UPDATE # 2 – MAY 29, 2020

Analyzing Air Quality and Climate Change Data During the COVID-19 Pandemic
What Are We Learning?

Background – For over 30 years, the Maryland Department of the Environment (MDE) and the University of Maryland College Park (UMCP) have worked in partnership to conduct policy-relevant research on air quality and climate change. This partnership has often involved collaboration with other states and partners like the National Aeronautics and Space Administration (NASA), the National Institute of Standards and Technology (NIST), the National Oceanic and Atmospheric Administration (NOAA) and other universities like Howard University and the University of Maryland Baltimore County. This collaborative research effort has led to some of the states' and the nation's most successful efforts to reduce air pollution and protect public health. Maryland's Departments of Transportation and Natural Resources have also provided support to the current effort.

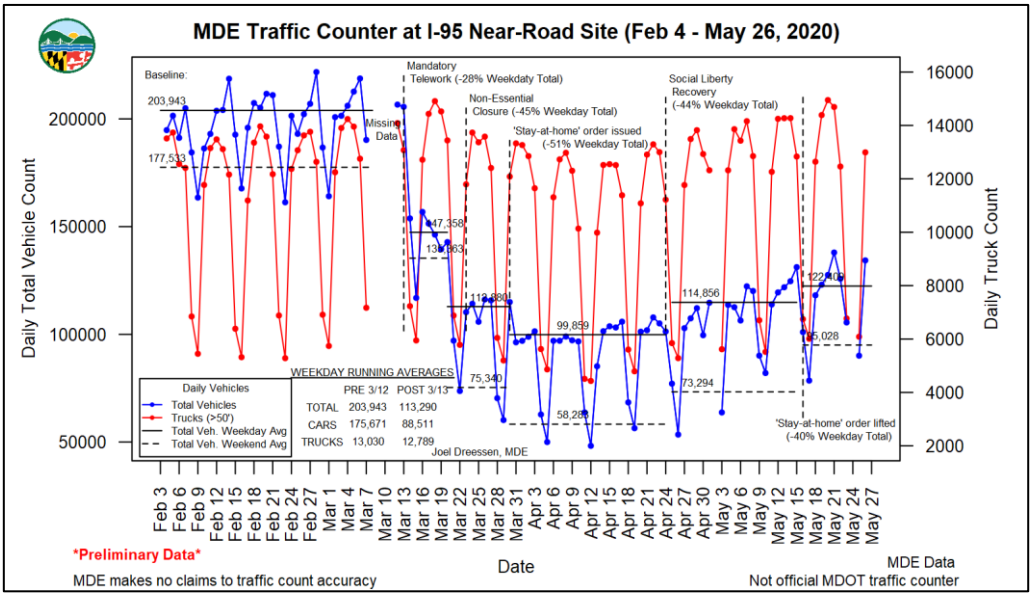
COVID-19 Analyses – The goal of this research is to help inform policy makers working on efforts to further improve air quality and to reduce greenhouse gases (GHG). This effort, started in early March, is using traffic, satellite, air quality, GHG and other data to analyze how reduced traffic and other changes linked to social distancing during the COVID-19 pandemic are affecting pollutants that contribute to poor air quality and climate change. The analyses are evolving and it is not possible to draw definitive conclusions at this time, but the data is extremely interesting. Update # 1 on this issue was released on April 18, 2020.

What We Have Seen to Date … A Quick Overview

- Traffic continues to be down, but both car and truck traffic began to slowly increase around the middle of April. Truck traffic appears to have returned to normal levels.
- Satellite measurements of nitrogen dioxide (NO_2) continue to show significant reductions in column NO_2. NO_2 is a very good indicator for combustion related emissions.
- Levels of air pollutants like ozone (photochemical smog) and fine particles ($PM_{2.5}$) are also very low right now. These low levels appear to be driven more by the historical downward trend from regulatory programs and less by COVID-19 related activities.

- Levels of carbon dioxide (CO_2) in the air, measured from tall towers and by University of Maryland College Park airplanes flying around Baltimore are also lower than expected. CO_2 is the most prevalent GHG linked to climate change.
- Analysis shows emissions from power plants and other energy generation sources are also down. Emissions of nitrogen oxide (NO_x) and sulfur dioxide (SO_2), key emissions linked to ozone and $PM_{2.5}$ air pollution are down. Emissions of CO_2 are also low. Interestingly, these low emissions in the energy sector appear to be more driven by historical downward trends driven by regulatory programs and not so much COVID-19 related activities.
- Data on vehicle miles travelled (VMT) show dramatic reduction in VMT in the 50 to 80% range. This means that mobile source emissions of NO_x and CO_2 should be down significantly. Efforts to quantify these reductions are ongoing.
- Initial analysis of telework indicates that common sense efforts to expand telework policies could generate significant reductions in GHG emissions.

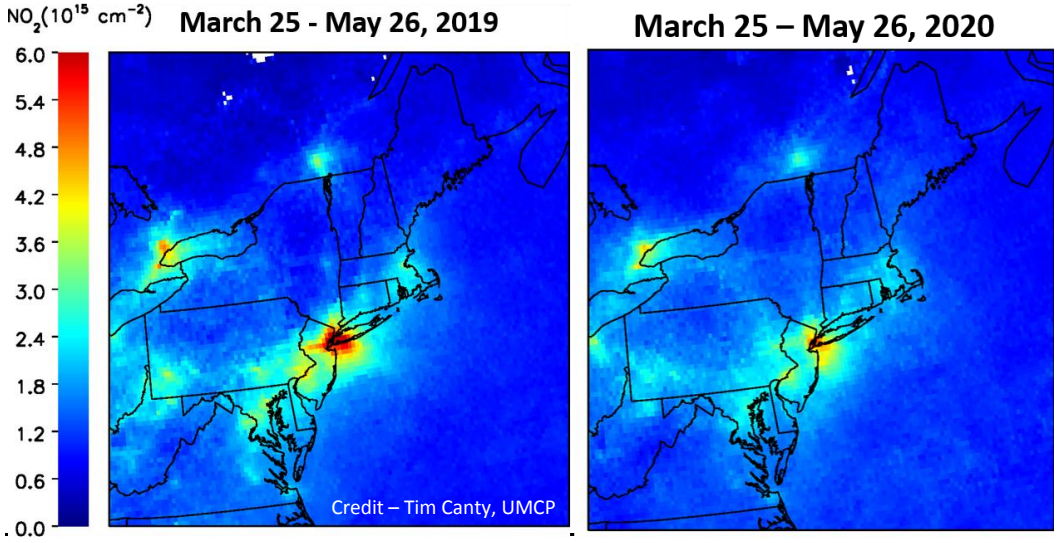
Traffic Data – Initial and primary analyses of traffic data use MDE's roadside air monitoring station located at the I-95 rest stop between Baltimore and Washington. Light duty gasoline vehicle traffic (cars and passenger trucks) remain down by approximately 40% though it has been steadily increasing back towards levels seen before social distancing measures were implemented. The most recent data points indicate traffic only 32% below baseline levels. Heavy duty diesel vehicles experienced a maximum 8% decline during the lowest week in April. However, since March 14th, truck traffic in general has only been down 2% in aggregate and has been at levels similar to the baseline prior to COVID-19 related response activities.



Satellite Data – Satellites have become a powerful tool to analyze air quality and climate change. NASA works closely with UMCP and MDE on satellite data analysis. UMCP has been using the satellite data to look at changes in tropospheric column NO_2. Tropospheric column NO_2 is the NO_2 measured in the lowest layer of the atmosphere observed by the satellite from its orbit. These data are directly related to ozone air pollution and are also a good indicator for changes in emissions of combustion sources (power plants and vehicles). The data shown below, which is still very preliminary, shows maps of NO_2 acquired before and during the COVID-19 pandemic. The red in the satellite images correspond to about 2 ppb near the earth surface, within the air quality standard for NO_2, but enough to make a lot of smog and possibly lead to an ozone event.

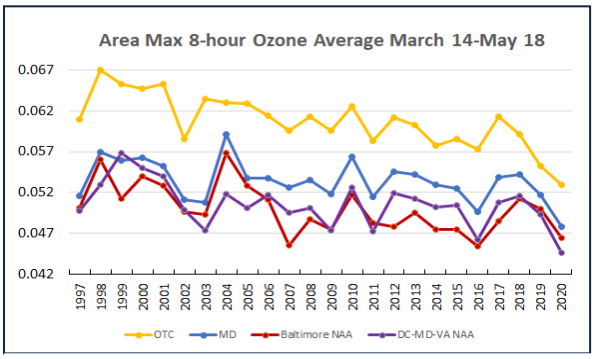
Satellite Observations of NO_2

Average Tropospheric Column NO_2 for March 25 – May 26, 2019 (left) and 2020 (right) as Observed by TROPOMI (TROPOspheric Monitoring Instrument). Data Are Only Used When Cloud Cover is Less Than 30%



Air Quality Data

Preliminary MDE analysis of air quality data from March 14th-May 18th attempts to tease out the level of improved air quality associated with the COVID-19 response activities. This is complicated as multiple factors, including weather, historical downward trends, and challenging springtime atmospheric chemistry, must be considered. To isolate the benefit of COVID-19 related activities, only the additional benefit above long term downward air pollutant and emissions trends

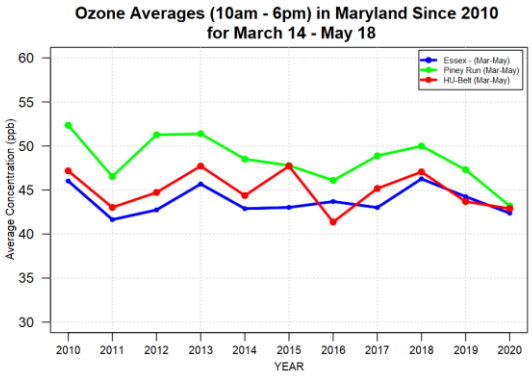


OTC = Ozone Transport Commission

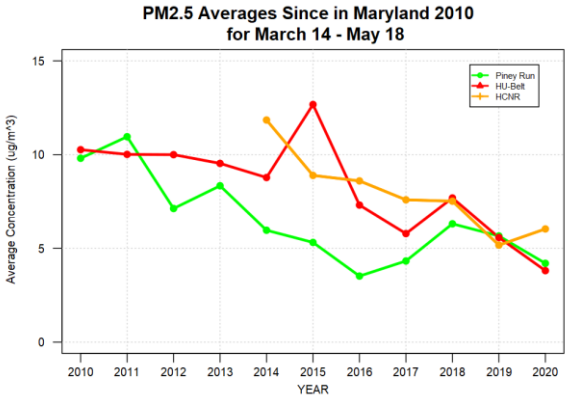
Credit – Tom Downs, ME

driven by regulatory programs were considered.

Average concentrations measured below the historical trends can provide preliminary estimates of how much the COVID-19 response activities have reduced NO_x air pollution. NO_x measurements were estimated to have decreased 15 to 18% in the urban areas. NO_x showed little change at the elevated Piney Run site, but total reactive nitrogen (NOy), which includes long-range transport species, measured a 9% decrease beyond the historical downward trend. Ozone is low, with peak 8-hour ozone measurements setting all-time or near-all-time lows regionally. However, maximum temperature data shows the period has been quite cool, making a quantitative assessment of the impact on ozone premature.



$PM_{2.5}$ concentrations are amongst the lowest ever recorded in Maryland, but they are within the noise of the historical downward trend data, with no clear COVID-19 response related impact noted at this time.



Preliminary overall conclusions are summarized below.

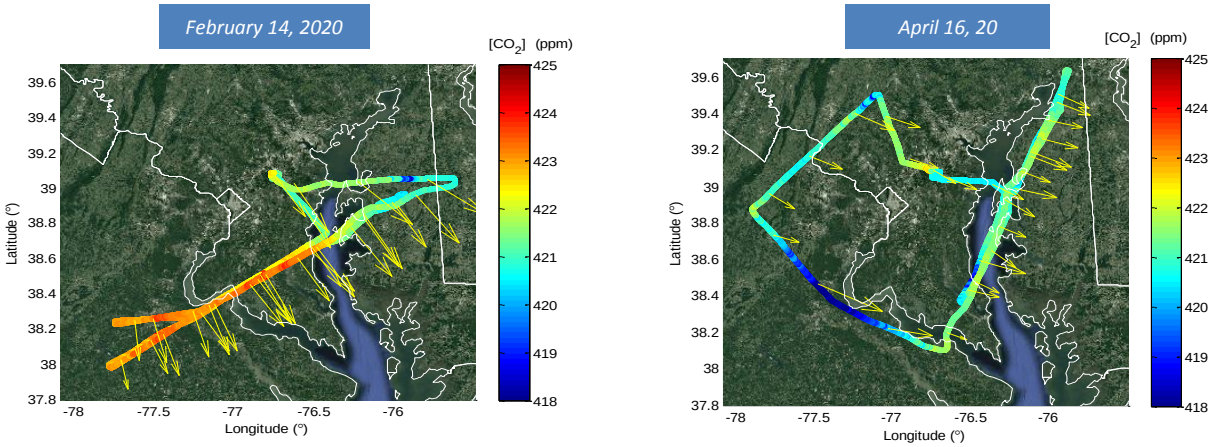
- Ozone or smog is near record lows, but other factors can play a major role in these reductions.
- $PM_{2.5}$ levels are also amongst the lowest ever recorded. Like ozone, other factors are playing a major role in these reductions.
- Carbon monoxide (CO) levels are down by approximately 25% above and beyond existing trends. CO is an air pollutant directly linked to mobile source emissions, especially cars and light duty trucks.
- NO_x concentrations in the urban areas are also down by about 15% above and beyond existing trends.
- Levels of NOy, often used as an indicator for air pollution transported from upwind states, are down about 9% beyond the existing trend at the MDE mountain top Piney Run monitor in Western Maryland.

- Black carbon levels at the MDE near road air monitoring site in Howard County are down about 30% beyond current yearly trends. Black carbon is also a potent contributor to climate change and is often associated with mobile source emissions, especially diesel.

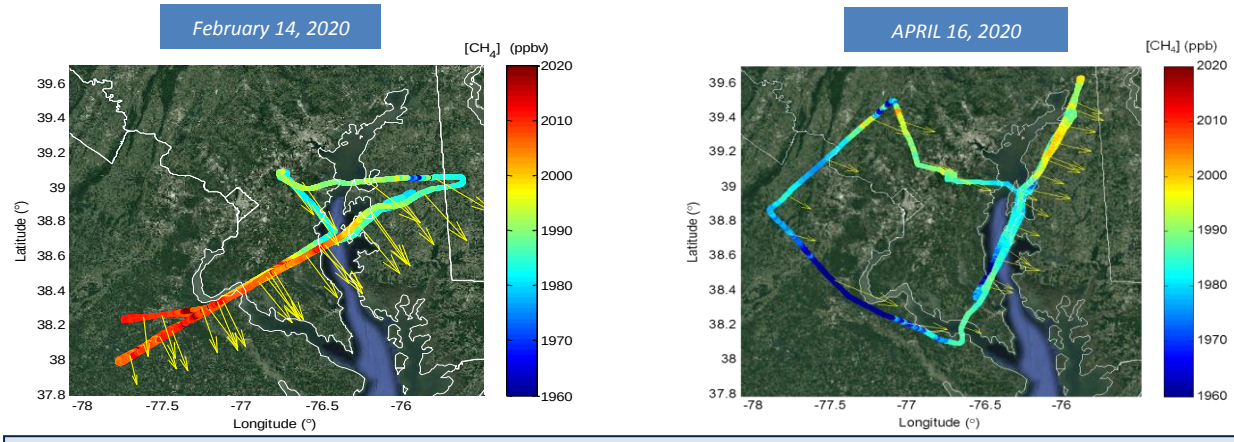
New Greenhouse Gas and Climate Change Analyses

We are cooperating with NASA, NOAA, and NIST in this effort. Only part of the data has been analyzed, and all must be confirmed, but emissions of both CO and CO_2 from Baltimore and Washington appear to have fallen roughly 30% due to travel and other restrictions implemented to fight COVID-19. NOAA is supporting efforts to model air quality primarily for forecasting needs, and has brought a research aircraft to the eastern US. Flying over major cities between Washington, DC and Boston, MA, this aircraft has been measuring GHG's CO_2, CH_4, and CO. Results will be combined with observations from the UMCP Cessna and Purdue/SUNY Duchess. By examining the concentrations upwind and downwind of urban areas, we can estimate the mass flux of each gas. We also look at ratios of gases.

CO2 Levels Before and After Start of OVID-19 Response Activities Measured by UMCP Research Aircraft



Methane (CH4) Levels Before and After Start of COVID-19 Response Activities Measured by UMCP Research



How to interpret the aircraft data. These four graphs show the CO2 and CH4 GHG data collected by the UMCP aircraft on 2/14/20 and 4/16/20. The lines follow the flight path for each day. The colors show measured concentrations. Reds indicate higher amounts. Blue indicates lower amounts. Both CO2 and CH4 are lower after start of social distancing, but CO2 shows a greater impact.

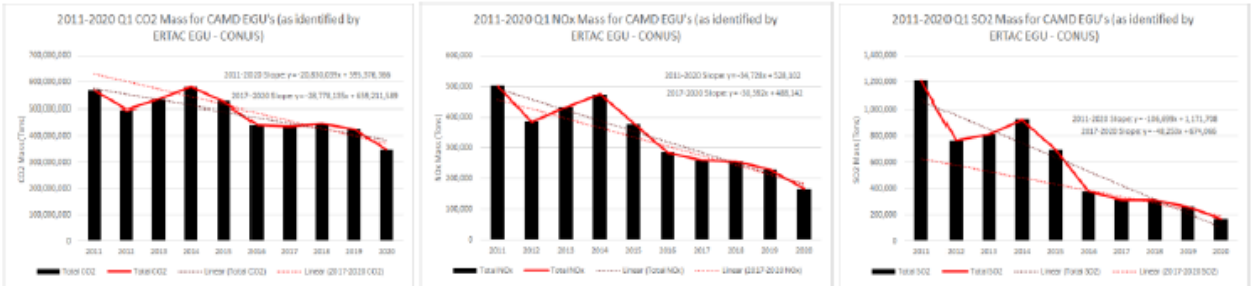
For example, if methane emissions remain unchanged during the COVID-19 crisis, then the ratio of CO/CH_4 and CO_2/CH_4 should indicate changes in emissions. This gives us a snapshot of GHG emissions for an urban area.

We have performed only a partial analysis of some of the flight data, but initial results indicate reduced emissions of criteria pollutants and GHGs in the Baltimore/Washington area. The mass balance and ratio approaches both indicate about 30% less CO_2 and CO being emitted into Maryland's air due to COVID-19 response activities. These reductions are clearly linked to reduced vehicle traffic and likely linked to changes in industry and energy generation.

Emissions Data

Analysis of regional generation and continuous emissions monitoring systems (CEMS) data indicates that, while generation and demand has changed little, recent emissions of CO_2, NO_x and SO_2 from power plants are lower in March 2020, compared to March-only average values from 2016-2019. March 2020 CO_2, NO_x, and SO_2 are down 23%, 35% and 47% respectively, compared to the March 2016-2020 averages. Given that power plant activity, as measured by heat input, has changed very little over the same time period, and March 2020 values appear to be within the 2011-2020 historical trend, the observed reduction in emissions are likely driven more by decreased coal usage and increased natural gas usage, and less by the COVID-19 response activities.

CO_2, NO_x and SO_2 Emission Reduction Trends in the Power Sector



CAMD EGU:Electric Generating Units included in EPA Clean Air Markets Division data base, ERTAC EGU:The EGU workgroup of the Emission Reduction Technical Advisory Committee,

The CEMS data support this conclusion. They indicate that coal usage has decreased, while natural gas usage has increased. To determine if any of the observed emissions reductions are linked to COVID-19 response activities, daily CEMS data was reviewed before and after social distancing measures were implemented. The CEMS activity indicates that observed reductions are within the historical downward trend, rather than a sudden reaction to COVID-19 response activities. Some states (IL, KY, MA, NY, OH, TN and WV) *may* show downward trends in power plant activity after implementation of social distancing, but there are not enough data points to

draw any definitive conclusions to date. The CEMS data is only available through March 31st, and social distancing was not implemented until, on average, March 16th-23rd, leaving less than two weeks of data to examine. Examination of the daily data will be updated when 2nd quarter Clean Air Markets Division (CAMD) data is released in July of 2020.

Additional Efforts from Federal Partners

NASA provides daily, global satellite coverage of the trace gas NO_2 and of aerosols (aerosol optical depth, AOD) on spatial scales of about 10 km. CO_2 coverage is once every two weeks or so. They also have surface-based monitors for looking upward from a fixed point to determine the local atmospheric burden of pollutants. Initial results from NASA indicate dramatic reductions in NO_2 over many locations worldwide, including the mid-Atlantic, but care must be taken to separate the effects of COVID-19 response activities from changes related to weather and seasonal cycles.

NIST supports an array of tall towers instrumented with research-grade GHG monitors and numerical simulations to use tower data and meteorological models to estimate GHG fluxes. They provide extensive support of scientists and students and also support UMD's research aircraft with both instruments and flight hours.

Changes in Vehicle Miles Traveled (VMT)

VMT data is determined through a variety of different means. The most common is through the Highway Performance Monitoring System (HPMS) compiled by MDOT using vehicle count

Weekly Statewide VMT Reduction Due to COVID-19

First 2 weeks of March 2020 is considered a business as usual (BAU) baseline

Days	Event	Week VMT (million mile)*	Avg daily VMT (million mile)*	%VMT Decline (from BAU)*	%VMT Decline (from BAU) MDOT**
Mar 01-Mar 15	BAU 2 weeks of "Normal" traffic	1,260.086	180.012	0	0
Mar 16-Mar 22	State employee telework (Mar 13) Schools Closed (Mar 16)	548.290	78.327	56	27
Mar 23-Mar 29	All non-essential business closed (Mar 23)	352.607	50.372	72	46
Mar 30-Apr 05	Stay at home order (Mar 30)	297.472	42.496	76	51
Apr 06-Apr 12	Less significant changes in policies driving reduced driving	294.558	42.080	77	52
Apr 13-Apr 19		308.122	44.017	76	51
Apr 20-Apr 26		327.842	46.835	74	49

Source of data from StreetLight* * Preliminary MDOT data* *Credit:Urszula Kukier, MDE, MDOT*

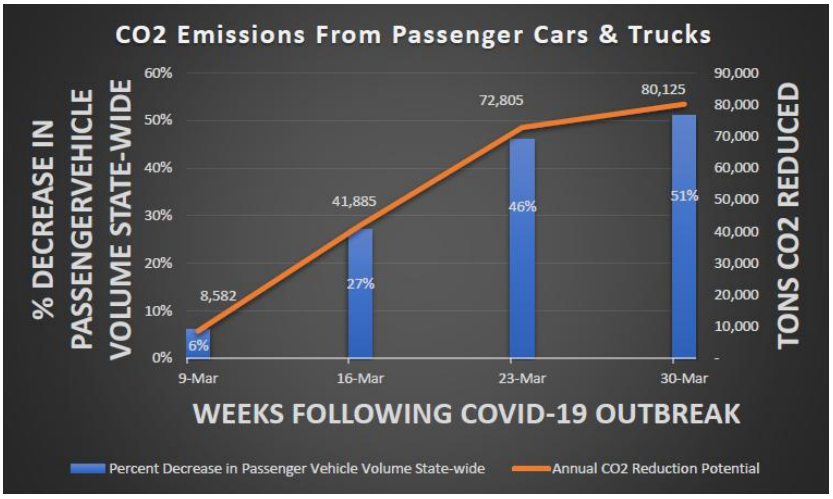
data from an established statewide traffic monitoring system. Federal agencies use this data as a benchmark for their statistics, trends and emissions inventories. The HPMS data is reported monthly. A newer, alternative source of VMT is available from StreetLight Data, which is more real-time, using smart phones as sensors to measure activity on all streets. The VMT analysis to date has used both the StreetLight data and preliminary MDOT data. This analysis looked at the change in weekly VMT during March and April 2020 as Governor Hogan's Executive Orders on telework and social distancing took effect.

This preliminary analysis indicates a 56 to 27% VMT reduction during the first week of reduced activity that involved mandatory state employee teleworking and school closings. Statewide VMT reduced by another 16 to 19% (or 72 to 46% from BAU) during the week of March 23rd-29th when non-essential businesses closed and an additional 4 to 5% (or 76 to 51% from BAU) when the stay-at-home order was implemented. The VMT change remained fairly consistent from that point forward.

This is a very preliminary analysis of readily available data. There is ongoing analysis of the StreetLight data to better understand if VMT could be overestimated if cell phone signals could be counted more than once in the case of multi-passenger vehicles. MDOT and MDE have also been analyzing HPMS data and performing mobile source modeling for this same time period. The next steps will be to continue integrating all of this data to refine VMT reduction estimates.

The Role of Telework

MDE conducted a preliminary assessment of the impact of stay-at-home orders on traffic activity in the State and the resultant CO_2 emission reductions. Preliminary data indicate that stay-at-home orders resulted in a 27% decrease in state-wide weekly traffic activity. When non-essential businesses closed during the week of March 23rd-29th, statewide light duty traffic activity decreased an additional 19%. By the end of March, a 51% reduction in vehicle activity was recorded. MDE used the stay-at-home orders as a surrogate for large-scale enhancements to teleworking policies. Those impacts can be seen in the figure above. The CO_2 reduction impact was extrapolated as an annual reduction for comparison to other reduction programs and initiatives.



The 27% reduction in vehicle activity the week following the mandatory state employee teleworking requirement resulted in a CO_2 emission decrease of approximately 41,855 metric tons per year.

MDE also used the data in this analysis and earlier work conducted to calculate the relationship between telework and the carbon footprint of the MDE workforce to generate very preliminary, but interesting estimates of CO_2 reductions associated with potential changes to telework policies. Policies that target 25%, 50% and 75% as workforce telework goals could generate approximately 2 to5 million metric tons of CO_2 ($mmtCO_2$) additional annual GHG reductions. These are large reductions.

Days Teleworked (%)	Maryland State Employees (mmtCO2)	Total Maryland Workforce (mmtCO2)
25%	0.04	1.8
50%	0.07	3.6
75%	0.11	5.3

The Future

We must continue to analyze and interpret the observations from many surface monitors, three aircraft, and satellites. These results will provide input into numerical models that can verify physical consistency, offer an independent emissions estimate and calculate impacts on air quality. The results provide a preview of what could be achieved by replacing half the passenger vehicle fleet with zero-emission vehicles and tightened emissions from electricity generation.

For Additional Information – For additional information contact Tad Aburn (george.aburn@maryland.gov) or Russ Dickerson(RRD@UMD.EDU). A summary of the UMCP/MDE partnership may be found at https://www2.atmos.umd.edu/~rammpp/