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.
Assessment of the COVID-19 pandemic effect on regional electricity generation mix in NYISO, MISO, and PJM markets

Derya Eryilmaz*, Margarita Patria, Caroline Heilbrun

Charles River Associates, 200 Clarendon St., Boston, MA, United States

ARTICLE INFO

Keywords:
Covid-19
regional electricity markets
generation mix

ABSTRACT

This paper explores the impacts of the stay-at-home advisory issued in response to the COVID-19 pandemic on regional electricity generation fuel mixes for the three major RTOs: NYISO, MISO, and PJM. We find that the COVID-19 pandemic affected these regional markets differently, although one common finding is that overall electricity generation declined after the stay-at-home advisories were issued. We also empirically tested the impact of the stay-at-home advisories on electricity generation for different fuel types.

1. Introduction

The COVID-19 pandemic has created immediate and observable impacts on power markets in the United States. The first noticeable impact on the U.S. power industry was a downward shift in electricity demand across regional transmission organizations (“RTOs”). There was a significant and almost-immediate drop in electricity consumption amongst residential, commercial, and industrial end-use sectors. Because demand determines both the quantity of electricity supplied and the marginal generation dispatched, this swift shift in demand has disproportionately affected the fuel sources of marginal generating units.

In this article, we explore the impacts of the stay-at-home advisory issued in response to the COVID-19 pandemic on regional electricity generation fuel mixes for the three major RTOs: New York ISO (“NYISO”), Pennsylvania-New Jersey-Maryland Interconnection (“PJM”), and Midcontinent ISO (“MISO”). NYISO encompasses the state of New York, which was highly affected by the U.S. COVID-19 outbreak. The MISO territory includes 15 states in the Midwestern U.S. plus Manitoba, and the PJM territory encompasses 13 states along the Eastern seaboard plus Washington, D.C.

1.1. Assessment criteria for regional electricity generation

Electricity generation plants use a mix of fuels that varies by regional market depending on available resources, market prices, and market rules. Each regional market has a certain capacity, delivered cost of fuels, and infrastructure constraints that affect the regional fuel mix. Generation fuel mix may change over time in response to local power plant investments and regulations. We examine the historical total daily megawatts generated by fuel type for NYISO, MISO, and PJM from January 1, 2019 through May 31, 2020. The earliest stay-at-home advisories were issued on March 21, 2020 in the PJM and MISO territories, and on March 22, 2020 in NYISO. After the stay-at-home advisories, there is a sharp decline in total electricity generation from various generation fuels for NYISO, MISO, and PJM.

For each RTO, we calculate the Shannon-Wiener diversity index, a fuel diversity measure of a given generation portfolio. Higher diversity indices indicate a greater variety of generation sources. Further, we compare the average and variance of the diversity index for the periods before and after stay-at-home advisories were issued. Although we do not find an observable difference in the average diversity index before and after the advisories were issued for these RTOs, the variance is ~35% percent lower for MISO and NYISO and 8 percent higher for PJM.

We also examine the hourly load shape by fuel type for the month of April for 2019 and for 2020 to assess the effect of stay-at-home advisories. Overall, we find that peak load shifted down in all three regional markets. We also calculate the Peak-to-Base ratio, showing the share of peak load of total system load on an average day in April 2019 and in April 2020. In all three RTOs, we observe that the share of peak demand of the total generation load was lower in April 2020 compared to the same period in 2019. There are multiple forces at play, however...
it seems reasonable to attribute at least some of the change to the pandemic and the issuance of stay-at-home advisories.

In the following sections, we provide our assessment of the regional electricity generation mix changes that can be attributed to the ongoing pandemic for NYISO, MISO, and PJM.

1.2. NYISO market

In NYISO, nuclear plants have the highest share of electricity generation. Nuclear is followed by natural gas. The average diversity index after the stay-at-home advisory in New York was issued is about 1 percent lower and the variance of the diversity index has declined by about 38 percent. Fig. 1 presents the 7-day moving average daily generation fuel mix by fuel type and the associated diversity index for the NYISO market.

In comparing the load shapes in April 2020 to April 2019, the peak (i.e., highest load) load is approximately 2 percent lower and base (i.e., lowest load) load is 6 percent higher during the pandemic. This suggests that, compared to April 2019, generation from baseload fuel types has increased and peak generation resources were not utilized as much in April 2020. On the other hand, generation from non-wind renewable resources is higher by about 10 percent and generation from natural gas has declined by 12 percent and nuclear has increased by about 3 percent. Further, the Peak-to-Base ratio is lower by 8 percent in NYISO during the stay-at-home advisory, which is the largest decline among the three regional markets.

The hourly load shapes in April 2019 and April 2020 for NYISO are presented in Fig. 2.

1.3. MISO market

The MISO market’s historical generation mix has been quite different from the NYISO market’s generation mix. Since January 2019, coal and natural gas have owned the highest shares in the overall generation portfolio, although we see a significant drop in generation for all fuel types during the pandemic. In contrast to NYISO, in MISO the average diversity index during stay-at-home orders is higher by about 6 percent, but the variance of the diversity index is about 34 percent lower compared to the period before the first order was issued in the MISO territory. Fig. 3 presents the 7-day moving average daily generation fuel mix by fuel type and the associated diversity index for the MISO market from January 2019 through end of May 2020.

Across the three RTOs, we see the highest shift in baseload and peak load in the MISO market. Baseload is about 9 percent lower and peak load is about 12 percent lower during the pandemic compared to the prior period. This suggests that generation from both baseload and peak load fuel sources have declined in April 2020. In fact, the most significant change we observe in baseload generators is that generation from coal resources has declined about 38 percent and nuclear generation has declined about 4 percent. On the other hand, generation from wind is higher by about 10 percent and generation from natural gas is higher by about 2 percent. Further, Peak-to-Base ratio is lower by about 2 percent, which is expected given significant decline both in base and peak load.

The hourly load shapes in April 2019 and April 2020 for MISO are presented in Fig. 4.

1.4. PJM market

Generation mix changes in the PJM market are less pronounced compared to the generation mix changes in NYISO and MISO markets.

In the PJM market, natural gas and nuclear own the highest shares in the overall generation portfolio. The average diversity index during the stay-at-home advisory is higher by about 1 percent. However, the variance of the diversity index is about 8 percent higher than pre-pandemic.

Baseload is about 5 percent lower and peak load is about 2 percent lower during the pandemic compared to the prior period, showing that generation from both baseload and peak load fuel sources has declined in April 2020. The most significant shift is in coal generation, which is about 38 percent lower. Further, generation from natural gas is 13 percent higher during the pandemic compared to the generation from natural gas in prior period. The Peak-to-Base ratio is lower by about 3 percent in the PJM market. The hourly load shapes in April 2019 and April 2020 for PJM are presented in Fig. 6.

Fig. 5 presents the 7-day moving average daily generation fuel mix by fuel type and the associated diversity index for PJM.

Baseload is about 5 percent lower and peak load is about 2 percent lower during the pandemic compared to the prior period, showing that generation from both baseload and peak load fuel sources has declined in April 2020. The most significant shift is in coal generation, which is about 38 percent lower. Further, generation from natural gas is 13 percent higher during the pandemic compared to the generation from natural gas in prior period. The Peak-to-Base ratio is lower by about 3 percent in the PJM market. The hourly load shapes in April 2019 and April 2020 for PJM are presented in Fig. 6.

1.5. Empirical assessment of the impact of pandemic stay-at-Home advisories on generation mix

Fig. 7 plots the historical generation diversity data and the linear trends for the periods before and during stay-at-home advisories. In the period prior to the COVID-19 pandemic, generation diversity for NYISO had a visible declining trend. After stay-at-home orders were issued, we observe zero slope, suggesting that generation diversity was relatively stable. In PJM, prior to the COVID-19 pandemic, the linear trend in generation diversity is declining slightly, and the diversity index has increased during the pandemic period. In MISO, the linear trend in generation diversity does not seem to change after the stay-at-home advisory was issued, however generation diversity has shifted upward during the pandemic.

In addition to the visual assessment of the historical data, we empirically test the impact of stay-at-home advisories on electricity generation from each fuel type by employing a linear regression analysis presented in Eq. (1). This empirical assessment informs us whether the magnitude of the estimated incremental change in electricity generation for the relevant generation type is statistically significant or not. Specifically, we regress hourly generation load by each generation type on a dummy variable (Covid), total system load, natural gas, coal and oil prices, and control variables for seasonality and hourly fixed effects. The dummy variable Covid, takes the value 1 after stay-at-home advisories were issued (i.e., after March 21, 2020). The estimated coefficient (α_{t,1}) on the Covid, variable is the estimated impact of COVID-19 related stay-at-home advisories on generation load for a given RTO, where we employ a seemingly unrelated regression estimation method assuming that the error terms of each regression for each fuel type (i.e., nuclear, coal, natural gas, wind and other renewables) are related.

Eq. (1). Regression Equation

\[
D_{t,f,i} = a_{t,1} + a_{t,1}\text{Covid}, + a_{t,1}\text{AggLoad}_{t}, + a_{t,1}\text{PRB}_{t}, + a_{t,1}\text{WTI}_{t}, \\
+ a_{t,1}\text{HH}_{t} + \sum_{k=1}^{24} a_{t,k,1}\text{H}_{t,k} + \sum_{m=1}^{12} a_{m,1}\text{m,1}\text{t}, + \mu_{t,1}
\]  

(1)
\( t \) = hour

\( i \) = ISO/RTO

\( f \) = fuel type

\( D_{t,i,f} \) = Hourly generation load by fuel type \( f \) (MW)

\( \text{Covid}_t \) = A 0/1 variable that takes the value 1 after stay-at-home orders, 0 otherwise

\( \text{AggLoad}_t \) = Total system load (MWh)

\( \text{PRB}_t \) = Average daily coal prices in Powder River Basin ($/MMBtu)

\( \text{WTI}_t \) = Average daily WTI oil prices ($/Barrel)

\( \text{HH}_t \) = Henry Hub average natural gas prices ($/MMBtu)

\( \sum_{a=1}^{24} a_{i,k} \zeta_k = \text{A 0/1 variable that takes the value of 1 for respective hours and 0 other hours} \)

\( \sum_{m=1}^{12} a_{i,m} \beta_m = \text{A 0/1 variable that takes the value of 1 for respective month and 0 other months} \)

\( \mu_t \) = Random error term

The estimated coefficient for each fuel type represents the incremental increase or decrease in electricity generation from the relevant fuel type during the COVID-19 pandemic (i.e., after stay-at-home orders were issued) relative to the prior period. Because the magnitude of generation from each fuel type varies significantly among generators, we evaluate the estimated coefficients only in terms of their directional effects. A positive coefficient indicates an increase and a negative coefficient indicates a decrease in electricity generation from the relevant fuel type.

In PJM, we find that electricity generation from nuclear and other renewables has increased, while electricity generation from natural gas and wind have decreased during the pandemic compared to the period prior to stay-at-home advisories. All fuel types are statistically significant except for coal and wind. In MISO, we find that electricity generation from wind, coal, natural gas, and hydropower is lower and statistically significant. Electricity generation from coal is higher but not statistically significant. In NYISO, we find that electricity generation from nuclear is higher and wind is lower but not statistically significant, while natural gas and hydropower generation is higher and statistically significant. Table 1 presents the estimated coefficients on the Covid variable for each regional market. Not all generation types could be estimated jointly by this model and we omit the generation types with the smallest share in each RTO. There are differences in generation mix reporting between RTOs as well. This explains why not all generation type coefficients are estimated for each RTO.

To compare the estimated impacts across fuel types within each region, we normalize the estimated coefficients using (as the denominator) the average electricity generation for the period prior to stay-at-home advisories. This normalization calculates the percentage impact. In other words, the direction of the impact does not change, but the estimated impact is comparable among fuel types in a given region. Note that these are rough estimates, to illustrate the impact behind the regression coefficients in Table 2. If we were to normalize the coefficients using averages based on a different period, the values are likely to change. These calculated impacts are presented in Table 2.

In PJM, electricity generation from other renewables has the highest percent increase, 13.60 percent, while nuclear is 1.56 percent higher and natural gas is 4.27 percent lower. In MISO, electricity generation wind is 18.36 percent higher and natural gas is 25.32 percent higher. Generation from hydropower is 41.94 percent higher, while generation fuel types...
Fig. 2. NYISO Load Shapes for April 2019 and April 2020.
Source: NYISO Real-Time Fuel Mix.

Fig. 3. MISO Daily Fuel Mix and Diversity Index.
Source: MISO Market Reports.
Fig. 4. MISO Load Shapes for April 2019 and April 2020.
Source: MISO Market Reports.

Fig. 5. PJM Daily Fuel Mix and Diversity Index.
from coal is 21.69 percent lower, and 0.15 percent lower from nuclear, which is not statistically significant. In, NYISO, electricity generation from natural gas is 1.10 percent lower and from wind is 1.21 percent lower during the pandemic compared to prior to pandemic. Electricity generation from nuclear is 0.23 percent higher. However, the nuclear and wind estimation is not statistically significant.

2. Conclusions

In this paper, we studied the changes in electricity generation from different fuel types for three major RTOs in the U.S. We find that the COVID-19 pandemic affected regional markets differently, although one common finding is that overall electricity generation declined after
the stay-at-home advisories were issued. We also empirically tested the impact of the stay-at-home advisories on electricity generation for different fuel types. We find that the level of generation from base and peak load sources has shifted after the stay-at-home advisories were issued.

Data sources

- Midcontinent Independent System Operator. “Generation Fuel Mix.” MISO Market Reports, accessed August 10th, 2020. https://www.misoenergy.org/markets-and-operations#t=10&p=0&s=&sd=.
- New York Independent System Operator. “Real-Time Fuel Mix.” NYISO Real Time Dashboard, accessed August 10th, 2020. http://mis.nyiso.com/public/P-63list.htm.
- PJM Interconnection. “Generation by Fuel Type.” PJM Data Miner 2, accessed August 10th, 2020. https://dataminer2.pjm.com/feed/gen_by_fuel.

Declaration of Competing Interest

The authors report no declarations of interest.

Appendix A

See Tables A1–A3

Table A1

| ISO/RTO | Nuclear | Coal | Gas | Hydro Power | Other Renewables | Wind |
|---------|---------|------|-----|-------------|-----------------|------|
| PJM     | 1.56%   | -1.27% | -4.27% | 13.60% | -1.70%         |      |
| MISO    | 0.15%   | -21.69% | 25.32% | 41.94% | 18.36%          |      |
| NYISO   | 0.23%   | -1.10% | 1.19% |           | -1.21%          |      |

Note: Gray shades indicate the estimated impact is statistically insignificant.

Table 2

Normalized Estimated Impact of Stay-at-Home Orders on Generation Type.

| ISO/RTO | Nuclear | Coal | Gas | Hydro Power | Other Renewables | Wind |
|---------|---------|------|-----|-------------|-----------------|------|
| PJM     |         |      |     |             |                 |      |
| MISO    |         |      |     |             |                 |      |
| NYISO   |         |      |     |             |                 |      |

Table A2

Estimated Coefficients for MISO.

| ISO/RTO  | Nuclear  | Coal   | Natural Gas | Hydro   | Wind    |
|----------|----------|--------|-------------|---------|---------|
| Covid    | 16.68    | -66.408*** | 4911.4***   | 484.7*** | 1135.9*** |
| Total    | 0.0131*** | 0.392*** | 0.549***   | 0.0262*** | 0.0123*** |
| PRB      | -19.53   | -181.49 | -273.26    | -88.55   | -4.73    |
| WTexasCrush | 161.5*** | -110.5* | 278.6***   | -165.0*** | -158.9** |
| HenryHub | 22.45*** | -162.3*** | 115.4***   | 8.132*** | 23.37*** |
| Constant | -50.4*** | -84.98 | -64.99     | -31.05   | -10.2    |
| R-Squared | 0.444 | 0.922 | 0.669      | 0.133    |         |
| Chi-Squared | 23818.2 | 351298.5 | 60299.5   | 4577.5   |         |
| p-value   | 0        | 0      | 0          | 0        |         |

Table 2

Normalized Estimated Impact of Stay-at-Home Orders on Generation Type.

| ISO/RTO | Nuclear | Coal | Gas | Hydro Power | Other Renewables | Wind |
|---------|---------|------|-----|-------------|-----------------|------|
| PJM     | 1.56%   | -1.27% | -4.27% | 13.60% | -1.70%         |      |
| MISO    | 0.15%   | -21.69% | 25.32% | 41.94% | 18.36%          |      |
| NYISO   | 0.23%   | -1.10% | 1.19% |           | -1.21%          |      |

Note: Gray shades indicate the estimated impact is statistically insignificant.

Table 2

Normalized Estimated Impact of Stay-at-Home Orders on Generation Type.

| ISO/RTO | Nuclear | Coal | Gas | Hydro Power | Other Renewables | Wind |
|---------|---------|------|-----|-------------|-----------------|------|
| PJM     | 1.56%   | -1.27% | -4.27% | 13.60% | -1.70%         |      |
| MISO    | 0.15%   | -21.69% | 25.32% | 41.94% | 18.36%          |      |
| NYISO   | 0.23%   | -1.10% | 1.19% |           | -1.21%          |      |

Note: Gray shades indicate the estimated impact is statistically insignificant.
Table A3
Estimated Coefficients for PJM.

|            | Nuclear       | Coal         | Natural Gas   | Other Renewables | Wind        |
|------------|---------------|--------------|---------------|------------------|-------------|
| Covid      | 505.1***      | −324.1*      | −1262.0***    | 372.1***         | (43.85)     |
| −5.43      | (−2.18)       | (−7.85)      | −9.09         | (−0.64)          |             |
| Total      | 0.102***      | 0.377***     | 0.432***      | 0.0505***        | 0.00815***  |
| −96.22     | −223.07       | −236.26      | −108.54       | −10.5            |             |
| PRB        | −238.6***     | −3875.0***   | 3830.4***     | 388.5***         | 161.3***    |
| (−5.36)    | (−54.48)      | −49.82       | −19.85        | −4.94            |             |
| WTexasCrush| 4.081*        | 59.90***     | −75.15***     | −0.948           | −3.256*     |
| −2         | −18.39        | (−21.35)     | (−1.06)       | (−2.18)          |             |
| HenryHub   | 403.4***      | 6480.8***    | −6607.9***    | −13.15           | −394.3***   |
| −14.88     | −149.58       | (−141.10)    | (−1.10)       | (−19.83)         |             |
| Constant   | 26762.2***    | 17596.9***   | −38741.7***   | −7811.3***       | 2213.6***   |
| −54.92     | −22.6         | (−46.02)     | (−36.45)      | −6.19            |             |
| R-Squared  | 0.518         | 0.832        | 0.826         | 0.597            | 0.218       |
| Chi-Squared| 32168.2       | 147618       | 142124.6      | 44389            | 8321.9      |
| p-value    | 0             | 0            | 0             | 0                | 0           |

**Table A3**

**Estimated Coefficients for PJM.**

**Dr. Derya Eryilmaz** is an energy economist and an Associate Principal in the Energy Practice of Charles River Associates. Dr. Eryilmaz has more than 10 years of experience in economic modeling and research for oil pipeline, natural gas and power industry. She is an expert in the applied economic analysis of the energy sector surrounding market power, market manipulation and price discrimination issues and energy forecasting. She provides expert testimony support on various regulatory and litigation cases and worked on several federal and state regulatory filings involving energy disputes in the United States and Canada. Dr. Eryilmaz has published several peer-reviewed journal articles including the *Energy Journal*, *Energy Economics* and the *Electricity Journal*.

**Dr. Margarita Patria** is a Principal in CRA’s Auctions & Competitive Bidding Practice. She has extensive experience in economic analyses of energy markets, as well as in auction and market design. She has been leading successful energy procurement auctions in multiple states. Dr. Patria has been a visiting scholar and a teaching fellow at Boston College, where she taught Economics of Energy Markets. Dr. Patria research interests are in applied econometrics, game theory and energy markets. She is the author of several academic papers published in peer reviewed journals including *Games and Economic Behavior* and *Review of Industrial Organization*.

**Ms. Caroline Heilbrun** is an Analyst in CRA’s Energy Practice. Caroline is involved in several costing-based studies and energy market forecasts. Her interests include integration of energy storage into power markets and redesigning rates to drive decarbonization. Ms. Heilbrun recently co-authored a Law360 piece with Dr. Eryilmaz about energy storage as a transmission asset in ISO-RTOs following FERC Order No. 841.