Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Elsevier hereby grants permission to make all its COVID-19-related research that is available on the COVID-19 resource centre - including this research content - immediately available in PubMed Central and other publicly funded repositories, such as the WHO COVID database with rights for unrestricted research re-use and analyses in any form or by any means with acknowledgement of the original source. These permissions are granted for free by Elsevier for as long as the COVID-19 resource centre remains active.
Trend analyses of electricity load changes in Brazil due to COVID-19 shutdowns

Danielle Bandeira de Mello Delgado\textsuperscript{a}, Karollyne Marques de Lima\textsuperscript{b}, Marianna de Camargo Cancela\textsuperscript{c}, Camila Alves dos Santos Siqueira\textsuperscript{d}, Monica Carvalho\textsuperscript{e,}* , Dyego Leandro Bezerra de Souza\textsuperscript{f,}\textsuperscript{g}

\textsuperscript{a} Graduate Program in Mechanical Engineering, Federal University of Paraíba, João Pessoa, Brazil
\textsuperscript{b} Graduate Program in Renewable Energy, Federal University of Paraíba, João Pessoa, Brazil
\textsuperscript{c} Division of Surveillance and Situation Analysis, Brazilian National Cancer Institute, Rio de Janeiro, Brazil
\textsuperscript{d} Graduate Program in Collective Health, Department of Collective Health, Federal University of Rio Grande do Norte, Natal, Brazil
\textsuperscript{e} Department of Renewable Energy Engineering, Federal University of Paraíba, João Pessoa, Brazil
\textsuperscript{f} Research Group on Methodology, Methods, Models, and Outcomes of Health and Social Sciences, University of Vic-Central University of Catalonia, Spain
\textsuperscript{g} Department of Collective Health, Federal University of Rio Grande do Norte, Natal, Brazil

**ARTICLE INFO**

**Keywords:**
Pandemic
Electricity
Energy sector

**ABSTRACT**

This study aims to calculate and assess the electricity load trends for Brazil and its geographic regions, considering the changes due to the COVID-19 pandemic. Statistical trends were evaluated by the Joinpoint software, and the analysis comprehended the period between January 1 and September 29, 2020. Daily load data were grouped into weeks, with the calculation of weekly percentage changes considering a 95% confidence interval and $p<0.05$. The weekly electricity loads were compared in the periods before and after physical distancing decrees were enforced in Brazil (March 15, 2020). The decreases were different across the regions: the South subsystem presented the highest drop, with -19% when comparing the medians before and after implementation of the physical distancing measures. The Southeast and Northeast regions accompanied the decline, with decreases of -15% and -14%, respectively. The North region, however, has almost returned to initial levels, with a decrement of -3%.

1. Introduction

The various states of emergency declared around the world, as a response to the COVID-19 pandemic, have required that only essential businesses were permitted to operate (International Energy Agency - [1]). Most non-essential businesses and services adopted “home office” approaches. As a result, new energy use patterns are emerging: residential loads have increased and shifted, while commercial and industrial loads have decreased. Disruptions due to the COVID-19 pandemic are causing severe socioeconomic issues, including the closure of schools and universities, partial or full shutdowns of industries and the tertiary sector, and changes in family dynamics.

Energy systems are the cornerstone of the economy, strongly related to economic development [2], and crucial to healthcare and scientific investigation, which are required to mitigate the effects of the COVID-19 pandemic. Understanding how electricity loads are shifting across sectors can help avoid disruptions and even shutdowns of energy systems and quantify the impact and meaning of the new load curves for utilities and consumers. North American power markets could experience disruptions for at least 18 months due to the economic shutdown, and electricity loads have declined 5%–15% [3]. Electricity bills are based on different local tariff structures and time-of-use rates, but increases of 20–30% (as expected by [4] for some locations of the USA) are very significant, especially for families experiencing income losses. Identification of the changes in electricity loads can help quantify the economic impact of COVID-19 [5] and even enforce climate change-related schemes [6].

In the Brazilian Electricity Sector, the pandemic has raised the concern of agents, governments, and consumers due to the possible economic and financial impacts, demanding actions that ensure the solvency of the sector (Brazilian Electricity Regulatory Agency - [7]). Electricity loads have decreased during lockdowns [8], and increases in

---

\* Corresponding author.
\E-mail address: monica@cear.ufpb.br (M. Carvalho).

https://doi.org/10.1016/j.epsr.2020.107009
Received 24 July 2020; Received in revised form 8 November 2020; Accepted 18 December 2020
Available online 23 December 2020
0378-7796/© 2020 Elsevier B.V. All rights reserved.
residential energy loads were far outweighed by reductions in commercial and industrial operations [9]. Monitoring electricity-related load data over time can gauge the effects of the COVID-19 crisis and associated lockdowns. A study carried out by the Brazilian Chamber of Commercialization of Electricity [10] predicted a reduction of 2.9% in the electricity load for 2020. This progressive decline has been intensified since March 21, 2020, after the enforcement of measures to contain the dissemination of COVID-19. At the end of May 2020, the decrease in the Free Contract Market had been 18%, due to low consumption levels in the main sector of the economy – the demand of the Regulated Contract Market was 13%, which is a less pronounced drop due to the continuity of the demands of the residential sector [10].

The effects of the pandemic were felt in all stages of the Brazilian Electric Power System, from generation to consumption. The significant decrease in consumption led to a decline in the power dispatched by the Electric Power System, from generation to consumption. The significant decrease in consumption contributed to a recovery of the water levels of the Southeast-Midwest reservoirs and the maintenance of the level of the South reservoirs (Brazilian National Electric System Operator – ONS) [11]. The decline in the energy load of the Brazilian National Interconnected System (NIS) predicted for 2020 should reduce by 2.9% in comparison with 2019 values, which is a decrease of 1969 MWmean – this translates into approximately 1.4 GWhmean less than the amount predicted in the annual plan of energy operation 2020–2024 [12].

As the Brazilian COVID-19 situation is currently still unfolding, the oscillating plateau region has not been met yet, with oscillations in the numbers of new cases on the way up. Besides the obvious health-related tragedy, significant issues will arise in different fields, especially in the electricity sector. Due to the fast dissemination of COVID-19, its impact on the electricity sector is still underexplored. Recognizing the health-, economic-, and energy-related effects of the pandemic, the study presented herein developed statistical trend analyses to identify the effects of COVID-19-related mobility restrictions on Brazilian electricity loads. To this end, electricity load data were collected for Brazil and its geographic regions since January 1, 2020. This study presents timely information that enables the electric sector agents to build a load profile and analyze the dispatches of electricity to the system. Data provided herein can also contribute to the strategic orientation of economic-financial support actions to the electric sector and direct the formulation of policies for the smooth recovery of the sector.

2. Materials and methods

2.1. Electricity load data

Electricity load data were obtained from the National Interconnected System (NIS), which does not include the state of Roraima. Data were made available from the operation history of the Brazilian National Electric System Operator (ONS) [13], which is an official information platform. Daily data considered the values provided by the daily energy balance of ONS, of consumption plus losses, from the power plants that constitute the system. All data are publicly available. Data collection required a considerable effort: data were available graphically [13], and one subsystem was consulted at a time, with daily data (148 days) collected for each regional subsystem and the overall Brazilian system. Data were manually extracted and introduced into a spreadsheet.

Electricity load data were collected as mean MegaWatts (MWmean), considering the period from January 1, 2020, until September 29, 2020, for the Northeast, North, Southeast-Midwest, and South subsystems, and the Brazilian overall system. Daily data were grouped into weeks and analyzed considering the weekly mean power required by the Brazilian system and its regional subsystems.

3. Statistical analysis

Data were analyzed by the Joinpoint Regression Program20, version 4.8.0.1 [14]. This program assesses the trends throughout time, according to significant modifications in their evolution patterns. As daily data were grouped into weeks, the temporal unit employed herein was one week. Trend analysis encompassed a total of 39 weeks. Grouping data in weeks enables a more precise evaluation of trends, as daily load data could be susceptible to oscillations due to the variation in electricity loads during weekdays and weekends.

The program identifies the joinpoint (time points in which the trend significantly changes) and calculates the percentage of change per time interval. It is possible that the trend curve presents more than one joinpoint, or that no joinpoint is identified (no change in pattern). The regression takes electricity load trend data and fits to the simplest joinpoint model allowed by data. The regression starts with zero joinpoints (which is a straight line) and tests whether more joinpoints are statistically significant and must be added to the model (up to the maximum number defined by the user). This enables the user to test that an apparent change in trend is statistically significant. The Monte Carlo Permutation method is employed to test the significance.

The Week Percentage Change (WPC) was calculated to identify the statistical significance for each segment (p-value<0.05), with a 95% confidence level. The analysis was carried out considering assumptions of heteroscedasticity and variance of Poisson. Significant modifications in the curve represent the joinpoints. The connection of linear elements by a graph enables a succinct characterization of trends, which enables the evaluation of an indicator throughout a time interval [15]. For the periods with a statistical significance of WPC, the trends can be classified as “increasing” or “decreasing.” For those values with no statistical significance, the term “stable” was employed. Models with zero to three joinpoints were analyzed, and the model that presented the best fit with observed data was selected.

A comparative analysis was also carried out between the period prior to the beginning of the isolation decrees in the country (until March 14) and the period after (as of March 15). The objective of this analysis was to compare the existence of significant differences between the load averages at the beginning and at the end of the evaluated period, for each of the Brazilian subsystems studied. Means, medians, and standard deviations were calculated, along with Student’s t and Mann-Whitney U tests, at a 95% confidence level and statistical significance for p<0.05. Student’s t-test compares the means of two independent groups to determine whether there is statistical evidence that the associated population means are significantly different. The Mann-Whitney U test is used to compare differences between two independent groups when the dependent variable is either ordinal or continuous, but not normally distributed.

4. Results and discussions

Since the onset of the COVID-19 pandemic, there has been a broad variety of studies developed to investigate the impact of the COVID-19 outbreak on different sectors. Fig. 1 shows the behavior of the weekly load power in the Brazilian system, and Fig. 2 depicts the weekly load for the geographic regions. This assessment demonstrates the utility of joinpoint regression for the energy sector, focusing on electricity. Reductions in load demand can ease the operation of the electric system by releasing more security margin. However, changes of load shape and distribution as well as the lockdown policy still bring challenges for the power, as mentioned by Zhong et al. [16].

In Fig. 1, there are two joinpoints for the Brazilian system, at weeks 11 and 16. Between week 1 and 11, the WPC was 0.13, representing an almost stable trend (although statistically non-significant). For weeks 11–16, the WPC indicated a statistically significant decreasing trend with −4.77, followed by a relatively stable period for weeks 16–39 with WPC 0.79 statistically significant.
The behaviors presented for the Brazilian subsystems (geographic regions) in Fig. 2 are similar to Fig. 1, with two joinpoints. For the North region, all trends were statistically significant, with a slightly increasing trend between weeks 1 and 9, a pronounced decreasing trend for weeks 9–16, followed by an increasing trend for weeks 16–39. For the Northeast region, there was a relatively stable behavior at the beginning, between weeks 1 and 10, followed by a sharp decrease for weeks 10–17 (statistically significant), and then with a statistically significant increase after week 17.

For the Southeast/Midwest subsystem, a stable trend was identified for weeks 1–11 (positive), followed by statistically significant trends for weeks 11–16 (sharp decrease with WPC \(-5.65\)) and 16–39 (increasing).

Similar behavior was verified for the South region, with a relatively stable trend for weeks 1–11, followed by a statistically significant drop (WPC \(-6.70\)) between weeks 11 and 15, and after week 15 there was a slightly increasing trend (statistically significant).

Table 1 shows a comparison of data before (January 1–March 14) and after (March 15 – September 29) the beginning of the isolation decrees in Brazil.

The results demonstrate a reduction in the Brazilian electricity loads for the overall Brazilian system and its subsystems when comparing the periods before and after the beginning of mobility restrictions due to COVID-19. Because of the different load profiles within the Brazilian subsystems, the decreases were also different across the regions. The South and Southeast-Midwest subsystems presented the highest drops, \(-19\% and \(-15\%, respectively, when comparing the medians before and after implementation of the physical distancing decree. The Northeast region accompanies the decline, with a \(-14\% decrease. However, the North region has already almost returned to initial levels, with a decrement of \(-3\% when comparing periods 1 and 2. Regarding the overall Brazilian system, the decrease in electricity loads is still considerable, \(-15\%.

However, when comparing period 1 with a modified version of period 2 (March 15 – May 27), the Southeast-Midwest and South subsystems presented the highest drops, \(-21\% and \(-19\%, respectively, when comparing the medians before and after implementing the physical distancing decree. The North and Northeast regions less pronounced declines, with 14.50% and 7%, respectively. These pronounced drops have been smoothed out throughout time, as activities have gradually resumed in June and July.

Because the electricity loads of the Northeast subsystem are mostly associated with residential consumers, this region has been less affected. In the case of the North subsystem, the concentration of metallurgical industries in the area has alleviated the drop \[17\]. These drops generate
distortions that can entail increases in costs for consumers and organizations and could lead to a reorganization of the electric sector by the government (which should include discussions on the weight of subsidies in the cost of electricity in Brazil).

Changes in daily load curves are already visible. As mentioned by Fell [18], the mid-afternoon peak loads (although the winter season is beginning in Brazil, air-conditioning is employed year-round for comfort) have shifted to the evening.

Impacts from the coronavirus pandemic on the electricity sector are beginning to appear worldwide, with shifting load patterns and load drops in several regions. As the mild weather arrives at the North hemisphere, and if business and industrial activities remain closed, load suppression will continue. In Tunisia, an unhealthy load curve appeared, with a 1 GW difference between the daily off-peak and peak [19] - this represents half of the maximum load, leaving the operation of the system operation in a challenging technical scenario, with increasing costs. In Italy, considering when the most restrictive measures were announced (week 9–15 March 2020), the electricity load decreased considerably due to the progressive blockage of production activities, with an accumulated decrease of 151.33 GWh when comparing with the same week in 2019 [1,20]. Clair [21] reported a 20% decrease in electricity load in France (strict lockdown), a 18% decrease in Andorra, Portugal and Spain (very strict lockdown, business stopped in Spain) and in Belgium, the Netherlands, and Luxembourg, and a 12% decrease in the United Kingdom, suggesting a very significant impact with a good correlation with the strictness of confinement measures.

The International Labour Organization [22] published a report estimating the worldwide potential to work from home and verified that 20%–30% of occupations can be performed remotely. This means that, if commercial energy loads do not recover and home-based work is the “new normal”, surplus generation will be an issue faced by energy distributors. This assumes that the increase in residential energy loads will partially offset the expected decline in commercial and industrial loads, which was not verified in Italy, for example [23].

With commercial/industrial loads shifted to the residential sector, some governments are changing payment plans to help mitigate the increase in domestic bills – which, for the many citizens experiencing the economic consequences of the crisis, is a significant issue. On March 24, 2020 the ANEEL temporarily established (for 90 days) that Brazilian urban and rural residential consumers would not have electricity supply suspended due to lack of payment [24]. This measure included services and activities considered essential. On April 8, 2020, the Brazilian government exempted eligible low-income residential consumers from the payment of tariffs between April and June [25]. The COVID account is a program introduced by Resolution 885 [26], which enabled the injection of resources to improve the cash flow of the sector, increasing the amortization time for paying off debts and suspending power cuts in an attempt to avoid market losses and protect consumers against increases in tariffs. Specific sectoral funds financed the increase in the social tariff discount and to guarantee the liquidity of energy suppliers (approximately 400 million USD were allocated to this end). Different horizons of energy policy responses to the COVID-19 crisis were reported by Steffen et al. [27], including short-term horizon (months) immediate crisis response, mid-term horizon (years) economic recovery, and long-term horizon (decades) making the energy transition shock-proof.

Electricity prices in major markets have slumped (with European electricity markets having witnessed the maximal price decrease across the world) [16]. Brazil presented a considerable variation in the marginal cost index of electricity, when comparing with previous years. Brazil registered zero marginal cost for electricity, for all subsystems, during some periods of 2020 [28]. This indicates that most of the electricity generated originated from solar, wind, and hydro (no fuel costs).

The scenario is still uncertain, and these estimations and projections must be updated every week to reflect either more stringent or more flexible physical distancing measures enforced by the government. The COVID-19 pandemic imposed strict sanitary policies to contain the virus, which caused a global drop in economic activities. In the electricity sector, the main impacts are related to a loss of liquidity of payment flows due to the decrease in consumption, increase in nonpayment rates, and dynamics of the indicators of technical and non-technical losses [7]. The two transmission auctions that were scheduled for the beginning of 2020 were delayed to December 2020 – which means that investments of approximately R$ 7.6 billion were postponed to 2021 and 2022 [29]. As a consequence, the expected transmission investments for the next transmission auction been reduced from R$ 15.0 billion to R$ 7.4 billion.

Recognizing that the current situation is, above all, a health crisis, the study of COVID-19-related trends is relevant to understand the dynamics of the pandemic after social restrictions are enforced [30] and should include other sectors affected. As mentioned by Rosenbloom and Markard [6], continuous adaptation and attention to the context will be required to tackle the shifts in electricity loads. Considering a direct relationship between electricity load change and Gross Domestic Product change, following Fezzi & Fanghella [31], in the very short-run the heterogeneous impacts of the pandemic across sectors cannot be separated. Some activities have verified an increase in revenue (food supply and e-commerce, for example) while companies of the manufacture hospitality, and personal service sector have been negatively affected.

As a large-scale and complex network, the electricity sector has significant effects on the environment: one of the consequences of the behavioral changes of people has been a decrease in global greenhouse gas (GHG) emissions. These decreases are not permanent, but have certainly motivated further adjustments in the use of transportation, and heating and cooling. Due to these electricity drops, the participation of renewable sources has increased and been sustained due to a decrease in the need to use non-renewable energy sources, with environmental benefits. The emission cuts could reach 2 GT CO2-eq, which is a major

### Table 1

Comparison of the periods before (1) and after (2) March 15, 2020: minimum and maximum electric power, mean load, standard deviation, and median load value (all in MW) for Brazil and its geographic regions.

| Region/Subsystem | Period | Minimum power (MW) | Maximum power (MW) | Mean (MW) | Standard deviation (MW) | Median (MW) | p-value |
|------------------|--------|--------------------|--------------------|-----------|-------------------------|-------------|---------|
| North            | 1      | 36,868.00          | 39,556.00          | 38,326.73 | 842.93                  | 38,485.00   | 0.180* |
|                  | 2      | 34,167.00          | 42,332.00          | 37,785.96 | 2288.45                 | 37,153.50   |         |
| Northeast        | 1      | 72,795.00          | 79,746.00          | 76,089.27 | 2258.83                 | 77,520.00   |         |
|                  | 2      | 64,778.00          | 73,830.00          | 67,780.00 | 2431.88                 | 66,992.50   |         |
| Southeast-Midwest| 1      | 256,275.00         | 289,423.00         | 275,198.27| 10,653.56               | 277,036.00  |         |
|                  | 2      | 213,427,00         | 273,980.00         | 236,853.50| 17,521.50               | 234,671.00  | <0.001* |
| South            | 1      | 78,901.00          | 97,353.00          | 89,413.36 | 4994.39                 | 89,729.00   | <0.001* |
|                  | 2      | 66,927.00          | 82,139.00          | 73,208.64 | 3218.79                 | 72,914.00   |         |
| Brazil           | 1      | 444,842.00         | 497,843.00         | 479,928.73| 15,989.58               | 484,522.00  |         |
|                  | 2      | 385,439.00         | 464,875.00         | 415,615.75| 24,997.05               | 411,516.00  |         |

* Student’s test.,  
* Mann-Whitney’s test.
contribution to efforts to reach net-zero emissions by 2050 [32]. Regarding the expected health effects of reduced air pollution from COVID-19 physical distancing (given the decreases in travel and electricity use), the study by Cicala et al. [33] estimates U.S. county-level improvements in air quality, leading to an expected decline in mortality. However, despite the importance of GHG emissions for understanding global climate change, there is no monitoring system for global emissions in real time and GHG emissions are reported a posteriori [34]. Although real time electricity data are available for some locations, there is usually no information on the associated carbon emissions. Due to the forced drop in energy consumption in 2020, daily global GHG emissions decreased by ~17% by early April 2020 compared with the mean 2019 levels.

Just regarding the Brazilian changes, the drop in mean electricity consumption, comparing 2019 and 2020 values for the study period, was 55 GWh. The methodology reported by Carvalho and Delgado [35] was used to calculate the environmental impacts associated with the consumption of electricity from the Brazilian electricity grid (66.67% hydro, 9.28% natural gas, 9.15% wind, 8.25% sugarcane bagasse, 2.79% nuclear, 1.62% coal, 1.55% oil, and 0.69% solar). This leads to 227 t CO\textsubscript{2}-eq/GWh, and considering the decrease recorded during the study period, results in 12,485 t CO\textsubscript{2}-eq. Because of the mobility restrictions and physical distancing measures implemented, the economic downturn has temporarily suppressed emissions, but low economic growth is not a low-emissions strategy.

The IEA [36] has established a Stated Policies Scenario, which reflects current announced policy intentions and targets, for which global energy demand rebounds to pre-pandemic levels in early 2023 - however, this does not happen until 2025 in the event of a prolonged pandemic and deeper slump, as shown in the Delayed Recovery Scenario. This means holding back energy demand and GHG emissions but also slowing many of the structural changes in the energy sector that are essential for clean energy transitions [36].

It is necessary to expand the comfort zone of the electric sector by exploring extreme scenarios, disruptive innovations, and questions that transcend the energy and climate goals across the sustainability spectrum [37]. The economic crisis of 2020 is deeply anchored in constrained individual behavior, due to confinement measures. At the moment of writing (November 2020), second waves of the pandemic are being experienced by many countries, and the duration and depth of the crisis is still unclear. Keeping track of evolving GHG emissions can help inform government responses to the COVID-19 pandemic to avoid locking future emissions trajectories in carbon-intensive pathways. As mentioned Rosenbloom and Markard [6], leveraging recovery programs to advance the climate agenda is an important opportunity to transition toward a more sustainable post-pandemic world.

As mentioned by Werth et al. [38], understanding the impacts of COVID-19 on the electric sector provides unique insights on how critical situations are managed, and this emergency is an important case study to prepare for scenarios of large load reduction and high renewable output. The impacts of the COVID-19 pandemic on the Brazilian electricity loads have been highlighted herein, and it is now the time to underscore the importance of finding ways to support clean energy transitions despite the current challenges. Finally, this study has been elaborated while facts were still developing. Further research is necessary to explore the duration of social changes (e.g., remote working, video conferencing, e-commerce) and how these can contribute to low-carbon pathways.

Conclusions

The shutdowns, lockdowns, and physical distancing measures enforced by the different Brazilian state governments have affected the electricity loads of the country and its different subsystems considerably. Relaying physical distancing measures should indicate a slow return to a business-as-usual scenario. However, it is still early to speculate on whether the pandemic has permanently influenced behavioral patterns. Electricity loads were affected by the mobility restrictions enforced to contain the dissemination of the COVID-19 pandemic. As a result, load forecasts are being revised to consider changes in work and school operations.

The COVID-19 pandemic and the consequent reductions in mobility and consumption have directly affected the financial health of the Brazilian electric sector, especially of the electricity distribution agents, which are the sector responsible for financial collection. In this sense, the governmental actions to promote the economic-financial balance and the health of the sector (preserving the generation, transmission, and distribution chain) were mainly focused on contracts.

This study evidenced that the Brazilian geographic regions presented different electricity load profiles, with different decrease dynamics, as the decrees that regulated mobility restrictions were issued on different dates. Based on this information, it is essential that these dynamics are observed nationally and regionally, leading to effective supporting actions.

The severity and long-term impact of COVID-19 on the electric sector is an important area of future research. Future work by the authors includes the disaggregation of energy data into residential, industrial, commercial sectors, considering the overall Brazilian system and its regional subsystems.

Funding

The authors wish to acknowledge the support of the National Council for Scientific and Technological Development (CNPq, Research Productivity grant 307394/2018-2) and the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (Caps) - Finance Code 001.

CRediT authorship contribution statement

Danielle Bandeira de Mello Delgado: Methodology, Writing - original draft. Karolynne Marques de Lima: Data curation, Writing - review & editing. Marianna de Camargo Canesla: Validation, Visualization. Camila Alves dos Santos Siqueira: Data curation, Visualization. Monica Carvalho: Conceptualization, Supervision, Funding acquisition, Writing - review & editing. Dyego Leandro Bezerra de Souza: Methodology, Supervision, Resources.

Declaration of Competing Interest

None.

References

[1] IEA. Covid-19 impact on electricity. 2020a. Available at https://www.iea.org/reports/covid-19-impact-on-electricity. Access 07 jun 2020.
[2] N. Howarth, M. Galeotti, A. Lanza, K. Dubey, Economic development and energy consumption in the GCC: an international sectoral analysis, Energy Transit. 1 (2) (2017) 6.
[3] Walton, R. (2020). Electric grid challenges will grow if COVID-19 impacts extend into summer demand season: NERC. Available at: https://www.utilitydive.com/news/electric-grid-challenges-will-grow-if-covid-19-impacts-extend-into-summer-d/576705/ >. Access 09 jun 2020.
[4] Duly, F.; Names, T.; Ratnathicam, I.; McPhail, D. (2020). How COVID is impacting residential energy use – the first three weeks of data. Available at: https://uplightblog.com/blog/how-covid-is-impacting-residential-energy-use-the-first-three-weeks-of-data/. Access 09 jun 2020.
[5] S. Chen, D. Igan, N. Pierri, A.F. Presbitero, Tracking the Economic Impact of COVID-19 and Mitigation Policies in Europe and the United States, Working paper, Int. Monetary Fund (2020).
[6] D. Rosenbloom, J. Markard, A COVID-19 recovery for climate, Science 368 (6490) (2020) 447.
[7] ANEEL (2020a). Technical note n° 01/2020-GMSE/ANEEL. Available at: https://www.aneel.gov.br/documents/656877/0/NT.pdf/901e12ed-ea7d-91a7-c805-e27b2508a2ee Access 01 jul 2020. [In Portuguese].
[8] Allerman, R. (2020). Covid-19 electricity load impact april 9, 2020 Available at: https://www.enerversa/wp-content/uploads/2020/04/Covid-19-Load-impacts-April-9-2020.pdf Access 09 jun 2020.
[9] IEA. COVID-19. Exploring the impacts of the Covid-19 pandemic on global energy markets, energy resilience, and climate change. 2020b. Available at: https://www.iea.org/reports/global-energy-review-2020. Access 07 jun 2020.

[10] BCCE. Monitoring of consumption in function of Covid-19. (2020). Available at: http://www.ccee.br/portal/faces/pages/publico/noticias-opiniao/noticias/noticialeitura?contentid=CCCE_654416&afilo=57864411935056&afilo=01&state=fr989cvd_137#.X%4%0%4%0%Contentid=CCCE_654416%26afilo=0D7864411935056%26afilo=01&state=fr989cvd_141. Access 08 jun 2020. [In Portuguese].

[11] ONS. Load predictions for the 2020-2024 extraordinary load review. (2020b). Available at: http://www.ons.org.br/paginas/noticias/20200323-ONS-verifica-redu%C3%A7%C3%A3o-da-carga-m%C3%A9dia-de-energia-nos-%C3%BAltimos-dias.aspx. Accessed 01 jul 2020. [In Portuguese].

[12] ONS. Summary of the monthly operation program. (2020d). Available at: http://www.ons.org.br/paginas/conhecimento/acervo-digital/documentos-e-publicacoes?categoria=Relat%C3%ADrios&PMO=ACAO. Accessed 31 oct 2020.

[13] IEA. Achieving net-zero emissions by 2050. 2020c. Available at: https://www.iea.org/reports/global-energy-outlook-2020/achieving-net-zero-emissions-by-2050. Access 28 oct 2020.

[14] National Institutes of Health. National cancer institute. division of cancer control & population sciences. (2020). Joinpoint Trend Analysis Software version 4.8.0.1. Available at: https://surveillance.cancer.gov/joinpoint/. Access 07 jun 2020.

[15] H.J. Kim, M.P. Fay, E.J. Feuer, D.N. Midthune, Permutation tests for joinpoint regression with applications to cancer rates, Stat. Med. 19 (3) (2000) 335–351.

[16] H. Zhong, Z. Tan, Y. He, L. Xie, C. Kang, Implications of COVID-19 for the Italian electricity system. (2020) 885. Available at: https://www.in.gov.br/en/web/dou/-/resolucao-normativa-n-885-de-23-de-junho-de-2020-2630390115. Access 24 oct 2020. [In Portuguese].

[17] Fabregas, D.L.B de Souza, The effect of lockdown on the outcomes of COVID-19 in Spain: an ecological study, PLoS ONE 15 (7) (2020), e0236779.

[18] C. Feizi, V. Fanghella, Real-time estimation of the short-run impact of COVID-19 on economic activity using electricity market data, Environ. Resour. Econ. 76 (4) (2020) 885–900.

[19] IEA. Achieving net-zero emissions by 2050. 2020c. Available at: https://www.iea.org/reports/world-energy-outlook-2020/achieving-net-zero-emissions-by-2050. Access 28 oct 2020.

[20] Carvalho M., Delgado D.B.M. Potential of photovoltaic solar energy to reduce the emissions during the COVID-19 pandemic. 2020. Available at: https://www.fsr.eui.eu/covid-19-and-the-brazilian-electricity-sector/Access 06 jul 2020. [In Portuguese].

[21] B. Steffen, F. Egli, M. Pahle, T.S. Schmidt, Navigating the clean energy transition in the COVID-19 Crisis, Joule 4 (2020) 1137–1141.

[22] N. Rodrigues, L. Losekann, Impacts of COVID-19 on the Electricity Demands and its implications for Brazil. Editora Brasil Energia, Rio de Janeiro, 2020.

[23] A. Nikas, A. Gambhir, E. Trutnevyte, K. Koasidis, H. Lund, J.Z. Thellufsen, I. Sognnaes, Perspective of comprehensive and comprehensible multi-model energy market pricing of energy and ancillary services during pandemic of COVID-19 in Italy. Energies 13 (13) (2020 Jan) 3357.

[24] BRASIL. (2020b). Normative resolution n 885, of June 23, 2020. It provides for COVID-ACCOUNT, financial operations, the use of the energy development account (EDA) tariff charge for these purposes and the corresponding procedures. Available at: https://www.in.gov.br/en/web/dou/-/resolucao-normativa-n-885-de-23-de-junho-de-2020-2630390115. Access 24 oct 2020. [In Portuguese].

[25] IEA. COVID-19. Exploring the impacts of the Covid-19 pandemic on global energy markets, energy resilience, and climate change. 2020. Available at: https://www.iea.org/reports/global-energy-review-2020. Access 10 jun 2020. [In Portuguese].

[26] BCCE. Monitoring of consumption in function of Covid-19. (2020). Available at: http://www.ccee.br/portal/faces/pages/publico/noticias-opiniao/noticias/noticialeitura?contentid=CCCE_654416&afilo=57864411935056&afilo=01&state=fr989cvd_137#.X%4%0%4%0%Contentid=CCCE_654416%26afilo=0D7864411935056%26afilo=01&state=fr989cvd_141. Access 08 jun 2020. [In Portuguese].

[27] ANEEL. (2020b). COVID-19: ANEEL approves measures to guarantee the safety of electricity distribution. Available at: https://www.aneel.gov.br/sala-de-imprensa/exibicao-2/-/asset_publisher/zXQRZs8zV1Z6/content/covid-19-aneel-aprova-medidas-para-garantir-seguranca-na-distribuicao-de-energia/656877/inheritRedirect=false. Access 10 jun 2020. [In Portuguese].