Volume 4 | Issue 2 | 2022

Official Publication
aee®
Association of Energy Engineers

# International Journal of Strategic Energy & Environmental Planning

Editor Stephen A. Roosa
PhD, CEM, BEP, REP, CSDP

ISSN: 2643-6930 (Print)
ISSN: 2643-6949 (Online)

# International Journal of Strategic Energy and Environmental Planning

Stephen A. Roosa, Ph.D., CEM, Editor-in-Chief
Vol. 4, No. 2—2022

## Contents



JOURNAL OF THE ASSOCIATION OF ENERGY ENGINEERS®

Association of Energy Engineers

ISSN: 2643-6930 (print)
ISSN: 2643-6949 (on-line)

*International Journal for Strategic Energy and Environmental Planning* (ISSN 2643-6930) is published bimonthy by the Association of Energy Engineers, 3168 Mercer University Drive, Atlanta, GA 30341. Production Office: 3168 Mercer University Drive, Atlanta, GA 30341, 770-447-5083, ext. 224



Subscriptions: $439 for individual print subscriptions; $548 for combined print and online subscriptions; $466 for online only subscriptions. Print only institutional subscriptions are not available.

**AEE MEMBERSHIP CHANGES**

Please notify Association of Energy Engineers, 3168 Mercer University Drive, Atlanta, GA 30341
Tel: 770-447-5083, ext. 224, email membership@aeecenter.org

**EDITORIAL OFFICE**

EDITORIAL OFFICE: Articles and letters to the editor should be submitted to Stephen Roosa, Editor, *International Journal for Strategic Energy and Environmental Planning*, Email: *sroosa@aeecenter.org*.

**Publication Policy**

*International Journal for Strategic Energy and Environmental Planning* is a *peer-to-peer* communication channel for practicing energy managers. Thus, all articles must be of a practical nature and should not be pure or basic research. If the article appears to be basic research oriented, the author(s) must explain in a leading paragraph why practicing energy managers should know the material.

*Peer review* is offered if requested by the author(s), but peer review must be requested in the submission email or letter. This will add about 6 months to the lead time before publishing. All other articles will be editor reviewed.

Transfer of copyright to AEE must occur upon submission and if any of the material has been published in other journals previously, that source must be identified and referenced. If the previous publication was at an AEE conference or in another AEE publication, that should also be referenced. All articles appearing in the journal are opinions and works of the authors and not AEE or the editor.

If you are submitting an article for possible publication you hereby grant AEE the right to print and assign a release of copyright of submitted article to AEE. If you are submitting an article under a governmental agency and submitted work is covered in the public domain, you hereby grant to AEE the right to reprint submitted work.

# Pollution and the Pandemic: Explaining Differences in COVID-19 Rates Across 146 U.S. Communities

*Wesley L. Meares, John "Hans" Gilderbloom, Gregory D. Squires and Antwan Jones*

## ABSTRACT

There are wide differences between U.S. counties in terms of COVID-19 infections and deaths. Some counties with populations of 50,000 or more are experiencing few COVID-19 deaths while others have over 1,000 deaths. Our research seeks to account for these significant differences. To date, no peer reviewed research has been published on understating inter-county variations in COVID-19 cases and deaths. In this research, we are explained up to 75% of the variations across 146 counties using regression models based on COVID-19 rates as of 19 August 2020. Air pollution is a consistent predictor of high COVID-19 infections and deaths along with the impact of political leadership. We discovered that of the 146 mid-size cities, air pollution is correlated with higher COVID-19 cases. Counties located in southern U.S. cities also have higher rates of COVID-19. This research can be used to help shape best practices and inform policy makers of key differences between areas experiencing high and low COVID-19 infections and deaths.

## INTRODUCTION

The U.S. represents 4.23% of the world's population but it has the largest share of global cases and deaths, with over 38.8 million individuals with COVID-19 and nearly 637,531 deaths attributed to COVID-19 since the first laboratory-confirmed case on 21 January, 2020 [1-3]. World-wide, there have been 216.7 million cases with 4.5 million deaths in 222 countries and territories. While the pandemic has affected the lives of individuals, it has also substantially affected social institutions such as the economy, politics, governmental energy and environmental polices, and health care systems; these effects have had unprecedented regional consequences in the U.S. Impacts included the subsequent quarantines, the politicization of the quarantine affected COVID-19 rates of infection, and air pollutants that were quelled from the reduction in transportation emissions [4,5].

The quality of air varies significantly by state and city in the U.S., and such variations could contribute to differences in COVID-positive cases and COVID-related deaths in the U.S. This study makes a unique contribution by considering 146 semi-isolated U.S. counties to better understand the spatial effects that air quality, sociodemographic variables, and political characteristics have on confirmed COVID-19 case counts and deaths. This study has broad significance as there is scant published research on inter-community COVID-19 cases and deaths. Preliminary research from Harvard University suggests that COVID-19 cases are higher in cities with high pollution levels [6]. Pollution is the largest environmental cause of premature deaths. Some studies estimate that world-wide, pollution causes over 9 million deaths annually [7]. Some research suggests that in highly-polluted countries such as China that also experienced large number of COVID-19 infections, the reductions in air pollution translated to a decrease in all-cause mortality during the pandemic [8].

## METHODOLGY

The data used for this study were obtained from the 2018 American Community Survey (ACS), Johns Hopkins University, *New York Times*, Social Explorer, County Business Patterns, Local Government Websites, and the University of Washington's Atmospheric Composition Analysis Group in St. Louis, Missouri [2,9-13]. From the ACS data, we used the 2018 three-year estimates measures at the U.S. Bureau of the Census's geographic level of place although the unit of analysis selected is the county [14].

**Case Selection**

The units of analysis for our study are the counties in 146 mid-size U.S. cities, defined by the Bureau of the Census as cities with at least 50,000 residents that are not located within 20 miles (32.2 km) of another city of similar size. Figure 1 shows the location of the mid-sized cities located in the counties selected for this study. The counties of the dataset are neither evenly-distributed nor clustered, but randomly distributed in states throughout the continental U.S. (Moran's I: 0.049, z = 1.62). Several states (e.g., Nevada, Vermont, Rhode Island, Connecticut, and Massachusetts) had no cities matching our county selection criteria. The county as a unit of analysis allows for a more granular analysis than other options such as the much larger commuting zones. The physical distances between counties decreases the problem of spatial proximity.

The 146 cities that emerge from the 700 total places are significant for the current study. It is highly problematic to include highly-populated metropolises such as New York City, New York or Los Angeles, California in a sample which has 700 mid-size communities. Cities such as Louisville, Kentucky, Yuma, Arizona, or Erie Pennsylvania are more

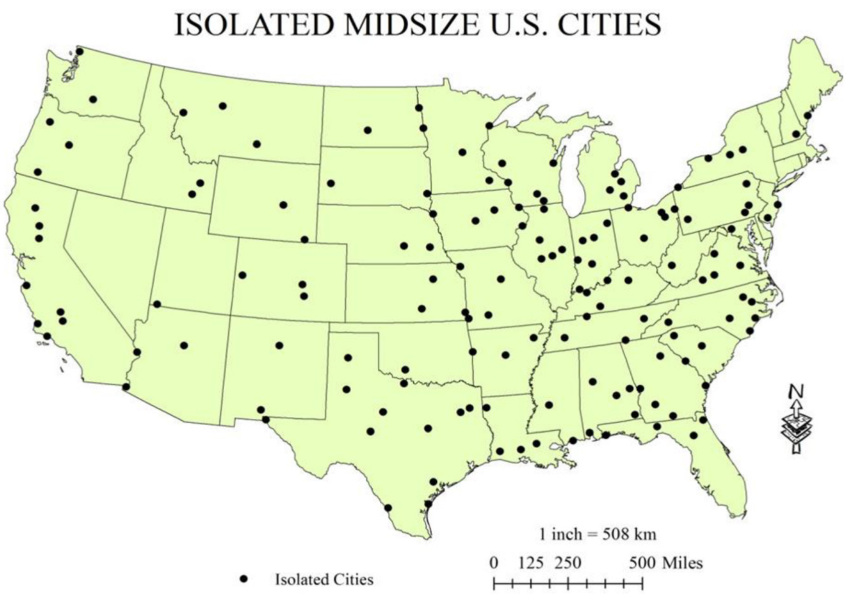


**Figure 1. Map of isolated mid-size cities in the U.S.**

typical of U.S. cities than a giant metropolis. For comparative purposes it is unworkable to combine both kinds of cities together. Instead of combining categorically different urban centers and then adjusting for urbanicity, this study selects cases using a well-validated set of decision rules from social science literature, which sufficiently address spatial lag and case selection concerns [15,16].

**Measures**

Two outcome measures are used to measure COVID-19 at the place level: the number and rate of COVID-19 cases (per 100,000 people) and the number and rate of COVID-19 deaths (per 100,000 people) in the county as of 19 August 2020. The focal independent measure, *air pollution exposure*, is captured by particulate matter (PM) or inhalable particles sized 2.5 microns or less in width. These fine particles come from power plants, motor vehicles, airplanes, combustion of wood, forest fires, agricultural burning, volcanic eruptions and dust storms. They can bypass the nose and throat, pass into the lungs and may enter the circulatory system causing serious health issues. The estimates of PM2.5 used were calculated by the Atmospheric Composition Analysis Group for the year 2016 [17].

This study controls for several measures in the analyses. The percentage of labor force that is considered essential is derived from the Brooking Institution's definition of essential workers based on the 4-digit North American Industry Classification System (NAICS) for industries [18]. This list of essential workers was derived from the guidance provided by the U.S. Department of Homeland Security in 2020 for jurisdictions to identify a broad array of what is considered to be the essential workforce during the COVID-19 pandemic. Given the data limitations, it is impossible to isolate the exact number of essential workers in these industries. For example, to provide medical services in hospitals doctors and nurses are essential yet administrative and janitorial staff are included in the number of employed. While these workers may be essential to keep hospitals functioning, they are not necessarily considered to be essential for treat COVID-19 patients. Despite this concern, this broader measure is seen as a more accurate measure since many will continue working to keep the organization functioning.

As an indicator of the political and policy environment for these cities, this study includes the political affiliation of the highest-ranking member of the legislative body. This is a binary measure; Republican is coded as 1 and other affiliations (Democrat/independent/nonpartisan) are coded as 0. A measure of the total number of days that a stay-at-home order, or equivalent, was in place at the state level is included. Third, is a measure indicating whether a state has had a mask mandate in place at least 15 days before 19 August 2020. This measure is captured at the state level due to the controversies of state power over cities [19].

To account for inter-city differentials, measures for the total population of the county, population density (per square mile), the percentage of non-white residents, median household income (in 2018 inflation adjusted dollars), the median value of owner-housing units, percentage of the workforce 16 years or older that commute by means other than driving alone, and a region variable identifying a southern location are included in the analyses. To address potential confounding, the study also includes the percentage of the population that is older than 65 and the percentage of residents considered to have three or more COVID-19 high risk factors.

**Statistical Analyses**

Descriptive statistics were generated for each variable, see Table A1 (all Tables are located in the Appendix), and bivariate correlations were analyzed using the dependent and independent variables. To illustrate potential key relationships, the ten counties with the highest and lowest rates of COVID-19 infections and deaths were identified and descriptive statistics on all of the independent measures were conducted. Finally, to assess the independent effects of air pollution a series of ordinary least squares regression models were performed.

Regarding multicollinearity, tolerances are all well above the critical threshold of .2 and the variance inflation factor does not exceed the critical threshold of 4. Furthermore, the presence of competing dependencies was explored and determined to be negative: in no case did two variables both show problematic values on the variance proportion table. Together, this methodology provides an accurate estimation and comparison of the impact of the control and test variables on COVID-19 cases and deaths across the selected mid-sized cities.

## RESULTS

Table A2 compares the number of COVID-19 cases for the top and bottom ten counties in our sample ($N$ = 146). It shows that COVID-19 infections are much higher in highly polluted counties. Levels of air pollution are generally twice as high in counties with high COVID-19 cases. Cases are much lower in counties that are not located in the South (defined by the U.S. Census Bureau as the states of Texas, Oklahoma, Arkansas, Louisiana, Maryland, Mississippi, Virginia, Tennessee, Alabama, Kentucky, Florida, Georgia, North Carolina, South Carolina, Delaware and West Virginia). In our top ten counties with fewest COVID-19 cases, none is in the South but in our bottom ten cases with the highest virus rate, eight are in the South. We also found evidence that states with Republican governors have higher rates of COVID-19 and some evidence that Republican mayors tend to have higher numbers of COVID-19 cases than those led by other political parties. Counties with larger percentages of non-whites tend to have more cases of COVID-19. Higher population and density levels also show higher rates of the virus. Those counties with people who have higher levels of pre-existing conditions have a higher number of COVID-19 cases. We also found that there was no difference in COVID-19 cases associated with the share of population over the age of 65.

Table A3 compares the number of COVID-19 deaths for the top ten and bottom ten counties. Interestingly, several top and bottom counties in terms of cumulative death rates due to the virus were different from those in the top and bottom of cumulative COVID-19 infection rates. As we showed earlier, the number of COVID-19 cases and deaths were consistent with air pollution having a contributing role. It indicates that COVID-19 deaths are much higher in highly polluted cities. Pollution is generally twice as high in cities with higher rates of COVID-19 deaths.

Also, COVID-19 deaths are not necessarily found in all Southern cities. This is similar to our findings regarding COVID-19 cases. There is no strong evidence that counties with Republican mayors tend to have higher COVID-19 deaths. However, counties with larger percentages of non-whites tend to have higher death rates. Counties with larger populations and higher population densities also show higher levels of COVID-19 deaths. Those counties with higher pre-existing conditions have higher numbers of deaths caused by the virus. We were surprised that the number of front line workers, use of shared transit, and median household income made no difference. The percentage of elderly is slightly higher in those counties with more COVID-19 deaths.

In Tables A4 and A5, the regression model predicting COVID-19 cases and deaths shows that the air pollution test variable using PM 2.5 is a statistically significant predictor. In fact, it has an equal if not stronger impact than some standard control variables (95% CI Model 1: 138.43, 654.5; Model 2: 68.008, 230.69; Model 3: 1.9, 23.56; Model 4: 1.19, 7.71). Table A4 is a regression analysis showing the net impact of key variables in our analysis of variations of COVID-19 cases. We also found some surprising results which were not apparent with the bivariate analysis. Across the board, air pollution (95% CI Model 1: 138.43, 654.5; Model 2: 68.008, 230.69), percent seniors (95% CI Model 1: -428.47, -138.55; Model 2: -120.39, -29.00), percent with pre-existing conditions (95% CI Model 1: 62.22, 316.81; Model 2: 67.67, 147.93), mask mandates (95% CI Model 1: -2399.78, -291.2; Model 2: -770.34 -105.65), population density (95% CI Model 1 Model 1: -4.96, -1.77; Model 2: -1.061, -0.06), and mayor's political party (95% CI Model 1: 385.54, 2135.8; although in Module 2 it is only approaching significance, $p = .56$) are all significant predictors. Emerging significance is found when looking at the raw number of cases, such as population (95% CI Model 1: 0.02, 0.02) and percent who commute with others (95% CI Model 1: -264.5, -36.88). The amount of explained variation is strong with 75% of the variance in raw counts of cases accounted for by these variables.

The regressions in Table A5 were less impressive in terms of explaining COVID-19 deaths; given the exploratory nature of our study they have value. Once again, the most consistent predictor was air pollution levels (95% CI Model 3: 1.9, 23.56; Model 4: 1.19, 7.71). The only other consistent predictors were percentage of people with pre-existing conditions (95% CI Model 3: 1.82, 12.48; Model 4: 1.76, 4.98) and percentage of seniors (95% CI Model 3:). The impact of race (95% CI: Model 4: .237, 1.10) and median household income (95% CI Model 4: .00, .00) fell for the raw number of deaths and then became significant when we measured per capita death rates. Mask mandates did not impact the raw number of deaths, but it did approach significance in terms of the rate of deaths ($p$ = .07, 95% CI: Model 4: -25.631, 1.01). Moreover, the impact of living in the South and the mayor being a Republican was lost in predicting COVID-19 deaths. The amount of variations was half to one-third explained in these last two equations found in Table A5.

## DISCUSSION

The development of an effective COVID-19 vaccine is a major step in the battle against this particular virus. Vaccines have only recently become widely available around the globe. In locations where they are readily available, the science suggests there remain circumstances in which it is important to wear masks, maintain social distance, and wash hands frequently. Though there may be government and private business mandates to comply, large numbers of people do not. Perhaps this will change as more people see the continuing effects of the virus. These are steps individuals can choose to take. However, the ability to avoid air pollution is not generally subject to individual decision making [20-22].

The findings of this study highlight the importance of air pollution as a key contributor to the number of COVID-19 cases and deaths. This is consistent with a wealth of research on the social determinants of health including a recent research paper on the impacts of air pollution on COVID-19 [6]. A key conclusion of that study was that "our results underscore the importance of continuing to enforce existing air pollution regulations to protect human health both during and after the COVID-19 crisis." Unfortunately, the U.S. Environmental Protection Agency under the Trump administration moved in the opposite direction as it has weakened or eliminated many rules and regulations designed to protect the environment [23,24].

Our research found that rates of COVID-19 and deaths from the virus vary widely across mid-size communities in the U.S. Several factors are statistically associated with either the number or rates of cases or deaths or both including the presence of mask mandates, population density, percentage of seniors, share with pre-existing conditions, racial composition, and median income—all expected. The political party of local mayors was a factor; jurisdictions with Democratic mayors have fewer incidents. Surprisingly, the share of essential workers was not a significant predictor.

These findings suggest the importance of learning more about the dynamics of local communities. What actions are local elected officials, business leaders, and non-profit organizations taking? Are local foundations supporting COVID-19 education and relief efforts?

There is a limit to what can be done in response to the impact of several of these variables. The share of the population that is elderly cannot be quickly altered, though care of the elderly might be improved. Population density is not likely to change quickly in cities or counties though individual neighborhoods could see changes as properties deteriorate or new developments grow.

Air quality is inextricably linked to sustainability [24]. Air pollution levels, which were the focus of our study, may not appear to be something that can be quickly changed. However, with appropriate leadership (and perhaps local organizing to pressure leaders) older industrial sites can be remediated in many cases. The U.S. Environmental Protection Agency could reintroduce or strengthen life-saving environmental protection regulations. State and local leaders could act on their own and many around the world are doing so [26-28]. Everyone hopes for a quick resolution of the current pandemic. In the meantime, we might follow the guidance of the Physicians for Social Responsibility who asserted in reference to the costs of air pollution "We must prevent what we cannot cure" [29].

**Acknowledgements**

We thank the rest of our research team for their assistance with the project: Ellen Slaten, Carla Snyder, Aneri Taskar, Chad Frederick, Karrie Quenichet and Isaiah Kingsberry. We offer a special thanks to Dr. Stephen Roosa, our editor. A previous version of this revised article won the University of Louisville's COVID-19 Hero Award.

## References

[1] Huang C, Wang Y, Li X, et al. (2020). Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. *The Lancet*, 395, pages 497-506.

[2] Johns Hopkins University (2020, September 18). COVID-19 in the USA. https://coronavirus.jhu.edu, accessed 20 September 2020.

[3] Centers for Disease Control and Prevention COVID Response Team, Jorden, M., Rudman, S., et al. (2020, January–February). Evidence for limited early spread of COVID-19 within the United States. *Morbidity and Mortality Weekly Report*, 69, pages 680-684.

[4] Berman, J. and Ebisu, K. (2020). Changes in U.S. air pollution during the COVID-19 pandemic. *Science of the Total Environment*, 739, 139864.

[5] Kavanagh, M. and Singh, R. (2020). Democracy, capacity, and coercion in pandemic response—COVID-19 in comparative political perspective. *Journal of Health Politics, Policy and Law*.

[6] Wu, X., Nethery, R., Sabath, B., Braun, D. and Dominici, F. (2020). Exposure to air pollution and COVID-19 mortality in the United States. *Science Advances*. DOI: https://doi.org/10.1101/2020.04.05.20054502.

[7] Landrigan, P., Fuller, R., Hu, H., et al. (2018). Pollution and global health—an agenda for prevention. *Environmental Health Perspectives*, 126, 084501.

[8] Chen, K., Wang, M., Huang, C., Kinney, P. and Anastas, P. (2020). Air pollution reduction and mortality benefit during the COVID-19 outbreak in China. *The Lancet Planetary Health*, 4, e210-2.

[9] American Community Survey (2018). 5-year summary file. https://data.census.gov/cedsci/table?q=2018%20acs%205%20year%20data&tid=ACSDP1Y2018.DP05&hidePreview=falsef, accessed 20 September 2020.

[10] New York Times (2020). New York Times corona virus data. https://www.nytimes.com/interactive/2020/us/states-reopen-map-coronavirus.html, accessed 20 September 2020.

[11] Bureau of the Census (2018). County business patterns. https://www.census.gov/programs-surveys/cbp/data/tables.html, accessed 20 September 2020.

[12] Social Explorer (2020). Community resilience estimates. https://www.socialexplorer.com/tables/CRS2020, accessed 20 September 2020.

[13] Atmospheric Composition Analysis Group (2020). Surface PM 2.5: 2016 annual average. https://sites.wustl.edu/acag/datasets/surface-pm2-5, accessed 20 September 2020.

[14] U.S. Bureau of the Census (2020). Geographies. https://www.census.gov/programs-surveys/geography/geographies.html, accessed 20 September 2020.

[15] Appelbaum, R. (1978). *Size, Growth, and U.S. Cities*. Praeger Publishers.

[16] Molotch, H. (1976). The city as a growth machine: toward a political economy of place. *American Journal of Sociology*, 82, pages 309-332.

[17] Van Donkelaar, A., Martin, R., Li, C. and Burnett, R. (2019). Regional estimates of chemical composition of fine particulate matter using a combined geoscience-statistical method with information from satellites, models, and monitors. *Environmental Science and Technology*, 53, pages 2,595-2,611.

[18] Tomer, A. and Kane, J. (2020, March 31). How to protect essential workers during

COVID-19. Brookings Report, published online. https://www.brookings.edu/research/how-to-protect-essential-workers-during-covid-19, accessed 20 September 2020.
[19] Herman, P. (1971). An historical examination of the city-state controversy over control of the New York City subways. *The Urban Lawyer*, pages 78-98.
[20] Gilderbloom, J., Squires, G. and Kingsberry, I. (2021, March 3). How many more children must be hurt by pollution? Harvard Medical School Primary Care Review. Cambridge, Massachusetts. http://info.primarycare.hms.harvard.edu/blog/children-hurt-pollution.
[21] Gilderbloom, J., Squires, G. and Meares, W. (2020). "Mama, I can't breathe." Louisville's dirty air has steep medical and economic costs. *Local Environment*, 25(8), pages 619-626. DOI: 10.1080/13549839.2020.1789570.
[22] Gilderbloom, J., Meares, W. and Squires, G. (2020). Pollution, place, and premature death: evidence from a mid-sized city. *Local Environment*, 25(6), pages 419-432. DOI: 10.1080/13549839.2020.1754776.
[23] Santucci J. (2020, July 6). The White House has sent conflicting messages on wearing masks and the new coronavirus cases, published online. https://www.usatoday.com/story/news/politic s/2020/07/05/trump-white-house-give-mixed-messages-masks-coronavirus-spread/5368455002, accessed 20 September 2020.
[24] Freidman, L. (2020, April 17). New research links air pollution to higher coronavirus death rates. *New York Times*. https://www.nytimes.com/2020/04/07/climate/air-pollution-coronavirus-covid.html, accessed 21 September 2020.
[25] Roosa, S. (2010). *The Sustainable Development Handbook*, page 89. The Fairmont Press: Lilburn, Georgia.
[26] Landrigan, P., Fuller, R., Acosta, N., Adeyi, O., Arnold, R., Baldé, A., Bertollini, R., Bose-O'Reilly, S., Boufford, J., Breysse, P. and Chiles, T. (2018). The Lancet Commission on pollution and health. *The Lancet,* 391, page 462-512.
[27] Keeley, M. and Benton-Short, L. (2019). *Urban Sustainability in the U.S.* Springer.
[28] Gilderbloom, J., Squires, G., Squires, D. and Kingsberry, I. (2022). Pollution the silent killer: destroying people, places and the planet. *International Journal of Strategic Energy and Environmental Planning*, 4(2), pages 38-48.
[29] Physicians for Social Responsibility (2020). Physicians for social responsibility. https://www.psr.org, accessed 21 September 2020.

## AUTHOR BIOGRAPHIES

**Wesley L. Meares** is an associate professor in the Department of Social Sciences at Augusta University. He also directs the university's Master of Public Administration program. His research has appeared in journals such as *Cities, Public Administration Quarterly, Journal of Mental Health*, and *Journal of Urban Affairs*. Email: wmeares@augusta.edu.

**John I. "Hans" Gilderbloom** is a professor in the Graduate Planning, Public Administration, Sustainability, Urban Affairs program and formerly had appointments in Economics, the College of Business and the School of Public Health at the University of Louisville. There

he also directed the Center for Sustainable Urban Neighborhoods for 30 years before it was moved to Neighborhood Associates in Washington D.C. in 2020 (http://sunlouisville.org). Dr. Gilderbloom has recently been appointed distinguished scientist to lead a research effort on the impact of pollution on COVID-19, health, housing, and learning. He is a member of the Editorial Board of the *International Journal of Strategic Energy and Environmental Planning*. Email: john.gilderbloom@louisville.edu.

**Gregory D. Squires** is a professor of sociology, and public policy and administration at George Washington University. He is a member of the Fair Housing Task Force of the Leadership Conference on Civil and Human Rights, the Social Science Advisory Board of the Poverty and Race Research Action Council in Washington, D.C. and the board of the Duke Ellington School of the Arts. Email: squires@email.gwu.edu.

**Antwan Jones** is an associate professor with appointments in Sociology, Epidemiology, Biostatistics and Bioinformatics, and Africana Studies at The George Washington University. As an urban sociologist, he is particularly concerned with socio-environmental processes that affect health and well-being during various stages of the life course. Email: antwan@gwu.edu.

APPENDIX follows:

## Table A1. Descriptive statistics.

| *Variable Name* | *Description* | *Min.* | *Max.* | *Mean* | *Standard. deviation* | *Source* |
|---|---|---|---|---|---|---|
| Cumulative confirmed COVID 19 cases as of 19 August 2020 | Cumulative confirmed COVID 19 cases as of 19 August 2020 | 185 | 27,184 | 4079.73 | 4430.41 | Johns Hopkins |
| Cumulative COVID 19 confirmed deaths as of Aug 19 2020 | Cumulative COVID 19 confirmed deaths as of 19 August 2020 | 0 | 1023 | 96.88 | 131.02 | Johns Hopkins |
| Cumulative confirmed COVID 19 cases rate per 100,000 as of 19 August 2020 | Rate of cumulative cases of COVID 19 per 100,000 as of 19 August 2020 | 226 | 5742 | 1531.19 | 994.98 | Johns Hopkins |
| Cumulative COVID 19 confirmed death Rate per 100,000 as of 19 Aug 2020 | Rate of cumulative COVID 19 deaths per 100,000 as of 19 August 2020 | 0 | 190 | 33.84 | 33.67 | Johns Hopkins |
| Total population | Total Population of the County | 53,332 | 127,533 | 262,353.87 | 213230.55 | ACS |
| Population density (per sq. mile) | Population density | 8 | 2395 | 383.28 | 400.59 | ACS |
| PM 2.5 | 0.01° × 0.01° grid resolution PM2.5 prediction 2016 | 2.2 | 12.5 | 6.804 | 2.01 | Atmospheric Composition Analysis Group |
| Percent of nonwhite residents | Percentage of residents that identified as not white | 4.57 | 78.99 | 22.9038 | 14.83 | ACS |
| Median household income | Median household income (in 2018 inflation adjusted dollars) | $35,516 | $91,999 | $53,870.66 | $8,998.17 | ACS |
| Median value | Median housing value of owner units | $85,200 | $649,800 | $176,187.67 | $76,921.27 | ACS |
| Percent of commuters that do not drive alone | Percentage of workers, 16 and over, that commute to work by not by not driving alone. | 11.6 | 35.99 | 19.58 | 4.33 | ACS |
| Southern states | Whether or not a state is in the Southern United States | 0 | 1 | 0.43 | 0.50 | ACS |
| Percentage of residents considered to have high risk factors | Percentage of resident with 3 or more health risk factors | 16.91 | 40.65 | 25.18 | 3.83 | Social Explorer |
| Percentage of population older than 65 | Percentage of the population that 65 or older | 8.6 | 28.8 | 15 | 3.01 | ACS |
| Mask mandate at least 15 days | Binary variable indicating that the state the city is in has had a mask mandate for at least 15 days from 8/19/2020 | 0 | 1 | 0.69 | 0.46 | New York Times Corona Virus Data |
| Number of days with stay-at-home order | The number of days that a stay-at-home order, or equivalent, was in place | 0 | 80 | 33.02 | 17.33 | New York Times Corona Virus Data |
| Percentage of essential workers | Department of Homeland Security Definition of essential jobs based on industry | 29.12 | 62.46 | 47.16 | 6.07 | County Business Patterns |
| Mayor's political party | Binary variable indicating whether or not the mayor is Republican | 0 | 1 | 0.25 | 0.43647 | Local Government Websites |

**Table A2. Top and bottom 10 counties based on cumulative cases per 100,000 as of 8/19/2020.**

| *Rank* | *County name* | *COVID 19 cases per 100,000* | *Total population* | *Population density (per sq. mile)* | *PM2.5* | *% of Nonwhite residents* | *Median household income* | *Median house value* | *% of commuters that do not drive alone* | *Southern* | *% Residents: high risk factors* | *% Total population: more than 65 years* | *State mask mandate 15 days or more* | *Days closed* | *% of essential workers* | *Mayor's political party* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Cascade Co., MT | 226 | 81,746 | 30 | 3.4 | 11.93 | 48,160 | 171,700 | 20.13 | No | 26.45 | 17.86 | Yes | 30 | 46.13 | Nonpartisan |
| 2 | Mesa Co., CO | 247 | 149,998 | 45 | 3.8 | 5.95 | 53,683 | 214,400 | 21.62 | No | 25.5 | 17.93 | Yes | 32 | 49.57 | Republican |
| 3 | Shasta Co., CA | 288 | 179,085 | 47 | 4.2 | 12.98 | 50,905 | 242,500 | 18.19 | No | 23.14 | 19.89 | Yes | 50 | 48.22 | Nonpartisan |
| 4 | Jackson Co., OR | 288 | 214,267 | 77 | 2.6 | 8.63 | 50,851 | 261,700 | 23.94 | No | 25.95 | 21.04 | Yes | 53 | 44.68 | Republican |
| 5 | Natrona Co., WY | 311 | 80,610 | 15 | 3.1 | 5.86 | 60,550 | 202,600 | 15.73 | No | 23.32 | 13.75 | No | 0 | 48.93 | Nonpartisan |
| 6 | Missoula Co., MT | 337 | 115,983 | 45 | 5.2 | 8.31 | 51,270 | 271,400 | 27.56 | No | 19.32 | 14.55 | Yes | 30 | 38.53 | Democrat |
| 7 | St. Louis Co., MN | 348 | 200,080 | 32 | 3.3 | 7.74 | 53,344 | 152,000 | 20.84 | No | 24.36 | 18.26 | Yes | 31 | 52.16 | Democrat |
| 8 | Deschutes Co., OR | 362 | 180,640 | 60 | 2.2 | 6.51 | 63,680 | 336,400 | 25.56 | No | 19.76 | 19.1 | Yes | 53 | 32.11 | Democrat |
| 9 | Chippewa Co., WI | 446 | 63,635 | 63 | 4.4 | 5.03 | 57,288 | 159,000 | 17.86 | No | 19.72 | 16.92 | Yes | 47 | 40.57 | Nonpartisan |
| 10 | Erie Co., PA | 451 | 275,972 | 345 | 7 | 13.23 | 49,716 | 130,000 | 20.93 | No | 27.59 | 16.79 | Yes | 30 | 54.84 | Democrat |
| **Avg.** | | **330.4** | **154,201** | **75.9** | **3.9** | **8.61** | **53,944** | **214,417** | **21.3** | **-** | **23.5** | **17.6** | **-** | **35.6** | **35.6** | - |
| 137 | Montgomery Co., AL | 3,268 | 226,941 | 289 | 9.5 | 63.49 | 47,990 | 127,500 | 15.44 | Yes | 30.91 | 14.18 | Yes | 26 | 48.57 | Independent |
| 138 | Lafayette Par., LA | 3,348 | 240,091 | 893 | 9.2 | 30.3 | 54,726 | 177,500 | 15.86 | Yes | 22.68 | 12.25 | Yes | 39 | 50.36 | Republican |
| 139 | Escambia Co., FL | 3,370 | 311,522 | 474 | 8.3 | 31.87 | 49,286 | 133,600 | 23.94 | Yes | 22.72 | 16.20 | No | 32 | 49.48 | Republican |
| 140 | Calcasieu Par., LA | 3,574 | 200,182 | 188 | 8.6 | 29.78 | 49,452 | 149,400 | 14.44 | Yes | 22.93 | 14.26 | Yes | 39 | 50.83 | Republican |
| 141 | Webb Co., TX | 3,660 | 272,053 | 81 | 8.1 | 4.57 | 42,293 | 119,900 | 18.76 | Yes | 40.65 | 8.96 | Yes | 29 | 58.82 | Democrat |
| 142 | Woodbury Co., IA | 3,768 | 102,398 | 117 | 7 | 13.83 | 55,483 | 117,700 | 16.32 | No | 23.8 | 14.43 | No | 0 | 45.28 | Nonpartisan |
| 143 | Victoria Co., TX | 3,977 | 91,970 | 104 | 6.8 | 12.44 | 55,631 | 136,900 | 19.81 | Yes | 31.16 | 15.41 | Yes | 29 | 49.77 | Nonpartisan |
| 144 | Yakima Co., WA | 4,551 | 249,325 | 58 | 4.1 | 21.87 | 49,871 | 167,700 | 20.74 | No | 29.66 | 13.19 | Yes | 42 | 55.77 | Nonpartisan |
| 145 | Nueces Co., TX | 4,853 | 360,486 | 430 | 7.6 | 10.07 | 55,048 | 130,700 | 16.52 | Yes | 33.26 | 13.69 | Yes | 29 | 50.24 | Republican |
| 146 | Yuma Co., AZ | 5,742 | 207,829 | 38 | 12.5 | 25.01 | 44,058 | 122,000 | 18.41 | Yes | 34.21 | 18.01 | No | 31 | 36.93 | Republican |
| **Avg.** | | **4,011.1** | **226,279** | **267.2** | **8.2** | **24.3** | **50,383** | **138,290** | **18** | **-** | **29.2** | **14.1** | **-** | **29.6** | **49.6** | - |

**Table A3. Top and bottom ten counties based on cumulative deaths per 100,000 as of 8/19/2020.**

| *Rank* | *County name* | *COVID 19 deaths per 100,000* | *Total population* | *Population density (per sq. mile)* | *PM 2.5* | *% of Nonwhite residents* | *Median household income* | *Median value* | *% of commuters that do not drive alone* | *Southern* | *% residents: high risk factors* | *% of total population: more than 65 years* | *State mask mandate 15 days or more* | *% residents high risk factors* | *% of residential workers* | *Mayor's political party* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Chippewa Co., WI | 0.0 | 63,635 | 63 | 4.4 | 5.03 | 57,288 | 159,000 | 17.86 | No | 19.72 | 16.92 | Yes | 47 | 40.57 | Nonpartisan |
| 2 | Jackson Co., OR | 0.93 | 214,267 | 77 | 2.6 | 8.63 | 50,851 | 261,700 | 23.94 | No | 25.95 | 21.04 | Yes | 53 | 44.68 | Republican |
| 3 | La Crosse Co., WI | 1.1 | 118,016 | 254 | 5.4 | 8.7 | 55,479 | 167,100 | 17.7 | No | 21.81 | 16.2 | Yes | 47 | 48.57 | Democrat |
| 4 | Natrona Co., WY | 1.24 | 80,610 | 15 | 3.1 | 5.86 | 60,550 | 202,600 | 15.73 | No | 23.32 | 13.75 | No | 0 | 48.93 | Nonpartisan |
| 5 | Missoula Co., MT | 1.72 | 115,983 | 45 | 5.2 | 8.31 | 51,270 | 271,400 | 27.56 | No | 19.32 | 14.55 | Yes | 30 | 38.53 | Democrat |
| 6 | Santa Fe Co., NM | 2.01 | 148,917 | 78 | 3.4 | 16.48 | 59,192 | 282,600 | 21.17 | Yes | 30.27 | 22 | Yes | 38 | 35.67 | Democrat |
| 7 | Bannock Co., ID | 2.35 | 85,065 | 76 | 5.0 | 10.18 | 49,739 | 152,500 | 23.16 | No | 21.94 | 13.38 | No | 37 | 45.19 | Republican |
| 8 | Boone Co., MO | 2.83 | 176,515 | 257 | 5.9 | 18.91 | 54,043 | 179,800 | 21.51 | No | 17.61 | 11.42 | No | 28 | 47.73 | Independent |
| 9 | Laramie Co., WY | 3.07 | 97,692 | 36 | 2.8 | 11.06 | 64,220 | 214,000 | 18.11 | No | 22.69 | 15.07 | No | 0 | 47.97 | Republican |
| 10 | Mesa Co., CO | 3.33 | 149,998 | 45 | 3.8 | 5.95 | 53,683 | 214,400 | 21.62 | No | 25.5 | 17.93 | Yes | 32 | 49.57 | Republican |
| **Avg** | - | **1.85** | **125,069** | **94.6** | **4.16** | **9.9** | **55,631** | **210,510** | **20.84** | - | **22.81** | **16.23** | - | **31.2** | **44.74** | - |
| 137 | Berks Co., PA | 90.25 | 416,642 | 487 | 9.2 | 17.35 | 61,522 | 174,200 | 20.16 | No | 26.67 | 16.58 | Yes | 30 | 47.76 | Democrat |
| 138 | Mohave Co., AZ | 91.72 | 206,064 | 15 | 7.8 | 9.49 | 43,266 | 151,100 | 19.99 | Yes | 31.98 | 28.8 | No | 31 | 45.95 | Nonpartisan |
| 139 | Yakima Co., WA | 97.46 | 249,325 | 58 | 4.1 | 21.87 | 49,871 | 167,700 | 20.74 | No | 29.66 | 13.19 | Yes | 42 | 55.77 | Nonpartisan |
| 140 | Lackawanna Co., PA | 100.26 | 211,454 | 461 | 6.8 | 8.39 | 50,875 | 149,700 | 19.99 | No | 28.37 | 19.28 | Yes | 30 | 52.07 | Independent |
| 141 | Cumberland Co., NJ | 103 | 153,400 | 317 | 7.8 | 32.79 | 52,593 | 162,500 | 19.17 | No | 27.85 | 14.55 | Yes | 80 | 52.52 | Republican |
| 142 | Mahoning Co., OH | 112.96 | 231,064 | 562 | 7.8 | 20.04 | 44,682 | 103,400 | 14.83 | No | 23.83 | 20.01 | Yes | 39 | 51.74 | Democrat |
| 143 | Caddo Par., LA | 122.4 | 248,361 | 283 | 7.6 | 53.61 | 40,866 | 144,400 | 14.06 | Yes | 30.52 | 15.97 | Yes | 39 | 53.46 | Democrat |
| 144 | Yuma Co., AZ | 145.31 | 207,829 | 38 | 12.5 | 25.01 | 44,058 | 122,000 | 18.41 | Yes | 34.21 | 18.01 | No | 31 | 36.93 | Republican |
| 145 | Ocean Co., NJ | 172.82 | 591,939 | 942 | 8.2 | 8.83 | 68,021 | 272,900 | 17.49 | No | 24.6 | 22.27 | Yes | 80 | 45.71 | Republican |
| 146 | Dougherty Co., GA | 190.01 | 91,049 | 277 | 8.6 | 73.03 | 37,633 | 103,900 | 21.65 | Yes | 28.27 | 14.63 | No | 22 | 39.3 | Democrat |
| **Avg** | - | **122.6** | **260,712** | **344** | **8.04** | **27.04** | | | **18.65** | - | **28.6** | **18.6** | - | **42.4** | **48.12** | - |

**Table A4. Ordinary least squares regression confirmed COVID-19 cases.**

| | *Model 1: Cumulative number of cases* | | | *Model 2: Cumulative case rate per 100,000* | | |
|---|---|---|---|---|---|---|
| | *Unst.* | *95 % CI* | *P-value* | *Unst.* | *95 % CI* | *P-value* |
| (Constant) | -3329.02 | (-10383.17, 3725.14) | .352 | -1858.43 | (-4082.09, 365.22) | .101 |
| Total population | .02 | (.02, .02) | .000 | .000 | (-.001, .001) | .647 |
| Population density (per sq. mile) | -3.36 | (-4.96, -1.77) | .000 | -0.56 | (-1.061, -.06) | .029 |
| PM 2.5 | 396.47 | (138.43, 654.51) | .003 | 149.35 | (68.01, 230.69) | .000 |
| Percent of nonwhite residents | -17.97 | (-51.97, 16.02) | .298 | 4.98 | (-5.736, 15.7) | .36 |
| Median household income | .00 | (-.07, .07) | .989 | .02 | (-.003, .04) | .083 |
| Median value | .01 | (-.004, .01) | .231 | .000 | (-.002, .003) | .778 |
| Percent of commuters that do not drive alone | -150.69 | (-264.5, -36.88) | .01 | -26.47 | (-62.35, 9.40) | .147 |
| Southern states | 1638.60 | (620.39, 2656.81) | .002 | 386.55 | (65.583, 707.52) | .019 |
| Percentage of residents considered to have high risk factors | 189.51 | (62.22, 316.81) | .004 | 107.8 | (67.67, 147.93) | .000 |
| Percentage of population older than 65 | -283.51 | (-428.47, -138.55) | .000 | -74.7 | (-120.39, -29) | .002 |
| Mask mandate at least 15 days | -1345.49 | (-2399.78, -291.2) | .013 | -438 | (-770.34, -105.65) | .01 |
| Number of days with stay-at-home order | 11.44 | (-17.8, 40.69) | .44 | -1.57 | (-10.78, 7.65) | .738 |
| Percentage of essential workers | 52.2 | (-24.97, 129.37) | .183 | 7.58 | (-16.75, 31.9) | .539 |
| Mayor's political party | 1260.67 | (385.54, 2135.8) | .005 | 268.83 | (-7.04, 544.69) | .056 |
| F | | 29.95 | | | 10.6 | |
| R2 | | .76 | | | .53 | |
| Adj R2 | | .74 | | | .48 | |

**Table A5. Ordinary least squares regression confirmed COVID-19 deaths.**

| | *Model 3: Cumulative deaths* | | | *Module 4: Cumulative deaths rate per 100,000* | | |
|---|---|---|---|---|---|---|
| | *Unst.* | *95 % CI* | *P-value* | *Unst.* | *95 % CI* | *P-value* |
| (Constant) | -280.08 | (-575.58, 15.42) | .063 | -122.03 | (-211.14, -32.91) | .008 |
| Total population | .000 | (.00, .00) | .000 | -8.65E-06 | (.000, .000) | .661 |
| Population density (per sq. mile) | .01 | (-.5, .08) | .697 | .000 | (-.024, .02) | .711 |
| PM 2.5 | 12.75 | (1.9, 23.56) | .021 | 4.45 | (1.19, 7.71) | .008 |
| Percent of nonwhite residents | .29 | (-1.13, 1.71) | .69 | .67 | (.237, 1.10) | .003 |
| Median household income | .00 | (.00, .01) | .081 | .00 | (.00, .00) | .031 |
| Median value | .00 | (-.001, .00) | .155 | .00 | (.00, .00) | .05 |
| Percent of commuters that do not drive alone | -4.04 | (-8.81, .72) | .096 | -.42 | (-1.86, 1.02) | .562 |
| Southern states | -20.24 | (-62.9,22.4) | .35 | -9.8 | (-22.66, 3.06) | .134 |
| Percentage of residents considered to have high risk factors | 7.15 | (1.82, 12.48) | .009 | 3.37 | (1.76, 4.98) | .000 |
| Percentage of population older than 65 | 5.3 | (-.77, 11.38) | .086 | 2.23 | (.4, 4.06) | .017 |
| Mask mandate at least 15 days | -28.57 | (-72.73, 15.6) | .203 | -12.31 | (-25.631, 1.01) | .07 |
| Number of days with stay-at-home order | 1.29 | (.06, 2.51) | .04 | .31 | (-.06, .68) | .101 |
| Percentage of essential workers | -1.83 | (-5.07, 1.4) | .264 | -.54 | (-1.51, .44) | .279 |
| Mayor's political party | 16.48 | (-20.18, 53.14) | .376 | .55 | (-10.51, 11.61) | .922 |
| F | | 10.33 | | | 4.9 | |
| R2 | | .52 | | | .34 | |
| Adj R2 | | .47 | | | .27 | |

## About this Journal

The International Journal of Strategic Energy & Environmental Planning is an official bi-monthly publication for members of the Association of Energy Engineers. The journal publishes original articles and papers detailing the latest strategic energy management issues such as management, corporate sustainability initiatives or energy policy.

## Published by the Association of Energy Engineers

Over 18,000 professionals in 105 countries trust the Association of Energy Engineers (AEE) to promote the interests of those engaged in the energy industry and to foster action for sustainable development. Our members operate in the dynamic fields of energy engineering, energy management, renewable and alternative energy, power generation, energy services, sustainability, and all related areas.

aeecenter.org