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Assessment of Impact of COVID-19 on Electricity Demand and Generation in Washington State

Abstract

This paper explores the impact of COVID-19 and related quarantine to electricity consumption and generation in Washington state. The result suggests that total consumption decreased, and residential sectors consumed more compared to prior to pandemic. The impact of total electricity generation remains ambiguous. Quarantine shifts generation fuel mix, hydro power contributes less to electricity and electricity from other non-renewable, other renewable as well as nuclear is higher.

Introduction

The pandemic of COVID-19 has caused an impact on every aspect of life. In addition to devasting effect on people's health and well-being, it established unprecedented challenges on economy and energy and electricity market in global scale. The first noticeable impact on electricity industry was downward shift in electricity demand by 3.8% in the first quarter of 2020 compared to the previous year (1). Because consumption determines both quantity of electricity supplies and marginal generation dispatched, COVID-19 has also affected the generation quantity and fuel sources mix (2).

Previous studies reported that state-wide and national lockdowns had a strong negative influence on total electricity demand and contributes to the increase of household electricity consumption (1; 3; 4; 5; 6). In region of Ontario, energy demand would increase steadily through

the week and ramp up on weekend (7). In Europe, severeness of containment has an influence on the impact of electricity demand reduction, a less strictive quarantine policy decrease less consumption (3). As the consumption pattern shifts throughout the day, the level of peak load generation and percentage share of sources mix has shifted after the quarantine as well. During the pandemic, renewable energy contributes more to electricity generation and power plants that use coal or oil contributes fewer in several U.S. regions (2).

As many other states in the United States, COVID-19 affected Washington state. After 15 months since Gov. Inslee announced stay-at-home order in Washington State on March 24th, 2020, Washington State was officially reopening on June 30, 2021 (8). Government polices intended to slow down the spread of COVID-19, such as lock downs and quarantine, had drastically changed people's living and working habits (6). For example, people spent more time indoors and worked remotely more often than before. This results a shift in electricity consumption and electricity supply distribution to end-user sectors in Washington.

This paper briefly assessed the impact of COVID-19 and following quarantine order on electricity consumption, total electricity generation as well as generation fuel source mix in Washington state. The results show that the change in people's activities reduced the total consumption and shifted the pattern of consumption in different sectors. Generation fuel mix pattern changes under quarantine.

Methodology and Data

This paper used the U.S. Energy Information Administration monthly and hourly electricity consumption and generation (9; 10; 11; 12; 13; 14; 15; 16; 17). Then I visualized total electricity consumption and generation in 2019 and 2020. To measure the shift of pattern of

consumption in different sectors and fuel mix, I compared the percentage share of electricity consumption in residential, industrial, and commercial sectors and Washington's major generation fuel mix (coal, natural gas, wood and wood-derived fuels, nuclear, conventional hydroelectric and nonhydroelectric renewables). Since the impact of quarantine order is almost instantaneous, a comparison between electricity consumption and generation during the quarantine and prior to it can represent the impact of COVID-19 effectively. Specifically, I selected April 2019 and April 2020 to estimate the shift of consumption in sectors as well as percentage change in electricity generation fuel mix.

In addition to visualized assessment of the historical data. I used a similar linear regression analysis presented by Eryilmaz, Patria and Heilbrun (2) to empirically test the impact of quarantine on electricity generation fuel mix in Bonneville Power Administration (BPAT). This assessment informs us whether the magnitude of the estimated incremental change in electricity generation by the relevant type of fuel is statistically significant or not[1] (2). Specially, I regress hourly generation load by each generation type on a dummy variable (Covid_t), total system load, and natural gas and coal prices on the April of 2019 and 2020. The dummy variable Covid_t takes the value of 1 on April 2020, the second month that the quarantine order was announced (i.e., April 1st, 2020). The estimated coefficient ($a_{1,f,i}$) on the Covid dummy variable is the estimated impact of COVID-19 related quarantine order on generation load for a given fuel type, where I follow Eryilmaz and Patria who employed a seemingly unrelated regression

[1] Statistical significance of a regression coefficient means that the value of estimated coefficient is statistically different from zero.

estimation method assuming that the error terms of each regression for each fuel type (i.e., nuclear, natural gas, hydro, other and other renewables)[2] are related (2).

Regression Equation

$$D_{t,f,i} = a_{0,f,i} + a_{1,f,i}\text{Covid}_t + a_{2,f,i}\text{AggLoad}_{t,i} + a_{3,f,i}\text{PCoal}_t + a_{4,f,i}\text{HH}_t + e_{t,i}$$

$t = \text{hour}$
$i = \text{BPAT}$
$f = \text{fuel type}$

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

$\text{Covid}_t = \text{A } 0/1 \text{ variable that takes the value 1 on April 2020, 0 other wise}$

$\text{AggLoad}_{t,i} = \text{Total system load (MWh)}$

$\text{PCoal} = \text{Daily close coal prices in the U.S. (\$/ton)}$

$\text{HH}_t = \text{Henry Hub daily close natural gas prices (\$/MMbtu)}$

$e_{t,i} = \text{Random error term}$

The estimated coefficient for each fuel type represents the incremental increase or decrease in this fuel's contribution to electricity generation in Washington during the pandemic (i.e., April 2020) relative to the prior period. Because the magnitude of generation from each fuel type varies from generators to generators, I estimated the impact only on their directional effects (2) A positive coefficient indicates an increase in the electricity generation from a fuel type and a negative coefficient indicates a decrease in the electricity generation from the fuel.

To compare the estimated impacts across fuel types, I used Eryilmaz and Patira's method to normalize the estimated coefficients by using the average electricity generation for April 2019 as the denominator and calculate the percentage impact (2). The direction of the impacts doesn't change, but estimated impacts are comparable now. The results are illustrated in Table 2.

[2]The NPAT data has a "other" category. I combined it with coal and wood and wood derived. "Other renewables" is consistent of solar and wind.

Result analysis

In Washington State, Covid-19 and related quarantine order has shifted electricity consumption pattern in different sectors. Quarantine order reduced total consumption, the peak load in 2020 decreased by about 13.69% compared to the peak load in 2019. Since people spent more time indoors now, consumption in industrial and commercial sectors reduced, and residential became the largest electricity consumption sector in 2020. In Figure 2, percentage share of industrial, commercial, and residential electricity consumption in April 2019 and 2020 are compared. Residential consumption increased by 4%, but commercial and industrial suffer reduction by 2% and 1%. Another noticeable impact is that the peak demand load month is almost two months late in 2020 compared to peak demand load month in 2019.

COVID-19-related quarantine order does not appear to affect the total electricity generation but made an impact the share of fuel mix to generate electricity. In fact, the peak generation load in 2020 is higher than 2019 visually. Figure 4 shows a decrease in electricity generated by conventional hydro and coal-fired plants and an increase in other renewable energy in addition to higher percentage share of natural gas contributing to generation. Compared to April 2019, conventional hydroelectric power and coal contribute 8.97% and 2.64% less to generate electricity. Since people work more at home, plants and generators that require constant maintenance (i.e., dam, coal-fired plants, etc.) will not be the first option to dispatch and electricity generation from them decreased. In another hand, plants that need less maintenance or have cheaper fuel generated more electricity (18). Natural gas increased by almost 10% while nuclear, wood and wood derived fuels and other renewable energy gains an increase less than 1%.

The empirical analysis shows that COVID-19 and related quarantine order reduced hydro power's contribution to electricity generation by 28.76 percent compared to generation prior to quarantine. Electricity generation from natural gas is 0.80 percent lower, which is insignificant. Electricity from nuclear is 0.42 percent higher, from other (including coal and wood) is 0.19 percent higher and from other renewable (solar and wind) is 14.48 percent higher compared to prior to pandemic.

Conclusion

This paper briefly studied the change in electricity consumption and electricity generation in Washington state before and after quarantine. I find that the COVID-19 pandemic affected total consumption and shifted consumption pattern in different sectors. One finding is that overall consumption declined after quarantine order was announced. Residential consumption was higher compared to prior to pandemic. During the quarantine, other renewable energy such as solar and wind contributes more. The empirical test indicates that pandemic has an impact on electricity fuel mix. Less electricity is from hydro power, the major renewable electricity energy in Washington before pandemic. Electricity from other renewable energy, such as solar and wind increased the most, and nuclear power follows. The level of electricity load sources has shifted after the quarantine order was announced.

Appendix

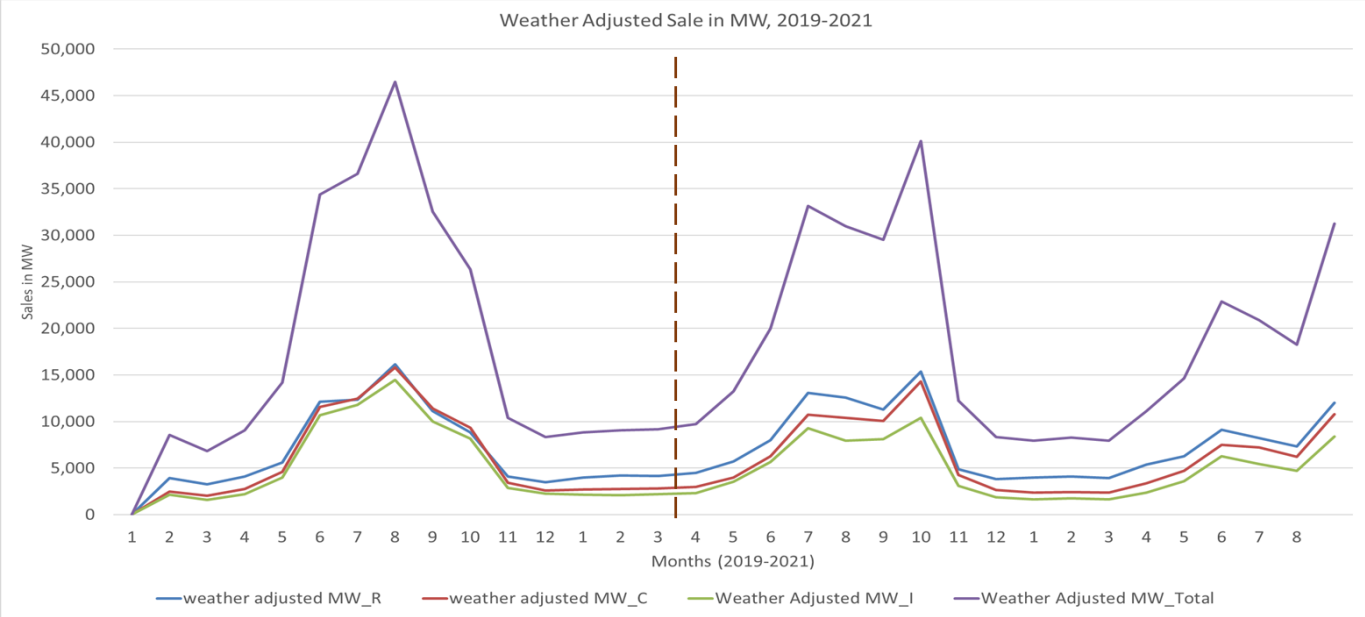

Figure 1: Monthly Electricity Consumption in Industrial, Commercial, and Residential Sectors (2019-2021)

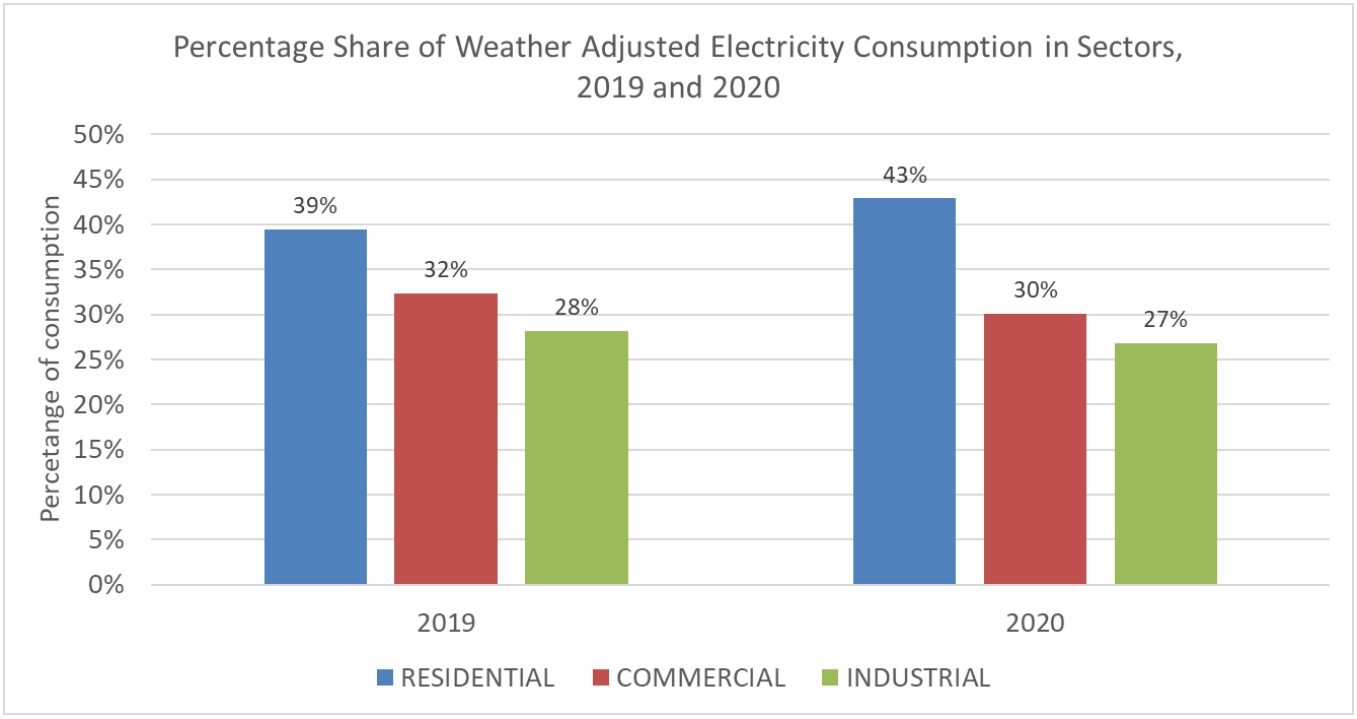

Figure 2: Percentage Share of Electricity Consumption in Different Sectors in April 2019 and 2020

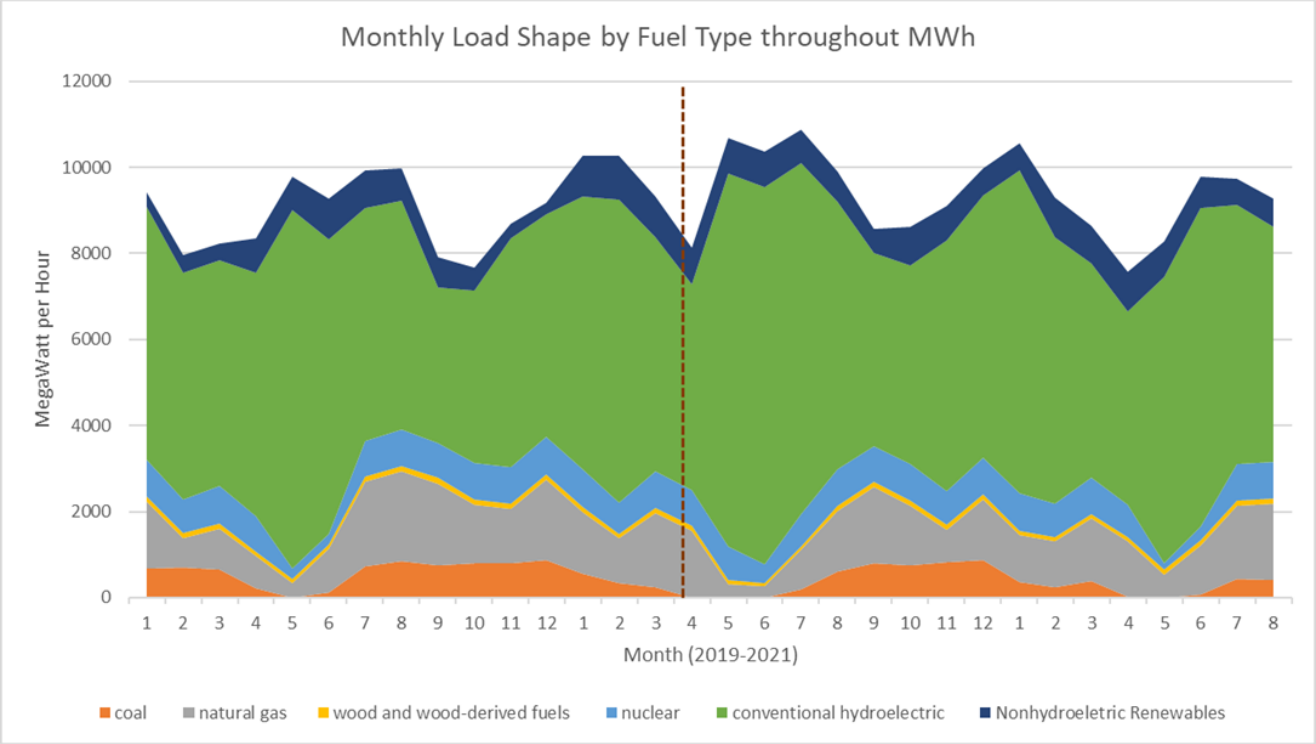

Figure 3: Monthly Electricity Generation by Fuel Types (2019-2021)

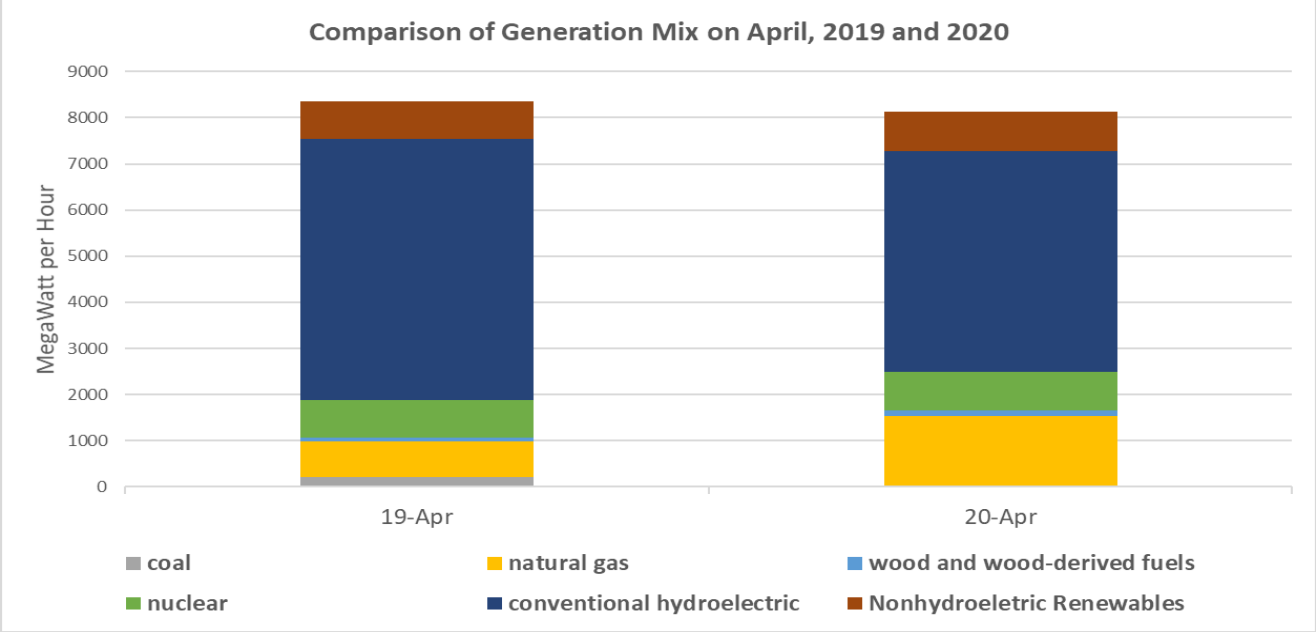

Figure 4: Percentage Share of Electricity Generation Fuel Types in Washington

Table 1: Percentage Change in Generation Types in April 2019 and 2020

Time	coal	natural gas	wood and wood-derived fuels	nuclear	conventional hydroelectric	Nonhydroeletric Renewables
Apr-19	2.66%	9.07%	1.08%	9.78%	67.82%	9.69%
Apr-20	0.02%	18.97%	1.51%	10.27%	58.85%	10.53%
Difference	**-2.64%**	**9.90%**	**0.43%**	**0.50%**	**-8.97%**	**0.84%**

Table 1: Normalized Estimated Impact quarantine order on Generation Type

	Hydro Power	**Nuclear**	**Other**	**Other Renewable**	**Natural Gas**
BPA	-28.76%	0.42%	0.19%	14.48%	-0.80%

Note: Shaded Gray area indicates that estimated impact is statistically insignificant

References

1. *The impact of the COVID-19 on households' hourly electricity consumption in Canada.* Abdeen, Ahmed, et al. 2021, Energy and Buildings, Vol. 250, p. 111280.

2. *Assessment of the COVID-19 pandemic effect on regional electricity generation mix in NYISO, MISO, and PJM markets.* Eryilmaz, Derya, Patria, Margarita and Heilbrun, Caroline. 7, 2020, The Electricity Journal, Vol. 33, p. 106829.

3. *The impact of different COVID-19 containment measures on electricity consumption in Europe.* Bahmanyar, Alireza, Estebsari, Abouzar and Ernst, Damien. 2020, Energy Research & Social Science, Vol. 68, p. 101683.

4. *Impact of the COVID-19 Pandemic on the U.S. Electricity Demand and Supply; An Early View From Data.* Duzgun, Agdas and Barooah, Prabir. 2020, IEEE Access, Vol. 8, pp. 151523-151534.

5. *Impact analysis of COVID-19 responses on energy grid dynamics in Europe.* Werth, Annette, Gravino, Pietro and Prevedello, Giulio. 2021, Applied Energy, Vol. 281, p. 116045.

6. *Review analysis of COVID-19 impact on electricity demand for residential buildings.* Krarti, Moncef and Aldubyan, Mohammad. 2021, Renewable and Sustainable Energy Reviews, Vol. 143, p. 110888.

7. *Analysis of the electricity demand trends amidst the COVID-19 coronavirus pandemic.* Abu-Rayash, Azzam and Dincer, Ibrahim. 2020, Energy Research & Social Science, Vol. 68, p. 101682.

8. Timeline: A look back at Washington state's COVID-19 response. *MyNorthwest.* [Online] October 7, 2021. [Cited: November 26, 2021.] https://mynorthwest.com/2974047/timeline-washington-states-covid-19-response/.

9. *Washington Net Electricity generation by Source, Aug.2021.* U.S. EIA.

10. *Electric Power Monthly, Table 1.1.A. Net Generation from Renewable Sources: Total (All Sectors), 2019-2021.* U.S. EIA. 2021.

11. *Monthly Form EIA-861M detailed data (1990-present), Table 8. Sales to ultimate customers, revenue, and average price by sector, Washington.* U.S. EIA. 2021.

12. Net generation from wind for Bonneville Power Administration (BPAT), hourly - local time. *EIA OPEN DATA.* [Online] 2021. [Cited: December 11, 2021.] https://www.eia.gov/opendata/qb.php?category=3390126&sdid=EBA.BPAT-ALL.NG.WND.HL.

13. Net generation from solar for Bonneville Power Administration (BPAT), hourly - local time. *EIA OPEN DATA.* [Online] 2021. [Cited: December 11, 2021.] https://www.eia.gov/opendata/qb.php?category=3390126&sdid=EBA.BPAT-ALL.NG.SUN.HL.

14. Net generation from other for Bonneville Power Administration (BPAT), hourly - local time. *EIA OPEN DATA.* [Online] 2021. [Cited: December 11, 2021.] https://www.eia.gov/opendata/qb.php?category=3390126&sdid=EBA.BPAT-ALL.NG.OTH.HL.

15. Net generation from nuclear for Bonneville Power Administration (BPAT), hourly - local time. *EIA OPEN DATA.* [Online] 2021. [Cited: December 11, 2021.] https://www.eia.gov/opendata/qb.php?category=3390126&sdid=EBA.BPAT-ALL.NG.NUC.HL.

16. Net generation from natural gas for Bonneville Power Administration (BPAT), hourly-local time. *EIA OPEN DATA.* [Online] 2021. [Cited: December 11, 2021.] https://www.eia.gov/opendata/qb.php?category=3390126&sdid=EBA.BPAT-ALL.NG.NG.HL.

17. Net generation from hydro for Bonneville Power Administration (BPAT), hourly-local time. *EIA OPEN DATA.* [Online] 2021. [Cited: December 11, 2021.] https://www.eia.gov/opendata/qb.php?category=3390126&sdid=EBA.BPAT-ALL.NG.WAT.HL.

18. What is a Natural Gas Generator. *WORLDWIDE POWER PRODUCTS.* [Online] [Cited: November 26, 2021.] https://www.wpowerproducts.com/what-is-a-natural-gas-generator/.

19. *COVID-19: Impact analysis and recommendations for power sector operation.* Elavarasan, Rajvikram Madurai, et al. 2020, Applied Energy, Vol. 279, p. 115739.

20. Washington State Profile and Energy Estimates. *EIA.* [Online] U.S. EIA, January 21, 2021. [Cited: November 26, 2021.] https://www.eia.gov/state/analysis.php?sid=WA.

21. *State Electricity Profiles.* U.S. EIA. 2021.

22. Natural gas (Henry Hub). *Markets Insider.* [Online] 2021. [Cited: December 11, 2021.] https://markets.businessinsider.com/commodities/natural-gas-price.

23. Coal. *Markets Insider.* [Online] 2021. [Cited: December 11, 2021.] https://markets.businessinsider.com/commodities/coal-price.