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COVID-19 Lockdowns Impact on Ozone Pollution

BY: David T. Stevenson, Director, Center for Energy & Environment

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Executive Summary

We can measure the amount of health harming ground level ozone in the air to parts per billion, but haven't a clue how to accurately model the atmospheric soup it formed in. The national COVID lockdown in March and April may provide an important clue to solve one part of the puzzle; how much ozone is manmade, and how much is just nature.

An initial look at air quality data is a strong indicator manmade air pollution fell by about half in the Philadelphia area in the last third of March while ozone only fell 2.5 percent. Computer models used by the Environmental Protection Agency to set national air quality standards project ozone levels should have fallen at least four times more during the lockdowns. If additional data confirms this finding, it means no amount of regulation will likely result in urban areas meeting the current EPA ozone standard of 70 parts per billion averaged over three years. That means the continuation of futile, economy killing regulation.

High levels of ozone heighten symptoms for people with respiratory ailments, such as asthma, and COPD, and can result in more hospitalizations. Ozone is not emitted directly, but forms from precursor chemicals in sunlight. Ozone forms naturally from emissions from plants, insects and animals, wildfires, soil, lightning, and volcanoes that account for almost 70 percent of precursor emissions.

Emissions from burning fuel in motor vehicles, power plants, and industrial processes add to the natural sources, and are regulated. Air pollution from other countries add to the problem, and can't be regulated. Nationally, median ozone levels fell 32-percent from 1980 to 2017, with half the reduction since 2008, as manmade emissions fell.

Manmade sources of ozone precursors fell dramatically in March and April. The Delaware Department of Transportation reports traffic on Interstate 95 near Wilmington was down 40 to 55-percent on weekdays, and 60 to 70 percent on weekends. Air traffic was down up to 96-percent based on TSA records. The American Petroleum Institute estimated refinery operation fell 20-percent.

Electric generation in the PJM regional electric grid dropped 7-percent while generation from coal fired power plants fell 40-percent. Nitrogen dioxide emissions from power plants fell 60-percent from April, 2019, to April, 2020. Nitrogen dioxide is a catalyst for ozone creation, and a marker for manmade air pollution.

Recent checks on air quality in sixteen counties that constitute the Philadelphia ozone non-attainment area showed the daily ozone average for the month to be only 3-percent, or about one part per billion, less than last April. Urban stations did average about 8-percent higher than the most rural stations, so manmade emissions had some impact on ozone levels. Ozone formation peaks on hot, sunny days. The average April high temperature in 2020 was 8 degrees cooler with ten percent less sunshine, so much of the change was likely influenced by weather rather than manmade air pollution reduction.

Only one air quality station of four that measure nitrogen dioxide has reported March data, and none have reported April data. The available data shows the pollutant fell 54 percent in the last eleven days of March when the lockdowns became fully effective, while ozone only dropped 2.5 percent. With the potential to only reduce ozone a few PPB through regulatory action, it is likely weather conditions could stack up in any given summer to lead to exceedances in urban areas for the foreseeable future.

The ozone air quality standard is up for review in 2020. A preliminary public policy assessment concludes the most up to date science supports previous findings ozone does impact respiratory health, especially in people with asthma. However, the assessment also concludes the only relevant health impact tests are controlled human exposure studies, and admits there are no such studies for people with limited lung function. That translates to the fact there is no solid scientific evidence to distinguish health impacts with ozone standards between 60 to 80 parts per billion.

The assessment also concludes EPA Administrator, Gina McCarthy, relied heavily on a single, non-peer reviewed study to reduce the ozone standard from 75 parts per billion to 70 in 2015. The study claimed short term exposure to ozone resulted in cardiovascular symptoms, and possible mortality. That study was discredited in the latest assessment.

The 2015 decision to reduce the ozone standard should be overturned, and we should return to a 75 parts per billion standard. That appears to be the Goldilocks choice that would leave headroom for nature's impact while protecting health from manmade air pollution. With a revised standard, the entire Philadelphia non-attainment area, and much of the country, should reach attainment in 2020, allowing easing of economy killing emission regulations. We need seventy-five to thrive.

Background

Government imposed quarantines, travel bans, and business closures have greatly reduced anthropogenic air pollution emissions that influence ground level ozone levels. This provides an opportunity to compare ozone measurements between 2019 and 2020 with air pollution levels dramatically lower than could be expected by any regulatory action taken in the foreseeable future.

The Delaware Department of Transportation responded to an inquiry traffic on interstate highway 95 near Wilmington has been down 40 to 55 percent on weekdays, and 60 to 70 percent on weekends during the month of April. The Wall Street Journal reported TSA airport security lines were down 96 percent. Point source emissions from sources such as oil refineries, and other manufacturing operations are also down. The American Petroleum Institute[1] estimated refinery operation was down almost 20 percent in April.

Electric generation in the PJM regional grid dropped over 7 percent while generation from coal fired power plants fell 40-percent Consequently, nitrogen dioxide (NO_2) emissions from power plants fell 60 percent from April, 2019, to April, 2020[2] (pre-pandemic February was down about 14 percent).

The U.S. Environmental Protection Agency (EPA) sets National Ambient Air Quality Standards (NAAQS) for seven air pollutants. The standards use the best available science to determine potential hazards to human health, and the maximum allowed ambient pollution level is set about 20 percent below that level. Pollution levels are measured at Air Quality Monitoring Stations (AQM) around the country.

Almost half the days in 1980, Delaware exceeded NAAQS, and some of those days were extreme hazard days. However, Delaware has been easily meeting the standards for six criteria pollutants in recent years, but is still high for ground level ozone. In 2019, Delaware met the standards for all seven monitored pollutants for the first time in all three counties[3].

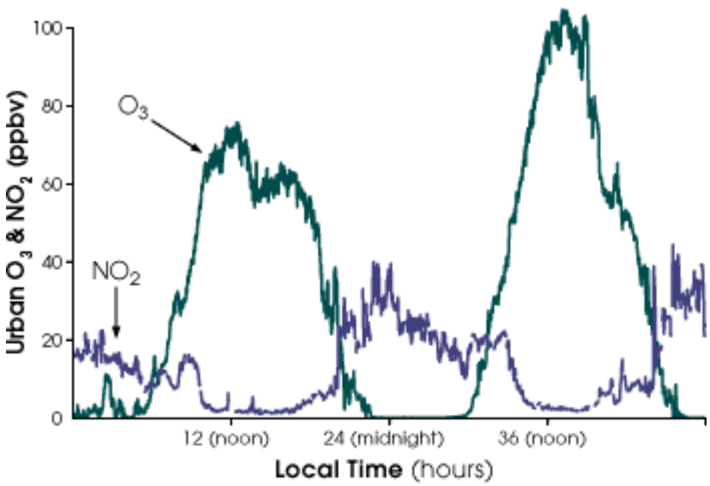
The standard is based on the three year average of the 4th highest 8-hour average, and New Castle County had exceedance days in 2017, and 2018, partially caused by smoke from western state wildfires. New Castle County will either need two more years of meeting the standard, or receive EPA approval to declare the high smoke days as exceptional events. Both Kent, and Sussex County easily meet the ozone standard.

There are a number of variables in ozone creation[4] including the amount of sunlight, temperature, wind, humidity, the amount of volatile organic compounds (VOCs), and even ocean breezes as ozone has a longer shelf life over water. The highest ozone days are on hot summer days grouped around the summer solstice, with low wind and moderate humidity, in urban areas with high VOCs. NO_2 is also somewhat sunlight and heat sensitive, and natural VOCs from plant life peak during the growing season. Ground level (tropospheric) ozone is actually produced locally in two general chemical reactions[2]:

- The energy of sunlight splits a nitrogen dioxide (NO_2) molecule into a nitric oxide molecule (NO) and a free oxygen atom (O). The free oxygen atom combines with an oxygen dioxide molecule (O_2) to form ozone (O_3). The reaction reverses fairly quickly as nitric oxide and ozone are very reactive. Coal fired power plants emit a combination of NO_2 and nitric oxide (which quickly reacts to become NO_2) and can be transported by the wind. NO_2 also occurs naturally, and from a variety of manmade sources, primarily motor vehicles.
- A sunlight split NO_2 molecule can also react in a complex way with a wide range of VOC to form ozone which tends to be longer lasting. VOCs can be generated by natural sources, such as vegetation, and by manmade manufacturing and combustion. Natural sources can be overwhelming, such as VOC sources like pinetene from pine trees. The EPA estimates natural VOCs may make up 69 percent of total VOC inventory.

In both cases NO_2 is considered a catalyst, the reaction can't occur without it, but the amount of NO_2 is ultimately unchanged over a 24 hour period. Ozone is highly reactive with any physical surface and can cause injury to plants and animals, and especially sensitive people with asthma or COPD. The local nature of ozone is confirmed by Figure 1 below which shows how ozone forms in the day and falls to essentially zero overnight, the reverse of NO_2.

Figure 1. Diurnal Ozone Production



Source: NASA Earth Observatory

There is a poor correlation between higher levels of NO_2 and higher levels of ozone. The author has made correlation calculations between NO_2 and ozone. Ambient levels of NO_2 averaged 19 PPB daily one-hour maximum during the ozone season with a range of 5 to 50 PPB over the years 2013 to 2015 (measured at the Martin Luther King Blvd. air quality monitoring station in Wilmington, Delaware). The 19 PPB is 80 percent below the NAAQS. A statistical correlation between NO_2 levels and ozone levels found the correlation was 0.08, so essentially there was no correlation between the two! Zero equals no correlation and +/- 1 equals perfect correlation.

For further verification we looked at 2013 ozone season data from the Lewes, Delaware, air monitoring station which measured NO_2 that year. Lewes is a rural station while Wilmington is more urban. The Lewes station showed an ozone season average ambient level of NO_2 of only 3 PPB, 97 percent below the NAAQS, with a range of 0.3 to 10 PPB. The statistical correlation between ozone levels and NO_2 levels was only 0.01, or once again essentially zero. Despite six times higher NO_2 levels the Wilmington ozone season average was only 1 percent higher than Lewes, 44.8 PPB compared to 44.2 PPB.

As life returns to normal the opportunity to establish low air pollution comparisons will diminish, so the April comparisons may be optimal.

The Philadelphia Non-Attainment Area (NAA)

The EPA established the Philadelphia NAA based on 2016 comments from state air quality divisions. The EPA does a technical analysis to identify areas with monitors that violate the 2015 ozone NAAQS[5]. The evaluation looks at any nearby areas that may contribute to ambient ozone concentrations at the violating monitor based on the weight-of-evidence of five factors. The five factors recommended in EPA's guidance are:

1. Air Quality Data (including the design value calculated for each Federal Reference Method
(FRM) or Federal Equivalent Method (FEM) monitor;

2. Emissions and Emissions-Related Data (including locations of sources, population, amount of emissions, and urban growth patterns);
3. Meteorology (weather/transport patterns);
4. Geography/Topography (including mountain ranges or other physical features that may influence the fate and transport of emissions and ozone concentrations); and
5. Jurisdictional Boundaries (e.g., counties, air districts, existing nonattainment areas, areas of Indian country, Metropolitan Planning Organizations (MPOs)).

The Philadelphia NAA covers 16 counties, and 18 AQMs in Pennsylvania, New Jersey, Delaware, and Maryland. The AQMs with the highest ozone measurements were all located near major highways, such as I-95 and the New Jersey Turnpike, had major point sources of emissions, such as power plants, refineries, airports, or other major industrial companies, and had population densities above 1,000 people per square mile.

The NAA AQM station chosen to represent the Design Value for the region is Bristol, PA (AQM 420170012 shown in orange in Figure 2). As long as that station exceeds the three year average ozone NAAQS all sixteen counties will be considered out of attainment. Figure 2 below shows the ozone trend lines for the stations. The rise in the 2016 trend lines is most likely caused by the impacts of smoke from western wildfires that persisted from 2016 to 2018.

Figure 2. Three-Year Design Values for Violating Monitors (2006-2016).

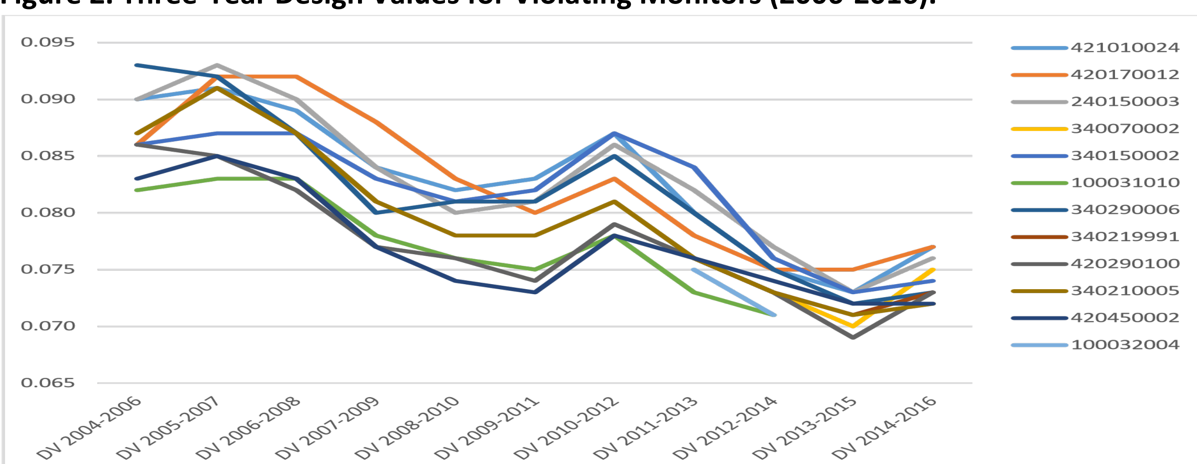


Table 1: Philadelphia NAA ambient ozone, PPB[3]

County	AQM Station	2014/2016 Design Value	2019 4th Highest Day	April 7, 2019 Peak Day	April 19, 2020 Peak Day
New Castle, DE	100031010	74	67	60	-
New Castle, DE	100032004	71	67	60	50
Cecil, MD	240150003	74	68	60	52
Atlantic, NJ	340010006	64	59	56	-
Camden, NJ	340070002	75	70	55	49
Camden, NJ	340071001	69	67	58	48
Cumberland, NJ	340110007	68	68	59	50
Gloucester, NJ	340150002	74	68	55	48
Mercer, NJ	340210005	72	66	56	52
Mercer, NJ	340219991	73	68	61	52
Ocean, NJ	340290006	73	68	57	49
Bucks, PA	420170012	77	67	59	50
Chester, PA	420290100	73	68	62	50
Delaware, PA	420450002	72	69	58	50
Montgomery, PA	420910013	70	65	47	52
Philadelphia, PA	421010004	61	67	43	48
Philadelphia, PA	421010024	77	71	62	51
Philadelphia, PA	421010048	74	72	57	51
Average		68	67.5	57	50

Comparison data to April, 2020

Table 1 above lists the fourth highest average ozone data for each AQM in the Philadelphia NAA for the 2014/2016 Design Value period, the fourth highest day for 2019, the peak day in April, 2019, and the peak day for April, 2020. Only two stations, located in Philadelphia, exceeded the 70 PPB standard in 2019, and by only 2 PPB. The highest peak day average from the 18 stations in April, 2019, was 57 PPB compared to the highest peak day average in 2020, of 50 PPB.

The difference in ambient ozone levels must be adjusted for differences in the weather. Ozone daily peaks always occur in the afternoon in line with the warmest, sunniest part of the day. April, 2019, averaged 68° F for daily high temperatures according to the Pennsylvania State Climatologist[6], while April, 2020 only averaged 60° F. Table 2 shows the weather conditions for the peak day 18 station average in 2019 and 2020, and the correlation between the weather condition and ozone levels.

Table 2: April 2019/2020 peak ozone days, and April, 2020 correlation O_3 to weather

Date	Ozone PPB	Temp. °F	Sunlight KWh	Humidity RH %	Wind Speed MPH
April 7, 2019	57	70	53.3	62	7
April 19, 2020	50	61	48.8	51	11
O3 Correlation		0.43	0.57	-0.39	-0.03

On April 7, 2019, the daily high was 70° compared to 61°on April 19, 2020, the peak monthly days. For this study I measured available sunlight by the electricity output of an 8.4 kilowatt (KW) solar installation. April, 2019, was 10 percent sunnier than April, 2020. The peak monthly day of April 7, 2019 was 8.4 percent sunnier than April 19, 2020. Higher humidity tends to literally dampen peak days. The average relative humidity was about equal both months, but was higher on the 2019, peak day at 62 percent, compared to 51 percent in 2020. Higher wind speeds also tend to lower peaks. Average wind speed was 10 MPH in April, 2019, compared to 11.7 MPH in April, 2020, with the peak day of April 7, 2019, at 7 MPH, compared to 11.7 MPH for April 19, 2020. It is likely most of the variation in peak days between the two years was weather related.

Four of the 18 stations also measure daily maximum one hour NO_2 levels. In April, 2019, the stations averaged 19 PPB with a range of 2 to 46 PPB compared to a standard of the 98th percentile of 1-hour daily maximum concentrations, averaged over 3 years of 100 PPB. The correlation between NO_2 and ozone averaged 0.40 for the four stations with a range of 0.09 to 0.53. The April, 2020, NO_2 data is not published yet.

The correlation between ozone peak days and weather conditions is significant for temperature, available sunlight, and humidity. However, attempts by EPA scientist, and the author to create an algorithm to estimate peaks based on weather conditions has proved fruitless, with the EPA declaring the relationship simply "non-linear".

In 2019, the 4th highest ozone, 8 hour average at the three stations with the lowest peaks during the ozone season were 59, 65, and 66 PPB. Yet even those sites had higher days that exceeded the 70 PPB standard at 79, and 72 PPB. With all the reductions of air pollution, and significantly more favorable weather, the 18 station average daily maximum for ozone in April, 2020, was only 3 percent lower than 2019, at 43.1 compared to 44.4 PPB. The peak ozone day in 2019 saw NO_2 at 21 PPB, about the average for the month. However, the second highest ozone day averaged less than half that amount of NO_2 at 10 PPB, about the same as the lowest 18 station average ozone day of the month at 12 PPB.

The average of the four peak ozone days in 2020, at the highest station, Philadelphia, was 76.5 PPB, while the four highest days in the lowest station averaged 66.5 PPB. However, ozone peak days from the lowest ozone recording station in the region could exceed the 70 PPB NAAQS requirement with the right weather conditions even with dramatically lower manmade air pollution. That suggests the ozone NAAQS is set too low. When the EPA reconsiders the ozone NAAQS, the standard should be raised back to the pre-2015 standard of 75 PPB.

Implications for a next ozone NAAQS review

The EPA is tasked with reviewing national air quality standards for seven harmful pollutants every five years. The ozone standard is up for review in 2020. The national COVID lockdown in April may provide an important clue to solve one part of the puzzle of how much ozone is manmade, and how much is just nature. The real time experiment may also inform decisions on setting national standards for safe levels of ozone, and relieve areas whose economies are unnecessarily restricted by emission regulations.

There is an ongoing debate at the EPA in establishing the ozone NAAQS as to how to determine baseline ozone levels from uncontrollable natural and international air pollution sources. A preliminary EPA public policy assessment[7] reviews this issue. Setting the standard too close to the uncontrollable background level establishes unrealistic expectations for compliance given the wide variation of potential peak days during heat waves, and other exceptional events.

One methodology to split the sources uses computer modeling, and Table 3 shows the results of the modeling from Figures 2-16, and 2-17 from the EPA Assessment.

Table 3: Computer ozone season modeling results by source for Philadelphia NAA in PPB

Season	Natural	International Pollution	USA Pollution	Baseline Average	Manmade %
Spring	18	12	14	44	32%
Summer	18	8	28	54	52%

The computer modeling suggests springtime air pollution from sources in the US accounts for 14 PPB, or 32 percent of the average baseline, and 28 PPB, or 52 percent in the summer. However, with all the reductions in air pollution, the 18 station average daily maximum baseline for ozone in April, 2020, was only 1 PPB, or 3 percent lower than 2019, at 43.1 PPB compared to 44.4 PPB. There is still limited NO2 data for 2020. One station in Wilmington, DE has released data for March. NO_2 dropped 54 percent after lockdowns began in the last third of the month, but ozone only fell 2.5 percent, or about 1 PPB (Figure 3, and Table 4). This suggests almost an order of magnitude less impact from controllable air pollution than the computer model predicts.

Figure 3:

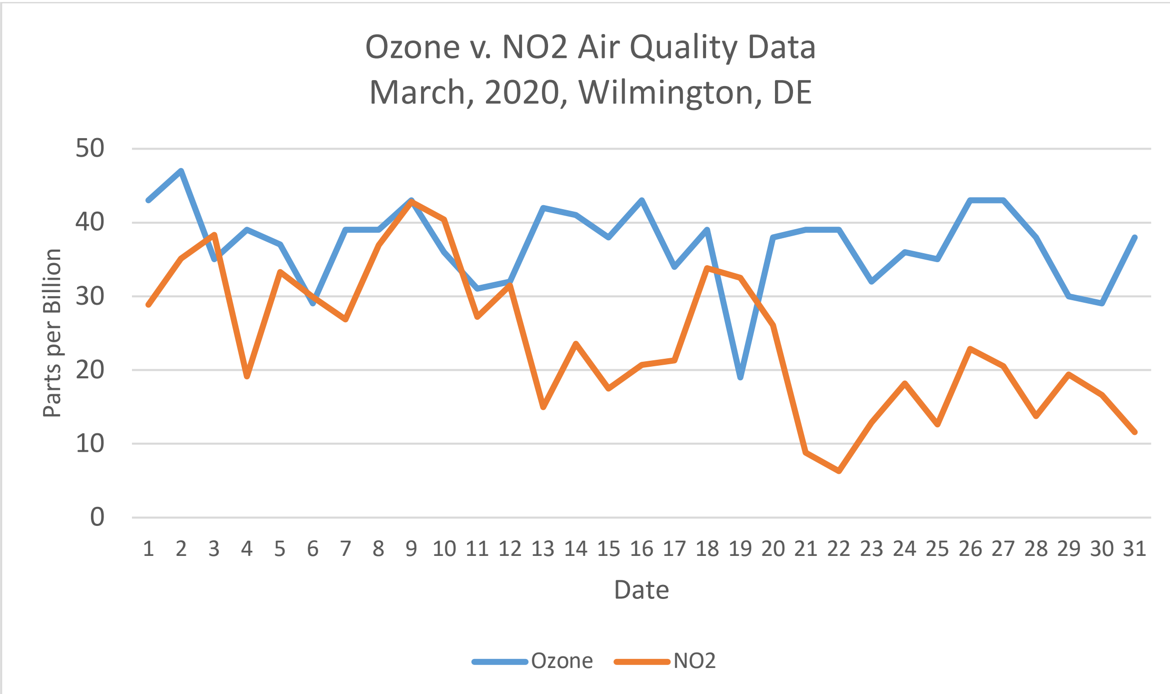


Table 4: Impact of COVID-19 Lockdowns on ozone and nitrogen dioxide – PPB

	Ozone	Nitrogen Dioxide
March 1st to 12th	37.5	32.5
March 21st to 31st	36.5	14.9
% Difference	-2.5%	-54.3 %

An alternative to computer modeling is to compare the most rural stations to the most urban stations to estimate controllable air pollution contributions. In April, 2019, the stations with the three highest monthly baselines averaged 46.2 PPB, 6.4 PPB higher than the three lowest stations. In April, 2020, the stations with the three highest monthly baselines averaged 44.2 PPB, 2.7 PPB higher than the three lowest stations. The difference between the two years is the right order of magnitude that might be expected from the lower air pollution levels during the COVID-19 shutdown. The highest baseline stations matched the model predicted baseline.

In June to August, 2019, the stations with the three highest monthly baselines averaged 49.6 PPB, 4.3 PPB, or 9 percent higher than the three lowest stations. The average baseline for the 18 stations was 47.8 PPB, 6 PPB, or 11 percent below the model estimate. In 2019, the summer baseline was only 3.4 PPB higher than the April baseline, not the predicted 10 PPB.

Taken together, the year over year ozone data, and the April data for the two years suggest air pollution from within the US is only contributing 4 to 6 PPB to baseline levels. Based on station data from the last two years the information in Table 3 might be corrected to Table 5. The computer model assumptions need revision.

Table 5: Rural to urban station based estimates for seasonal ozone in Philadelphia NAA PPB

Season	Natural	International Pollution	USA Pollution	Baseline Average	Manmade %
Spring	26	12	6	44	14%
Summer	34	8	6	48	12.5%

The real issues is what will peak days look like compared to the 70 PPB standard. In 2019, the three highest stations for ozone had average peak days of 79 PPB compared to the 18 station average summer base of about 48 PPB, and a 4th highest day average of 71 PPB. With the potential to only reduce ozone a few PPB through regulatory action, it is likely weather conditions could stack up in any given summer to lead to 4th highest day exceedances for some stations in the Philadelphia NAA for the foreseeable future.

The EPA policy assessment list conclusions in Section 3.5.3. The most up to date science supports previous findings ozone does impact respiratory health, especially in people with asthma. However, the assessment also concludes the only relevant health impact tests are controlled human exposure studies, and in its uncertainty analysis in Section 3.6, admits there are no such studies for people with asthma. That translates to the fact there is no solid scientific evidence to distinguish hospitalization rates between ozone standards of 60 to 80 parts per billion.

The assessment also concludes EPA Administrator, Gina McCarthy, relied heavily on a single non-peer reviewed study to reduce the ozone standard from 75 parts per billion to 70 in 2015. The study claimed short term exposure to ozone resulted in cardiovascular symptoms, and was the first study to find a connection between ozone and mortality. That study was found to be erroneous in the latest assessment.

Conclusion

In summary:

- It is likely anthropogenic air pollution fell roughly 50 percent from 2019, to 2020, due to the COVID-19 shutdowns, an amount unlikely to be seen from regulatory actions in the foreseeable future. Yet, with all the reductions in air pollution, the 18 station Philadelphia Non-attainment Area average daily maximum baseline for ozone in April, 2020, was only 1 PPB, or 3 percent lower than 2019, at 43.1 PPB compared to 44.4 PPB. This is confirmed by actual ozone and NO_2 data from March. This suggests almost an order of magnitude less impact from controllable air pollution than the EPA computer model predicts.
- In 2019, the three highest reporting ozone stations had average peak days of 79 PPB compared to the 18 station average summer base of about 48 PPB, and a 4th highest day average of 71 PPB. With the potential to only reduce ozone a few PPB through

regulatory action, it is likely weather conditions could stack up in any given summer to lead to 4th highest day exceedances for some stations in the Philadelphia NAA for the foreseeable future.

- There has been no significant new scientific data since the 75 parts per billion standard was set in 2008.
- The key report used to justify the lowering of the standard to 70 parts per billion in 2015 has been discredited.
- There are no controlled human exposure tests of vulnerable people to differentiate health impacts for standards set between 60 and 80 PPB, so there is no reliable data to support the current 70 PPB standard.
- The 2015 decision to reduce the National Ambient Air Quality Standard for ozone should be overturned, and we should return to a 75 parts per billion standard.

Notes:

1) American Petroleum Institute, U.S. GASOLINE AND DISTILLATE FUELS UPDATE - MAY 20, 2020, https://www.api.org/~/media/Files/Oil-and-Natural-Gas/Gasoline/US-gasoline-distillate-update.pdf
2) PJM Systems Mix, https://gats.pjm-eis.com/gats2/PublicReports/PJMSystemMix
3) US EPA, Outdoor Air Quality Data, https://www.epa.gov/outdoor-air-quality-data/download-daily-data
4) "Chemistry in the Sunlight", NASA Earth Observatory, http://earthobservatory.nasa.gov/Features/ChemistrySunlight/
5) EPA Technical Support Document, Philadelphia Nonattainment area 2015 ozone NAAQS, https://www.epa.gov/sites/production/files/2018-05/documents/phila_tsd_final.pdf
6) Pennsylvania State Climatologist, Weather records for Philadelphia, http://www.climate.psu.edu/data/city_information/index.php?city=phl&page=dwa&type=big7
7) Policy Assessment for the Review of the Ozone National Ambient Air Quality Standards, External Review, U.S. Environmental Protection Agency Office of Air Quality Planning and Standards Health and Environmental Impacts Division, October, 2019, Drafthttps://yosemite.epa.gov/sab/sabproduct.nsf/264cb1227d55e02c85257402007446a4/56F5BB9165D594C78525848C0046BECC/$File/O3-draft_PA-Oct31-2019-ERD.pdf