Preliminary data from the first two quarters of 2021 point towards a recovery. Air traffic is still below pre-pandemic values, but has raised significantly and presents a positive outlook. Then, both sea and land-based transport have nearly recovered, and 2021 almost reached pre-pandemic values. [38,39].

Regarding electricity and water consumption, we see clear signs of recovery. The recorded values are still slightly lower than 2019, but it wouldn’t be a surprised if 2022 showed growth already.

7. Conclusions

The pandemic and its countermeasures affected Cape Verde’s energy system deeply. For instance, electricity demand fell by nearly 10% although in a heterogeneous manner across the islands and sectors. Such reduction was positively correlated with GDP, as the richest islands are also the most touristic. Industry was the sector showing higher consumption reduction and household level presented the highest growth. Consequently, overall fuel consumption was reduced, although while keeping the proportional distribution among the different available fuels. Therefore, the pandemic influenced an emission reduction of 6.3%. On a different direction, the energy mix was not affected since the SO limits renewable shares to 20%. Therefore, curtailment increased, specially for wind power. Then, regarding reliability, both SAIDI and SAIFI indexes kept their improving tendency, which presents Cape Verde as one of the most reliable electric systems in Sub-Saharan Africa.

The economic impact of the pandemic was dramatic, which motivated parts of the population to incur in energy theft, causing the overall system loses to increase by 8.3%. However, the SO reports improvements in this regard from late 2020. Both theft and regular demand reduction caused a slight income decline for the SO. Yet, luckily, this barely affected the energy sector’s labour force, which kept the total employees reducing temporary positions in favour of permanent ones. In fact, the main effect on the employees was the attrition of education hours.

While the severity and long term impacts of COVID-19 remain still uncertain, it is worth mentioning, first, that it is possible to observe a partial recovery from late 2020 due to the increased energy demand, although it is still far from pre-pandemic values. Second, the reports from 2021 show clear improvement over 2020 figures almost reaching pre-pandemic values.

The pandemic’s energy impact in other countries showed differences across regions. This variations are easier to spot in Cape Verde as each individual island presented a different behaviour. The most touristic, which also present the highest GDP, suffered the largest consumption drops, while the poorer islands, focused on agriculture, only suffered minor reductions. In addition, the increase in energy theft is a clear marker of the endured economic crisis. Nevertheless, reliability indexes showed improvements, which is probably due to the fact that the labour force was not reduced in the energy sector. The case of Cape Verde highlights the electricity sector and its interconnections with water desalination and transport as markers of the overall activity in the country. We recommend to combine the three of them when monitoring the post-pandemic evolution of other island regions.

CRediT authorship contribution statement

Daniel Vázquez Pombo: Conceptualization, Methodology, Software, Validation, Formal analysis, Resources, Data curation, Writing – original draft, Visualization.

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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Appendix. Supplementary data

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