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January 2022

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The Best of *EM* 2020 and 2021

by Teresa Raine and Bryan Comer

In case you missed them the first time around, this month's issue spotlights some of the best topics and articles that have appeared in *EM* over the past two years.

Features

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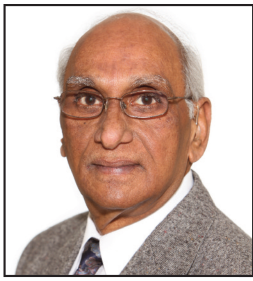


Remembering
S. Trivikrama Rao

Dr. S. Trivikrama Rao, who served as Editor-in-Chief for the *Journal of the Air & Waste Management Association (JA&WMA)* since 2012, passed away at his home in Cary, NC on November 25, 2021.

To his many friends and colleagues, he will be remembered as a researcher truly passionate about protecting human health and the environment, a leader dedicated to advancing the science used to support sound decision-making, building partnerships to leverage expertise and resources to addressing pressing environmental issues, and a generous mentor always willing to provide advice and create opportunities for colleagues.

Dr. Rao received a B.S. in mathematics, physics, and chemistry from Andhra Loyola College in 1962, a M.S. in Geophysics from Andhra University in 1965, and a Ph.D. in Atmospheric Science from the State University of New York at Albany in 1973. Following a year of post-graduate studies, he joined the New York State Department of Environmental Conservation (NYSDEC) as research scientist in 1974, becoming the Director of the Bureau of Air Research in 1985 and Assistant Commissioner of the Office of Science and Technology in 1996. During his time at NYSDEC, he also served as Research Professor at the State University of New York at Albany. In 2001, he joined NOAA as Director of the Atmospheric Sciences Modeling Division assigned to the U.S. Environmental Protection Agency (EPA), and in 2008 he transferred to EPA to become the Director of the Atmospheric Modeling and Analysis Division and served in that capacity until his retirement in 2012. Then, he continued to advance science by becoming the Editor-in-Chief of *JA&WMA* and served in that role until the time of his passing.

His research covered a large range of topics, including mathematical modeling of pollutant transport and dispersion, atmospheric dynamics, air pollution meteorology, air quality assessments, and statistical analysis of air quality measurements and model predictions. He led or co-led more than 25 externally funded research projects, published more than 250 papers and made countless presentations at scientific conferences across the world. During his time in Albany, he also taught graduate level courses and advised 14 M.S. and Ph.D. students.

Dr. Rao was recognized internationally for his contributions to science. He was an elected Fellow of both the Air & Waste Management Association (A&WMA) and the American Meteorological Society (AMS). He served on the editorial boards of several major international journals, and was a member of the National Academy of Sciences' Board on Atmospheric Science and Climate during 2013-2016. He received Silver, Gold, and Distinguished Career Service Awards from the EPA, a NOAA Administrator's Award, A&WMA's Frank A. Chambers, Honorary Member, and S. Smith Griswold Awards, and AMS's Award for Outstanding Contributions to Applied Meteorology.

His involvement with A&WMA spanned more than four decades and throughout this period, he contributed to the Association's activities in advancing science to effectively address nation's air quality issues and in facilitating interactions between the regulated and regulatory communities. These contributions took many forms. As author or co-author, he published extensively in *JA&WMA*, its predecessor Journal of the Air Pollution Control Association, and *EM* magazine. He provided leadership to A&WMA publications by serving on the *JA&WMA* Editorial Review Board (ERB; 2001-2010) and the Publications Committee (2010-2012). In addition, he was a founding member of *EM*'s Editorial Advisory Committee (EAC), serving from 2001 to 2010. He also coordinated a number of special issues for *EM* on topics including homeland security, interactions of climate change and air quality, air quality impacts on human health, multi-media environmental management, and exposure science. These special issues brought together perspectives from A&WMA's different constituent groups on cutting-edge issues faced by environmental managers.

Possibly his most profound and long-lasting impact on A&WMA was his service as *JA&WMA* Editor-in-Chief from 2012 until the time of his passing. While serving as Editor-in-Chief, he raised the scientific stature of the journal as reflected in the increase of its impact factor, broadened its international scope, and led a push to increase geographic and gender diversity among Associate Editors. Moreover, he regularly invited well-recognized scientists to contribute review articles relevant to the journal and created special and virtual issues focusing on topics of particular interest to the environmental community. He also initiated the establishment of the annual Arthur C. Stern Award to recognize an outstanding journal article that has significantly contributed to the environment field. Thanks to these and other efforts and his close collaboration with Associate Editors, reviewers, ERB, A&WMA staff, and the publisher, *JA&WMA* is well positioned for continued success in the future.

As he expressed in his farewell letter that he wrote in anticipation of his planned retirement from his Editor-in-Chief position at the end of 2021 and that was published a few days after his passing, his guiding vision while leading *JA&WMA* was to make "it the world's premier journal for policy-relevant research in the air quality and waste management fields" while hoping that the future would hold " even greater international recognition and stature" for A&WMA's flagship publication. Dr. Rao will be remembered for his dedication to A&WMA's mission, innumerable contributions to advance the science of air quality modeling and the enthusiasm and passion for everything he undertook. **em**

Journey into 2022
Are we there yet?

Nancy E. Meilahn Fowler » president@awma.org

As a parent of young children, I have heard the phrase "Are we there yet?" more than should be inflicted on any human being (although most can relate). However, clichés exist for a reason, and while we thought we were approaching a "new normal" this time last year, it appears that we might have to journey a little bit longer before we are "there."

As you have may have noticed, our journey into 2022 includes a change in leadership. I am honored that you have entrusted me with the responsibilities of President of A&WMA, and I am exceedingly thankful for the strong leadership of outgoing President Brian Bunger and his predecessor Kim Marcus. They, along with our capable Executive Director Stephanie Glyptis, set us on a course to successfully navigate this far in the treacherous waters of the pandemic, and I hope that I can continue leading us through. In addition, I can't say enough about how hard the staff has been working behind the scenes to pull off our continued success. A&WMA owes a huge debt of gratitude to our dedicated staff.

The incoming board of directors is an enthusiastic mix of public servants, academics, industry representatives, and the occasional consultant. It ranges from young professionals (YPs) to former YPs to more (ahem) experienced professionals. These dedicated individuals have a varied background and expertise that we will leverage to ensure the continued neutral forum for information exchange and quality technical expertise that our members expect from the Association.

We have incredibly committed, talented, and respected individuals in the leadership of the Association, but there are always many empty spots waiting to be filled. One of my goals for this year is to expand participation from our existing membership to fill these positions and attract new members, future leaders, and recognized experts from all fields and geographies. The pandemic-driven shifts in how we interact with each other presents A&WMA with an opportunity to increase our global presence, membership, and knowledge base.

I am dedicated to recruiting and mentoring the next generation of leaders to ensure the organization's future will be even more robust than the present. Almost everyone who is part of A&WMA is here because of the personal invitations they received and the mentorship and networking that follow. We must find a way to continue that in a time of reduced personal interactions.

I am a big reader, and Dickens' *Tale of Two Cities* seems relevant today. For many of us, the last two years could easily fall in the worst of times, but we are offering the best of times in this issue, with the best of *EM* 2020 and 2021. This retrospective includes a carefully curated selection of the best articles that members may have missed due to the personal or professional impacts of the pandemic. We know that many of you may have missed reading or paying attention to the A&WMA as other things took priority.

It is time to leave the worst of times behind us. This pandemic is a seminal event, the ripples of which will be spreading for generations. Instead, I would like to look at how well we have changed with the times, how the entire environmental industry is changing, and ponder how we adapt to the changes we are experiencing. COVID has offered A&WMA the opportunity to overcome difficulties and find new ways to thrive.

The current pandemic and related economic hardships have required us to be nimble in execution of our activities, which we are doing well. Some of these changes have been long in the works, but COVID has driven a rapid evolution. Our offerings are changing to reflect the technological advancements and the social changes in the industry, from electric power transformation to new developments in solid waste management. We have developed and fine-tuned successful virtual conference models, which has benefitted us by providing more truly international input. While we are all looking forward to some in-person interaction, we are also developing new formats for hybrid conferences, looking to combine in-person and virtual presence to a new, better event. We are attempting new approaches to accomplish our mission while valuing and continuing the high-caliber offerings we already have. A&WMA must continue to increase visibility and improve its reputation as a valued source of environmental information and innovation.

A&WMA has a solid foundation of knowledge and authority when it comes to air issues and is regaining recognition as an authority on waste management. In the industry, environmental and sustainability thinking is changing. Hermetically sealed buildings are no longer preferred, as pandemics thrive on low air exchange. Lean supply chains now need to be adjusted to avoid shortages. Single-use plastics and plastic packaging became go-tos to prevent contamination (and because shortages made other options fiscally impossible). Energy is rapidly transitioning to low or no-carbon fuels. Emerging chemicals are being added to our radar as risks on a regular basis. We need to build on our strengths and improve our outreach and communications within our membership and the global community. A&WMA's 2022 Annual Conference & Exhibition (ACE) will focus on science and sustainable global communities and will certainly deliver exciting content on the advances that we have made and those we are still working on.

While we look back over the past two years, I am eagerly looking forward to the partial return to in-person activities, with opportunities to attend ACE in San Francisco, and perhaps visit some of our Sections and Chapters to see how others have adapted and are preparing for tomorrow's challenges. Here's to a great year! **em**

The Best of *EM* 2020 and 2021

by Teresa Raine, *EM* Editorial Advisory Committee (EAC) Chair; and Bryan Comer, EAC Vice Chair and *EM* Plus Content Coordinator

In case you missed them the first time around, this month's issue spotlights some of the best topics and articles that have appeared in *EM* over the past two years.

This month, as part of our special 'Best Of' issue, we take the opportunity to celebrate the important and valuable work that is developed and created by A&WMA members and other professionals working throughout the environmental industry. This issue features articles that the Chair and Vice Chair of the *EM* Editorial Advisory Committee thought deserved a second read. They were selected from issues of *EM* Digital published between May 2020 and July 2021 and cover topics ranging from emerging contaminants like per- and polyfluoroalkyl substances (PFAS) to the impacts of COVID-19 on mitigating and adapting to climate change and its impacts on air quality. Other topics include progress made under the U.S. National Ambient Air Quality Standards, new sources of water pollution from ships that ironically come from an air pollution reduction technology, and a discussion of how a hydrogen economy can advance the role of wind and solar in decarbonizing our economies. We hope you enjoy this walk down memory lane, which highlights the impressive range of expertise held by the authors who contribute to *EM* and *EM Plus*.

Calling All Authors…*EM* Wants You!

Have an idea for an article you'd like to share? We want to hear from you. *EM* and *EM Plus* publish content on a broad range of topics within the fields of air and waste management, and we are always looking for new ideas. If you are interested in authoring or coauthoring an article, please refer to our general guidelines for authors. Articles are accepted on topics featured in our annual editorial calendar or on any other topic of interest to our members. Please contact A&WMA Managing Editor, Lisa Bucher at lbucher@awma.org to get the ball rolling.

New Member Benefit—A&WMA EShare!

Our greatest asset is the valuable information developed and presented by our members and other industry professionals through A&WMA conferences, webinars, and publications. Now, we are curating and sharing that information with our members, as an added benefit to your Association membership. Each month, an electronically published video, article, or document on a timely environmental topic will be shared via a members-only web page. Once we update the website, the previous month's content will no longer be available, so remember to log in and take advantage of this free member benefit each month!

A&WMA will be seeking experts to help us select the best presentations in a relevant and timely topic area. If you have any ideas of what you would like to see offered or would like to lead the effort to put together a selection of A&WMA's best information on particular environmental topic, please contact A&WMA Director, Marketing and Project Management, Tracy Fedkoe, at tfedkoe@awma.org.

As a reminder, A&WMA Member EShare can be accessed through the webpage www.awma.org/eshare, but you must be logged in using your current member account to view the page and content.

We hope you enjoy reading this issue and experiencing some of the best content and technical information A&WMA has to offer. **em**

In Next Month's Issue…
Environmental Justice

Environmental justice is a key priority for the Biden Administration, U.S. Congress, state and local governments, businesses, and communities. Environmental justice considerations are increasingly becoming key components of decision-making for governmental, energy, industrial, and transportation activities. The February issue considers federal, state, and other perspectives.

This article has been selected as part of our "Best of *EM*" issue. It first appeared in the May 2020 issue, which focused on per- and polyfluoroalkyl substances (PFAS).

Sources and Exposures to PFAS in the Environment

An overview of where PFAS came from, and how they got to be seemingly everywhere.

Per- and polyfluoroalkyl substances (PFAS) are everywhere—or so it may seem. New data reports continue to identify the widespread presence of PFAS in products, soil, drinking water, food, and even rainwater.[1] The nonprofit organization Environmental Working Group (EWG) reported on January 22, 2020, that PFAS had been found in "… the drinking water of dozens of U.S. cities, including major metropolitan areas… [and] …the number of Americans exposed to PFAS from contaminated tap water has been dramatically underestimated by previous studies, both from the [U.S.] Environmental Protection Agency [EPA] and EWG's own research."[2] The overall exposure of Americans to PFAS is evidenced by the detection of several PFAS, including PFOA and PFOS, in blood samples at geometric mean concentration of 1.56 and 4.72 micrograms per liter (μg/L), respectively.[3] [*Editor's Note:* See this month's cover story sidebar "PFAS Primer" for PFAS varieties and definitions.]

EPA's Third Unregulated Contaminant Monitoring Rule (UCMR3)[4] required sampling of large public water systems (i.e., those serving more than 10,000 people) for six PFAS—PFOS, PFOA, PFNA, PFHxS, PFHpA, and PFBS—between 2013 and 2015. PFOA and PFOS were detected in the greatest number of samples, although for both chemicals less than 1% of public water systems showed detections above 70 nanograms per liter (ng/L), which is the current EPA Lifetime Health Advisory for PFOA and PFOS. Since the publication of the UCMR3 data, several state environmental agencies initiated additional sampling of smaller systems at lower detection limits. For example, a 2019 study of 1,723 public water supplies in the state of Michigan found that low levels of PFAS (i.e., <10 ng/L) were detected in almost 7% of the water supplies, while 3% of the water supplies had concentrations between 10 and 70 parts per trillion (ppt).[5]

PFAS Uses

If PFAS are everywhere, where did they come from and how did they get there? The Interstate Technology Regulatory Council (ITRC) has developed several factsheets on PFAS, including a factsheet that describes the history and use of PFAS.[6] PFAS chemicals were first developed in the 1930s. By the 1950s, typical PFAS applications included the use of PFOA as a polymerization enhancer in the manufacture of fluoropolymers such as polyfluorotetraethylene (PTFE) and PFOS as mist suppressant in chromium electroplating. Given the unique and useful properties of PFAS, by the 1960s, these chemicals were quickly incorporated into many different processes as emulsifiers, surfactants, wetting and leveling agents, and corrosion inhibitors and products such as paints, inks, cleaners, and coatings.[6] Figure 1 presents a timeline of the development of PFAS and their increase in usage from 1950 through the early 2000s.

Starting around the mid-2000s, the production of PFOA, PFOS, their precursors, and similar PFAS with seven or more carbons began to be phased out in the United States by the eight companies that were involved in their production. Note that the United States has since ceased production of PFOS and PFOA; however, China is still a major producer of both substances.

Applications and products that have involved the use of PFAS include, but are not limited to, firefighting foam; surface coatings for various textiles, papers, paints, and inks; metal surface treatment; fume suppressants for electroplating; coatings for food packaging; and the production of lubricants, hydraulic fluids, and waxes. Overall, a wide variety of industries have used or are currently using these chemicals for many applications. Although PFOA and PFOS are the most common PFAS that have been detected in the environment, EPA estimates that thousands of different PFAS are used for hundreds of different applications in manufacturing and products.[7] Indeed, these substances were so prevalent that, in many cases, companies may not have

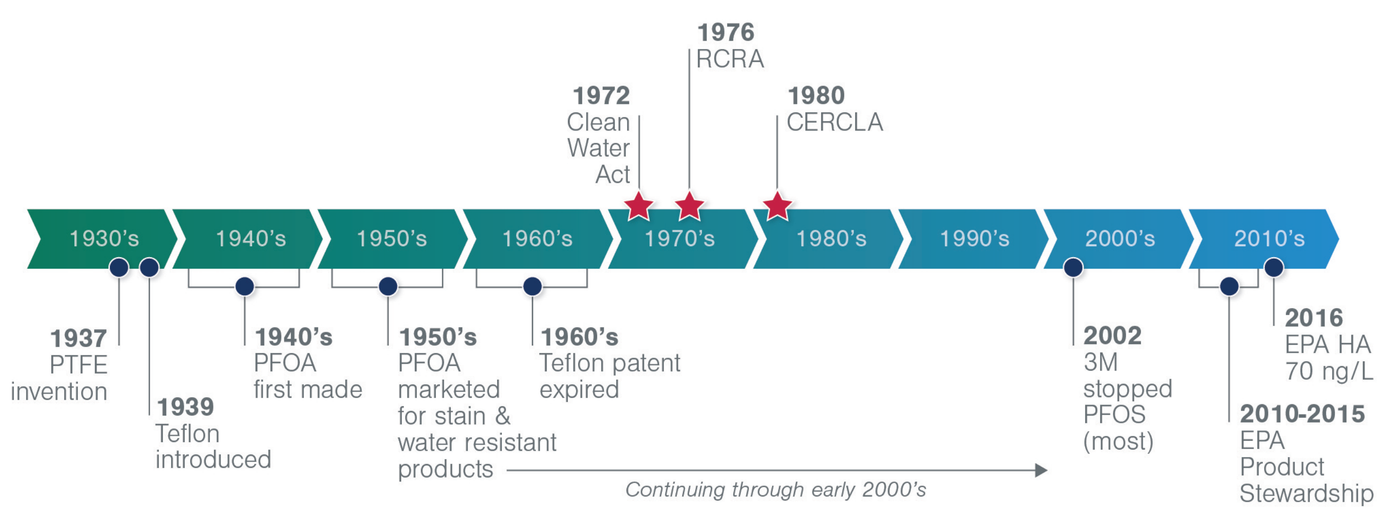


Figure 1. PFAS timeline.

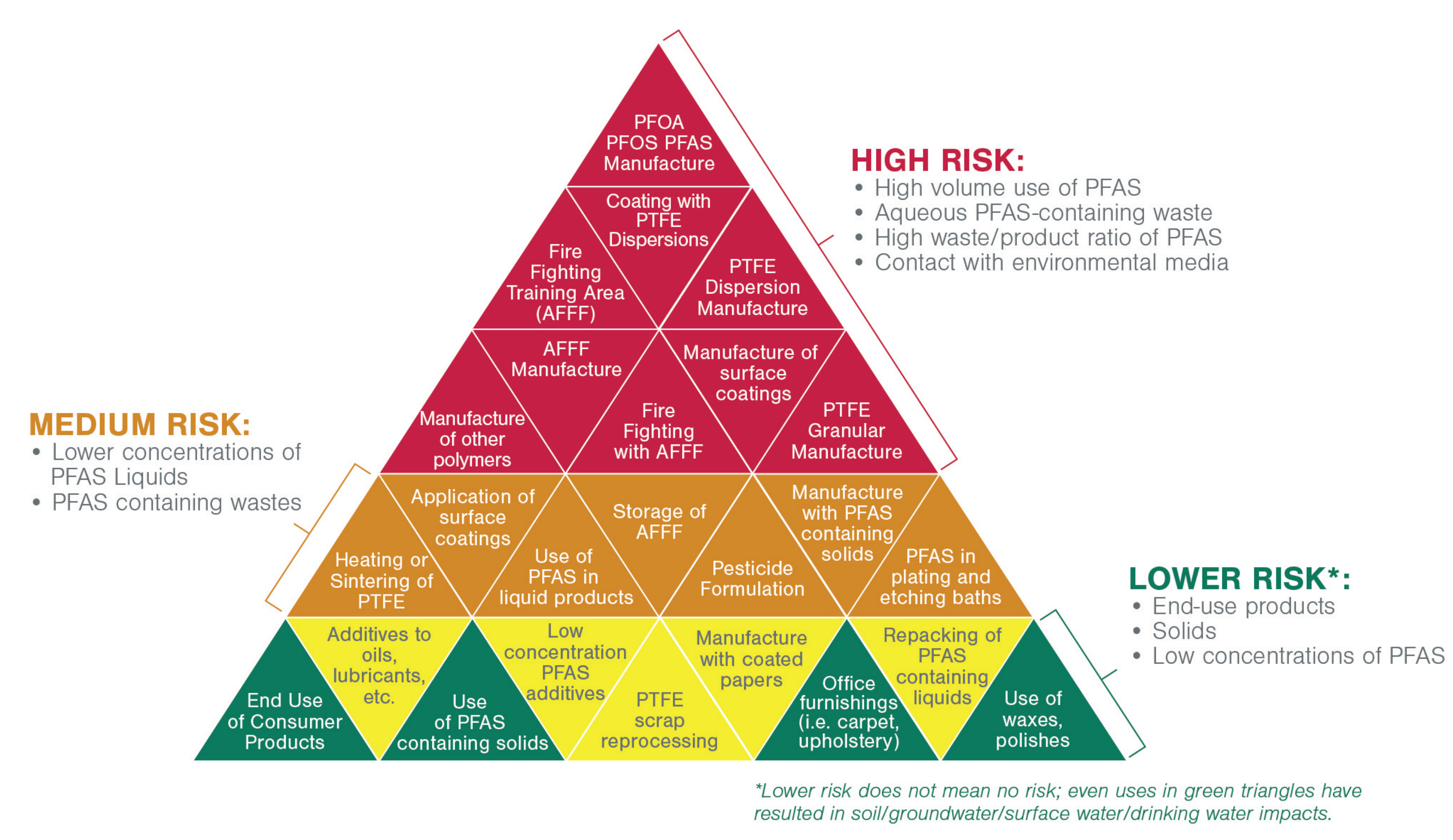


Figure 2. PFAS usage risk to the environment.

realized they were using PFAS as part of their manufacturing processes or may have had limited records documenting historical uses.

PFAS Sources

As shown in Figure 2, the potential for release to the environment is highly dependent on the specific products or processes (i.e., how PFAS was/is used), the activities conducted at a specific facility, and the location. These three areas are each a potential risk factor that will influence if or how PFAS could have been released into the environment.

Of the many uses identified for PFAS, the use of aqueous film fighting foam (AFFF) for fire training, AFFF equipment maintenance, and emergency response activities using AFFF may have resulted in the greatest amount of exposure and contamination to soil and groundwater. For these activities, PFAS was released directly into the environment; often by spraying the foam onto the ground. AFFF has been stored and used across the United States by fire departments, airports, and other facilities that store bulk quantities of flammable material. AFFF has been required at U.S. Department of Defense (DOD) facilities and, as of June 2019, DOD had identified 401 active or closed U.S. bases with at least one area with a known or suspected release of PFOA/PFOS due to firefighting and related activities.

Other sources of PFAS exposure and contamination include those industries that used PFAS in products or as part of a manufacturing process, as identified in Figure 3. In these activities, PFAS could have been released through air emissions or effluent that was sent to a municipal wastewater treatment plant. For example, a study of chromium electroplating facilities in Ohio found elevated levels of PFOS and other PFAS in effluent sent to local wastewater treatment plants. In 10 out of 11 facilities tested, the effluent contained some quantifiable level of PFOS (0.0314–39 μg/L).[8] As a result of these discharges, wastewater treatment plants, which receive effluent from manufacturing and other industrial sources, have been identified as a significant contributor to PFAS contamination in soil and groundwater.[9]

Owing to their use as both surfactants and coatings, PFAS can be present in many commercial and consumer products, including clothing, carpeting, upholstery, food packaging, construction materials, automotive products, and cleaning products. These products end up in municipal solid waste landfills from which they can be released to the air and in leachate.[10] PFAS, including PFOA and PFOS, have been detected in the leachate from municipal landfills across the United States with concentrations ranging from 30 ng/L to over 4,000 ng/L.[11,12] In many cases, these landfill leachates go directly to local municipal wastewater treatment plants,

Risk Factors

PFAS Usage

- PFAS production
- Fluoropolymer production
- PTFE as raw material
- AFFF – fire fighting, training, suppression, extinguishers
- Dispersions, fiber finishing
- Fluorochemicals, elastomers
- Paints, varnishes, inks, dyes
- Cleaning agents
- Coatings - textiles and carpets
- Coatings - paper
- Stain and oil/water repellants
- Pesticides, insecticides, herbicides
- Surfactants
- Metal surface treatment
- Electroplating, etching
- Polishes, adhesives
- Photographic paper, films
- Metal and plastic coatings
- Lubricants, hydraulic fluids
- Gaskets, seals rings, linings, tapes
- etc.

Facility Activities

- Production wells
- Air emissions, sintering
- Septic system
- Old sewer lines
- Waste water to WWTP
- Onsite landfill
- Biosolids applied to land
- Waste disposal practices
- Regulatory involvement
- Site redevelopment

Site Setting

- Drinking water sources
- Surface water
- Nearby residences
- Agricultural lands
- Sensitive habitats
- Other receptors (using GIS data)
- Federal/State/Local values (regulatory or guidance)
- High profile PFAS sites in State

Figure 3. Known PFAS risk factors.

which are ineffective in removing PFAS from the waste stream. Data show that the concentrations of some PFAS are higher in the effluent than in the influent. The increased concentrations may be related to the breakdown of substances such as fluorotelomer alcohols, which are precursors of some perfluoroalkyl acids.[9]

PFAS have also been found to accumulate in wastewater treatment plant biosolids. More recently, some states have begun to regulate biosolids generated from municipal wastewater treatment plants to limit potential exposure to these compounds. Previously, biosolids were land-applied, often at local agricultural operations, allowing a place for these materials to be disposed and providing a source of land fertilizer. With these new regulations in place, these biosolids must now be tested, and if PFAS is detected, alternative disposal methods need to be identified.

PFAS Exposures

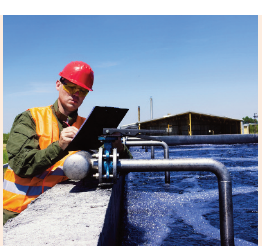
To better understand potential PFAS exposure, several studies have been initiated to estimate exposure levels. In 2018, the National Defense Authorization Act provided funding for the Agency for Toxic Substances and Disease Registry and the Centers for Disease Control and Prevention (ATSDR/CDC) to evaluate PFAS exposure in communities near current or former military bases with known PFAS contamination. ATSDR/CDC identified eight locations for conducting the exposure assessments that were slated to begin in 2019. For each assessment, ATSDR/CDC will collect blood and urine samples from participants, as well as environmental samples (e.g., dust) from participants' homes.[13] This study is expected to last several years.

Results from the 2019 National Health and Nutrition Examination Survey,[14] which periodically measures the presence of various chemicals in the blood serum of a cohort of people in the United States showed a decrease in geometric means between 1999--2000 and 2015--2016 of more than three-fold in PFOA concentration (5.21 µg/L to 1.56 µg/L) and more than six-fold in PFOS concentration (30.4 µg/L to 4.72 µg/L). In Germany, where the population was exposed to PFOA in drinking water, a follow-up study conducted two years after drinking water treatment was implemented showed reductions in PFOA in blood serum equating to a half-life of 3.26 years.[15]

Conclusion

PFAS in the environment is a large and growing problem that will continue to be an important driver for many media and exposure pathways, including drinking water, soil, and air. Detections of PFAS are continuing to expand as our knowledge of these chemicals increases and our analytical methods improve and allow the detection of substances at even lower concentrations.

As a result of these advances, increased regulation of PFAS is continuing. On February 19, 2020, EPA published a list of 172 PFAS that are now subject to reporting under Section 313 of the Emergency Planning and Community Right to Know Act and Section 6607 of the Pollution Prevention Act, more commonly known at the Toxic Release Inventory (TRI).[16] In addition, EPA is also considering establishing reporting



Some states have begun to regulate land application of biosolids generated from municipal wastewater treatment plants to limit potential exposure to these compounds.

thresholds that are lower than the statutory thresholds of 25,000 pounds for manufacturing or processing and 10,000 pounds for otherwise using the listed chemical.[17]

Other areas of regulation are expected to include new limits on permits (for both water and air emissions), additional drinking water standards (e.g., maximum contaminant levels), new sampling and cleanup requirements at hazardous waste sites, and additional limits on using these chemicals in consumer products. Businesses and environmental professionals should be aware of this important issue and be prepared to address it. **em**

Nadine Weinberg and **Maureen Leahy** are partners with ERM (Boston, MA) and (Hartford, CT), respectively.

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This article has been selected as part of our "Best of *EM*" issue. It first appeared in the July 2020 issue, which focused on climate change policy.

During the recent pandemic, U.S. domestic airline traffic almost came to a halt.

The Unpredicted Speed Bump:
What Impact Will COVID-19 Have on Global Climate Change Objectives and Progress?

A&WMA Immediate Past-President, Michele Gehring, offers keen insights into global climate change objectives—and the potential impacts of COVID-19—obtained by being an Official Observer at the last two United Nations Conferences of the Parties held in Poland and Spain.

As hopefully many of you already know, A&WMA was granted official observer status with the United Nations Framework on Climate Change (UNFCC) Conference of the Parties (COP) in 2017. This allowed us to participate at the COP meetings in Katowice, Poland, in 2018 (COP-24), and again at the COP meetings in Madrid, Spain, in 2019 (COP-25). I have had the honor of serving as one of A&WMA's delegates at both meetings. Despite the differences that each location brought to the meeting, both meetings were surrounded by the same aura of hope and ambition as the conferences opened. Both were also concluded with an overall feeling of "we could have done more." As we were gearing up to make plans for Glasgow and COP-26 this year, the dialogues regarding increased ambition and the anticipation of countries finalizing their nationally determined contributions (NDCs) were heating up, and expectations were growing around the potential that Glasgow provided. Then came COVID-19. I do not imagine that this global pandemic or the magnitude of it impact could be predicted by anyone, let alone all of the climate scientists that were trying to find a way to limit warming to 1.5 or 2 °C by 2050.

As I look back on the challenges discussed at COP-25, I cannot find a climate action pathway that has not been impacted from this global pandemic. Let us look at a couple that expressed the highest concerns over their progress at COP-25, the impacts on that pathway from COVID-19, and then do some pontificating about what those impacts mean to the eventual conversation we will have in Glasgow in November 2021.

Transportation

By 2050, the transport sector was aiming to achieve complete decarbonization through a combination of alternative energy vehicles, adaptation, and mitigation techniques. At COP-24, the transportation sector was slammed for being behind the eight-ball on their climate change plans. And, at COP-25, the United Nations World Tourism Office (WTO), presented some fairly grim predictions on greenhouse gas (GHG) impacts from the sector with no modification to habits. (Take a look back at the December 4, 2019, blog update from Madrid for hard data from the report; www.awma.org/blog_home.asp?display=81). Everyone at that talk recognized that progress would only occur if the transportation sector found significant ambition in a fairly short time.

Fast-forward to Spring 2020 and the COVID-19 pandemic. As of April 26, 2020, 45 of the 50 states had either statewide or partial shelter-in-place orders in effect in the United States. According to *The New York Times* (www.nytimes.com/interactive/2020/us/coronavirus-stay-at-home-order.html), this equates to at least 316 million people in the United States that were staying home (or being encouraged to); that is nearly 95% of the U.S. population not taking public transportation as frequently, not making the morning or afternoon commute on a local highway, or not gearing up for the summer road trip. With motor vehicle emissions accounting for nearly 60% of the U.S. transportation sector emissions according to the annual GHG inventory, the impact from this should be significant over the short-term.

In addition, domestic airline travel in the United States has nearly come to a stop. According to the Transportation and Security Administration (TSA; www.tsa.gov/coronavirus/passenger-throughput), the TSA screened approximately 2.5 million passengers every day in 2019; as of April 2020, that number had dropped to approximately 90,000 passengers per day. If you grab your calculator and do some quick math, you will find that is a 96% decrease in the number of people choosing to hop on an airplane in the U.S. alone. Unfortunately, that does not translate directly to a reduction in the number of flights, as some airlines must keep flying routes even with empty planes. I, for one, was on a flight back from Indianapolis to Washington in mid-March that had a whopping two passengers on it. However, the decline has still been quite significant. According to a report from Flightradar24.com (www.flightradar24.com/blog/charting-the-decline-in-air-traffic-caused-by-covid-19/) in early April, domestic airline travel had reduced by about 40%, and trans-Atlantic routes had decreased even more.

In 2018, emissions from the transportation sector represented the largest portion of GHG emissions, with a total reported emission of 1,882.56 million metric tons of carbon dioxide equivalents (CO_2e). Approximately 10% of these emissions originated from airlines (jet fuel and aviation gasoline). If we average that on a monthly basis, that is approximately 15.69 million metric tons of CO_2e per month from airline travel alone. Assuming a 40% reduction lasting at least four months, that should lead to a reduction in airline-related transportation emissions by nearly 40 million metric tons of CO_2e in 2020.

While that short-term impact certainly is not enough to turn the needle, I am curious to see how the periodic downfall impacts the long-term predictions. I am also curious to see how this "stay-at-home" mentality affects the attitude toward business travel in the future. Don't get me wrong, as an elite status holder with two different airlines and two different major hotel chains, I do not see myself putting the suitcase away anytime soon—in fact, I'll probably have it packed and ready to go when this lockdown ends—but, I do think that businesses will look at "essential" business travel differently. As we have been forced to replace in-person meetings with video conferences, will video conferences become the new normal and the perceived "need" be recognized as a "want" more than a "need"? The report from Glasgow in 2021 from the transport sector will be very interesting indeed. How much time or how many fractions of a degree will the transportation impacts from COVID-19 have bought us? How will the trends of staying at home changed mentalities or driven ambition? Will this serve as the industry's launch pad, or will it just be a speed bump in a turn that we accelerate out of?

Energy

In the *2019 Yearbook of Global Climate Action* (https://unfccc.int/sites/default/files/resource/GCA_Yearbook2019.pdf), the Energy sector's goal for 2050 was complete decarbonization. However, the yearbook reported that the changes seen were not in line with that target and stated that ambition would be necessary to accelerate the change, or the target would not be met. Commenters suggested that, in some ways, the target for this sector required an almost unimaginable change over a very short period. Perhaps COVID-19 has provided just that, or perhaps even that is not enough.

Looking at the energy sector impacts from COVID-19, most countries have seen a significant fall in electricity demand. For example, the Ukraine reported an 8% decrease in electricity consumption compared to the same period in 2019. This has caused them to curtail the import of electricity from Belarus and Russia and delay planned maintenance. They have also limited output from internal producers due to the significant surplus of electricity. Likewise, Italy, France, and the United Kingdom have all reported drops in consumption ranging from 12% to 25%. Some outlets suggest that the resulting decreased revenue from energy usage will drive the sector toward an increased use of renewables, as they can handle small-scale production better than the larger, fossil fuel-based producers. According to a report from the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP), in many national grids, renewable outputs are dispatched first, and the fossil fuel producers are used to fill the remaining demand. This means the renewable outputs are essentially operating untethered, while the fossil fuel producers are shutting down units and requesting government subsidies to stay alive.

Looking outside of existing production issues to the generation of new capacity, COVID-19 is also having a significant impact, albeit an opposite one. While production demands are fueling the renewables market, resource shortages and financial liquidity concerns are restricting generation of new renewable capacity. China, which is one of the main global producers of clean energy products such as solar panels, wind turbines, and batteries, has been hit hard by the coronavirus and the slowed production of these items demonstrates that. This reduced supply has significantly halted equipment installation and unit startup.

For example, India has reported that 3,000 megawatts of solar and wind energy products face delays as a result of supply limitation and investment curtailment. In the United States, similar trends are being seen. According to a report from *The New York Times* (www.nytimes.com/2020/04/07/business/energy-environment/coronavirus-oil-wind-solar-energy.html), the Solar Energy Industries Association has projected a downgrade in growth by as much as one-third and predicts that approximately half of the 250,000 workers in the solar energy market could lose their jobs, even if just temporarily, from the COVID-19 impacts on the industry.

Turning the conversation to oil production, decreased transportation, which I discussed earlier, has also driven a significant surplus of oil. This surplus has driven oil and gas prices to levels I, personally, do not remember seeing at the gas pump since the early 1990s. According to the April 2020 *Oil Market Report* (www.iea.org/reports/oil-market-report-april-2020) from the International Energy Agency (IEA), global oil demand is expected to fall by 9.3 million barrels per day this year. The lessened demand is leading to lessened production, which, in turn will likely impact global emissions not only from the reduced consumption of oil, but the reduced operation of the refineries that produce it.

The myriad of sector impacts is interesting and ultimately makes it hard to predict where the needle will fall on the energy sector. Will the increased reliance on renewables drive the market towards a change at a faster rate than would have happened without COVID-19? Will the impact on emissions from decreased oil production have a significant impact? Or, will the suspension or slowing of renewables projects slow the progress that was being seen in renewable capacity throughout the world?

Industry

During COP-25, the report from the industry sector was one of the most dismal, indicating that only 700 companies worldwide had established science-based climate-related targets, and only 100 of those were in line with a 1.5 °C pathway. There was no doubt that an exponential shift in ambition was required within the energy sector to drive the changes necessitated to meet targets. Overall, there was a unified response that industry buy-in was not evident in the climate action arena. In fact, a representative from Danfoss, a multinational manufacturing company headquartered in Denmark, commented that the greatest roadblock to industrial climate action was a successful economy. He predicted that if industry continued to sell and have profit with current operations, the only way to drive change will be through regulation, which, as we know, is widely varied not only in the United States, but worldwide.

So, how does COVID-19 alter the industry perspective? First, it is probably necessary to define what the UNFCC includes in the definition of "industry". The industry thematic area considers industrial activities over the entire supply chain, from extraction, through manufacturing, to the final demand for products and services. The largest contributors to this sector include manufacturers of cement, steel, chemicals, and plastics, as well as heavy-goods transport.

From supply chain disruptions to employee outages and decreased demand, there is no doubt that COVID-19 has and will have a significant impact on the industrial sector. The National Association of Manufacturers (NAM; www.nam.org/coronasurvey/) conducted a survey of its member companies to ask about the impacts of the pandemic on their operations. The survey showed that 35% of its members were facing supply chain disruptions, 53% anticipated a change in their operations, and 78% were anticipating a financial impact. Specific concerns were raised with reduced customer demand, inventory levels, and business continuity. IBISWorld (IBIS; www.ibisworld.com/industry-insider/coronavirus-insights/), a company that provides research reports on thousands of industries throughout the world, evaluated the impact of the pandemic to various sectors, including both mining and manufacturing, which are some of the leading sources of industrial GHG emissions in the United States. In the mining industry, the expected slowdown on manufacturing that uses the mining products has already led to a decline in commodity prices and experts expect it could also result in a significant disruption in demand as well. This impact is felt across various mining industries, whether precious metals, oil, or gas. In the oil and gas sector, the Canadian government predicts lowering drilling to adjust to lower demand levels, and IBIS reported that social distancing requirements are also leading many companies to shutter or close mines because they are unable to provide the worker separation that is required.

In the manufacturing world, many manufacturing facilities either operate factories in China or rely on supplies from China. As a result, these facilities are all facing supply shortages, or increasing costs to manufacturing as they seek out alternative sources for supplies. In addition, employee shortages and demand curves are forcing many manufacturing facilities to significantly curtail their operations and lay off workers. We have all certainly seen the many advertisements from automobile manufacturers, which are experiencing significant disruptions to their operations, as face-to-face vehicle sales have all but stopped and those consumers buying into virtual car shopping are limited.

In April, Germany reported an 82% drop in automobile sales compared to the same period last year. As a result, nearly all the German vehicle manufacturers have scaled back productions. While the manufacturing slowdowns are likely leading to a lowering of emissions, it is important to note that some industries are seeing a surge in demand, such as suppliers of nondiscretionary items and medical supplies.

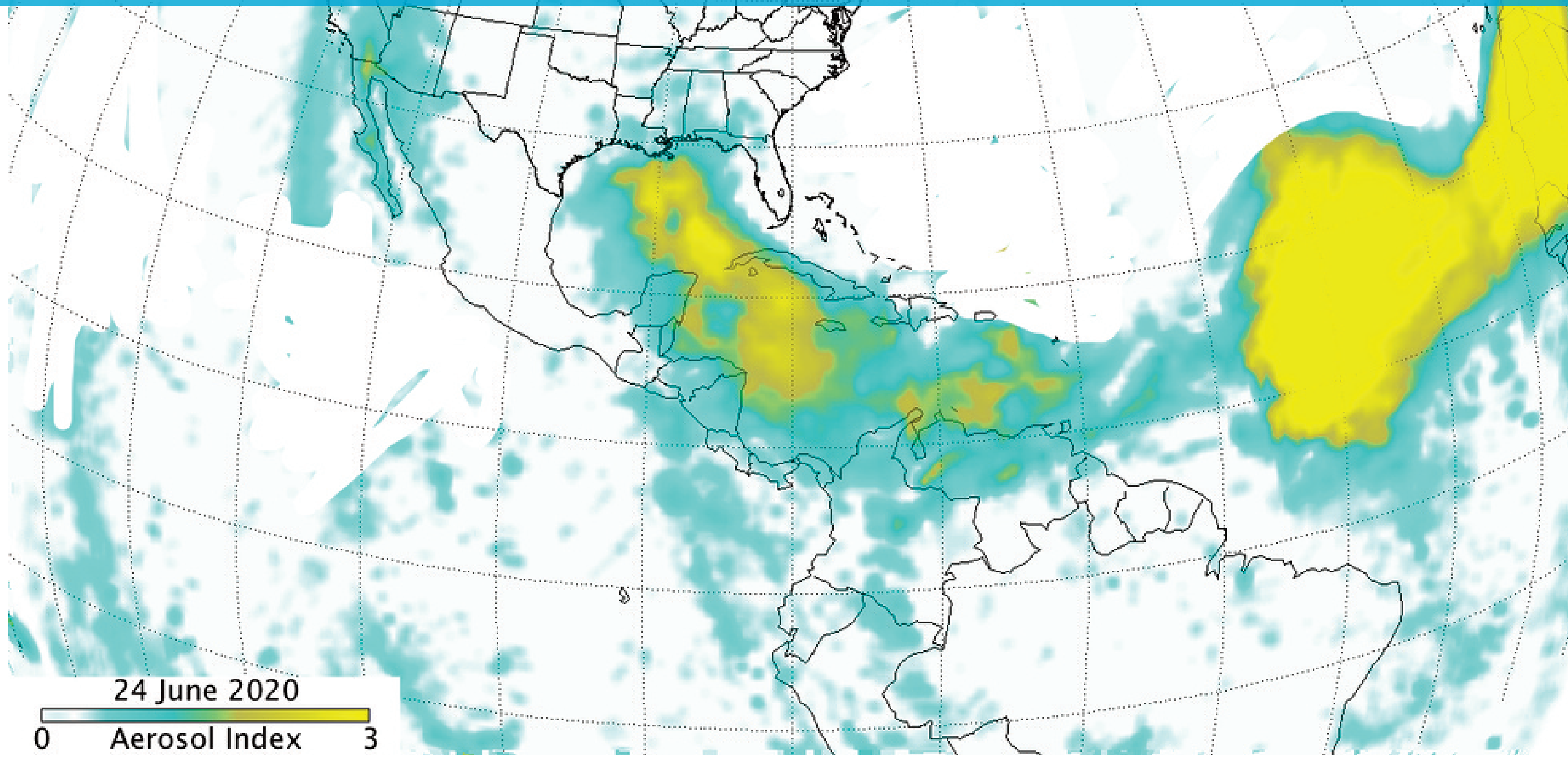
So where does this all lead from an environmental perspective? Decreased production will certainly lead to decreased emissions, even if just for a short term. And alternative supply solutions may shift to locations that have stricter environmental regulations than China, leading to an overall lower emission impact from the supply chain. But the ultimate question is how long will the decrease last and what will that mean to climate change predictions?

Closing Thoughts

In its *2019 Special Report on Global Warming of 1.5 °C* (www.ipcc.ch/sr15/), the Intergovernmental Panel on Climate Change (IPCC) indicated that achieving the temperature goals on the 1.5 °C pathway would require unprecedented actions and a combination of technology, behavior, and investment. It may just be that COVID-19 has gone a long way in changing behavior, but it could have stalled other efforts in technology development, investment, and installation. In reality, we know, thanks to studies from institutions such as the Centre for Research on Energy and Clear Air (energyandcleanair.org/wp/wp-content/uploads/2020/05/China-air-pollution-rebound-final.pdf), that during the period that China was under lockdown, its nitrogen oxide emissions declined by 40% and carbon dioxide emissions fell by approximately 25% over a four-week period. But we also know that as China slowly reopened its economy, those emissions started to rise back to normal levels. The European Space Agency's Sentinel-5P satellite (www.esa.int/Applications/Observing_the_Earth/Copernicus/Sentinel-5P) has tracked similar reductions in India and throughout Europe.

As countries manage reopening of their economies differently, the question remains as to what post-COVID-19 emissions look like on a global scale. Will emissions return to pre-COVID-19 levels quickly, will there be a surge above those levels as people make up for travel time lost during the lockdown, or, will our behavior have been permanently altered and will the shifts seen in our transportation and energy sectors be the jump start needed to overcome hurdles that previously stood in the way of achieving global climate change objectives? I look forward to following this conversation to COP26 in Glasgow next year and hearing reports from across the globe of how this pandemic has altered their models, predictions, and pathways to their climate objectives. Keep following our COP updates and conversations throughout the remainder of 2020 and into 2021 as we journey across the pond to join other observers for the next COP meeting in Glasgow. **em**

This article has been selected as part of our "Best of *EM*" issue. It first appeared in the December 2020 issue, which focused on the U.S. National Ambient Air Quality Standards Review.



Saharan Dust Plume.
Source: National Aeronautics and Space Administration (NASA) Earth Observatory: "A Dust Plume to Remember," June 27, 2020; https://earthobservatory.nasa.gov/images/146913/a-dust-plume-to-remember.

The National Ambient Air Quality Standards at 50

by Karen Hays, Robert Hodanbosi, and Jason Sloan

Recognizing the air quality improvements made under the U.S. National Ambient Air Quality Standards program over the past 50 years.

This year is the 50th anniversary of the U.S. Environmental Protection Agency (EPA), which is officially marked by the swearing in of William Ruckelshaus on December 2, 1970, as the agency's first administrator. Also passing the 50-year mark in 2020 is the U.S. National Ambient Air Quality Standards (NAAQS) program, established under the U.S. Clean Air Act Amendments of 1970. These half-century milestones provide an opportunity to reflect on environmental achievements accomplished due to cooperation between EPA and state, local, and tribal entities, as well as the regulated community. As a recent report from the Association of Air Pollution Control Agencies (AAPCA) highlights, the air quality improvements made under the NAAQS program exemplify the environmental progress made in the past 50 years and underscores the primacy role of state and local leadership under the Clean Air Act.[1]

The U.S. NAAQS program protects public health by establishing standards for six criteria air pollutants—carbon monoxide (CO), particulate matter (PM_{10} and $PM_{2.5}$), ground-level ozone (O_3), lead (Pb), nitrogen dioxide (NO_2), and sulfur dioxide (SO_2)—which are to be reviewed every five years.[2] State and local environmental agencies with delegated permitting, planning, enforcement, and regulatory authority work in coordination with EPA to develop state implementation plans (SIPs) to meet and maintain NAAQS while accommodating their own unique social, geographic, and economic factors. Public transparency for air quality progress is critical, and important information about long-term air quality and criteria pollutant trends are available through several reports and data analyses from EPA, including:

- An analysis (https://www.epa.gov/air-trends) of the ambient air pollution data provided to the national air quality system from thousands of monitors across the United States, collected by EPA, state, local, and tribal air pollution control agencies;
- Air Pollutant Emissions Trends Data (https://www.epa.gov/air-emissions-inventories/air-pollutant-emissions-trends-data) that provide nationwide estimates of emissions of criteria air pollutants based on the National Emissions Inventory (NEI);[3] and
- Design values (https://www.epa.gov/air-trends/air-quality-design-values), defined by EPA as "a statistic that describes the air quality status of a given location relative to the level of the NAAQS … typically used to designate and classify nonattainment areas, as well as to assess progress toward meeting the NAAQS."[4]

In May of this year, AAPCA published the 2020 edition of *State Air Trends & Successes: The StATS Report*, which lists key metrics and trends for the NAAQS program, as well as toxic air releases, visibility information for national parks and wilderness areas, greenhouse gases, and social and economic indicators that may impact air quality.[5] *The StATS Report* is published annually using data from EPA and other federal agencies, and includes trends for AAPCA's state members, as well as at the national level. The AAPCA 2020 report illustrates marked and improving national trends for the emissions and ambient concentrations of the six criteria air pollutants.

The success of the Clean Air Act in improving air quality has been cited regularly in reports and articles. A 2017 article, "The Clean Air Act: Substantial Success and the Challenges Ahead," in the *Annals of the American Thoracic Society* notes that, "Actions to control emissions from vehicles, factories, electric power plants, and more have reduced emissions of the most prominent pollutants […] by 73%, even while the U.S. gross domestic product has grown by more than 250%."[6] These actions include complex air pollution control efforts and technologies, such as scrubbers installed at power plants burning fossil fuels, which can remove more than 90% of SO_2 from emissions and also reduce emissions of other pollutants.[7] These emissions reductions contribute

Table 1. Percent change in ambient air pollution levels.

Pollutant	1980 vs 2019 (% change)	1990 vs 2019 (% change)	2000 vs 2019 (% change)	2010 vs 2019 (% change)
Carbon Monoxide (CO)	-85	-78	-65	-23
Lead (Pb)	-98	-98	-93	-85
Nitrogen Dioxide (NO_2; annual)	-65	-59	-51	-25
Nitrogen Dioxide (NO_2; 1-hr)	-62	-51	-36	-17
Ozone (O_3; 8-hr)	-35	-25	-21	-10
Coarse Particulate Matter (PM_{10}; 24-hr)	---	-46	-46	-17
Fine Particulate Matter ($PM_{2.5}$; annual)	---	---	-43	-23
Fine Particulate Matter ($PM_{2.5}$; 24-hr	---	---	-44	-21
Sulfur Dioxide (SO_2; 1-hr)	-92	-90	-82	-71

Table 2. Percent change in criteria pollutant and precursor emissions.

Pollutant	1980 vs 2019 (% change)	1990 vs 2019 (% change)	2000 vs 2019 (% change)	2010 vs 2019 (% change)
Carbon Monoxide (CO)	-75	-69	-56	-27
Lead (Pb)	-99	-87	-76	-30
Nitrogen Oxide (NO_X)	-68	-65	-61	-41
Volatile Organic Compounds (VOCs)	-59	-47	-27	-18
Direct Coarse Particulate Matter (PM_{10})	-63	-30	-27	-17
Direct Fine Particulate Matter ($PM_{2.5}$)	---	-36	-43	-20
Sulfur Dioxide (SO_2)	-92	-91	-88	-73

significantly to improved ambient pollution levels, though "complex chemical reactions result in [pollutants] not being a direct one to one relationship in reduced emissions and corresponding reduction in the particular air pollutant."[8]

Ambient Air Quality Trends

EPA's national-level analysis of 2019 monitoring data shows substantial reductions in the ambient concentrations of all criteria pollutants over the past several decades, resulting in improved air quality.[9] Compared to 1980, data for 2019 show at least a 35% decline in the ambient levels of CO, Pb, NO_2, O_3, and SO_2. Fine and coarse particulate matter ($PM_{2.5}$ and PM_{10}) levels have declined more than 40% since 2000. Further, more recent data point to a sustained trend of meaningful improvements, with monitored concentrations of all criteria pollutants down at least 10% from 2010 to 2019 (see Table 1).

Emissions Trends

When evaluating the emissions trends for criteria pollutants and criteria pollutant precursors, similar progress can be seen. Published in June of this year, EPA's 2020 air trends report, *Our Nation's Air – EPA Celebrates 50 Years!*, details the nation's substantial air quality progress through 2019, highlighted by a 77% reduction in the combined emissions of criteria pollutants and precursors since 1970.[10]

In coordination with state and local air agencies, EPA develops nationwide estimates of emissions annually for the NEI, which are "based on actual monitored readings or engineering calculations of the amounts and types of pollutants emitted by vehicles, factories, and other sources."[11] These data provide the basis for several analyses and reports, including EPA's yearly air trends report. As Table 2 shows, criteria pollutant and

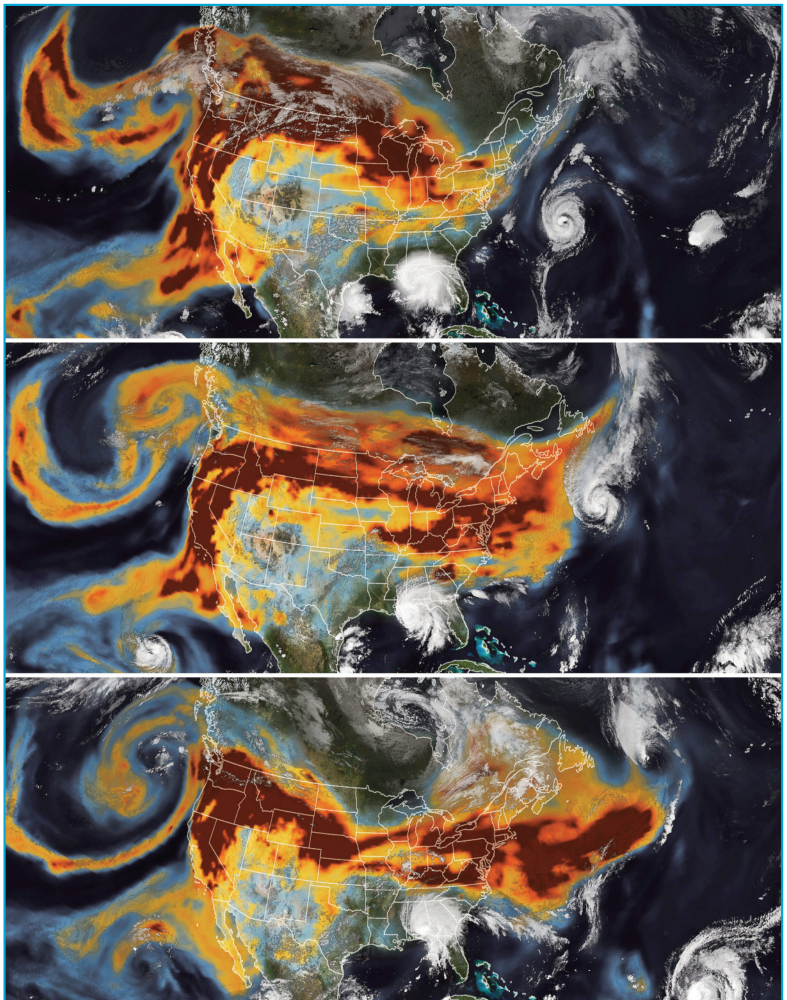


Figure 1. Wildfire Impacts.
Sources: National Aeronautics and Space Administration (NASA) Earth Observatory: "A Meeting of Smoke and Storms," September 19, 2020; https://earthobservatory.nasa.gov/images/147293/a-meeting-of-smoke-and-storms?src=eoa-iotd.

precursor emissions have declined substantially, with at least a 27% reduction in all emissions from 2000 to 2019.

Social and Economic Contexts

Emissions reductions and corresponding air quality improvements are the result of planning efforts undertaken by state and local air pollution control agencies in coordination with EPA, regulated industry, and other stakeholders. To better situate these remarkable improvements, both EPA's and AAPCA's 2020 reports track social and economic indicators that have the potential to impact air quality. Since EPA's inception, and the passage of the CAA amendments (and the first Earth Day) in 1970, the United States has experienced the following growth:

- An increase in Gross Domestic Product (GDP) of 285%, totaling US$21.43 trillion in 2019;[12]
- A 60% increase in population, from 203 million people in 1970 to an estimated 330 million today;[13]
- Energy consumption grew 48%, from 67.7 thousand trillion British thermal units (Btu) in 1970 to 97.6 thousand trillion Btu in 2018;[14] and
- Vehicle miles traveled were up 195%, from approximately 1.1 trillion miles in 1970 to nearly 3.26 trillion miles in 2018.[15]

Importantly, the trendlines for these social and economic indicators are not only very different from the air quality trends that characterize the NAAQS program, but they also reflect the vital work of state and local agencies as on-the-ground experts well-positioned to understand, and respond to, localized issues that may impact air quality.

Air Quality Success in the 21st Century

Earlier this year, with the NAAQS program entering a sixth decade as the cornerstone of the CAA, EPA proposed to retain the standards for ozone and PM. These proposals follow the CAA-stipulated periodic review of NAAQS to ensure the protection of public health and welfare. As EPA continues to evaluate these standards, state and local air agencies continue to improve air quality in their jurisdictions, using regulatory and planning tools to bring areas of the country that are not yet attaining a standard into attainment.

These strategies are not without challenges, some of which may be outside of the control of federal, state, and local entities. Wildfires, for example, can have widespread impacts, with smoke that can increase PM and ozone levels for numerous states (see Figure 1). 2020 provides two specific and countervailing examples, with stay-at-home orders in the first half of the year reducing air pollution levels due to reduced motor vehicle traffic and a Saharan dust cloud crossing the Atlantic Ocean in mid-June and resulting in increased particulate matter levels for at least 15 states (see satellite image on first page). An increase in air pollution outside of agency control may activate "exceptional events" provisions of the CAA for regulatory purposes, but air agencies must still communicate with an impacted public with accurate, up-to-date information.

In some instances, technological innovations have helped bridge the gap that may exist between agency expertise and public understanding. More sophisticated monitoring and modeling technology give a better understanding of air quality, while social media platforms and online dashboards provide at-the-ready communication tools. Other innovations, such as personal air sensors, continue to improve and may serve as future tools for evaluating air quality.

EPA's *FY 2018 – 2022 Strategic Plan* states that, "The idea that environmental protection is a shared responsibility between the states, tribes, and the federal government is embedded in our environmental laws, which in many cases provide states and tribes the opportunity and responsibility for implementing environmental protection programs."[16]

While today's air pollution control agencies are more technologically equipped and better informed than in 1970, the CAA's framework of cooperative federalism remains vital entering the third decade of this century. As the 2020 edition of *The StATS Report* spotlights, state and local agencies not only develop plans for maintaining and improving air quality across the United States, but also serve as critical checkpoints for emergent issues, like the impacts of wildfires, or increased citizen concerns about local air toxics issues. These agencies also often generate and share best practices for public education, tracking air quality progress, and SIP development.[17] The collaborative efforts of federal, state, tribal, and local agencies that characterize the past 50 years of environmental protection have proven foundational to achieving success under the CAA—and remain vital to air quality efforts in the 21st century.

More information on EPA's 50th anniversary is available online at https://www.epa.gov/50. **em**

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AAPCA is a national, non-profit, consensus-driven organization focused on assisting state and local air quality agencies and personnel with implementation and technical issues associated with the U.S. Clean Air Act. AAPCA represents nearly 50 state and local air agencies, and senior officials from 23 state environmental agencies currently sit on the AAPCA Board of Directors. AAPCA is housed in Lexington, Kentucky as an affiliate of The Council of State Governments.

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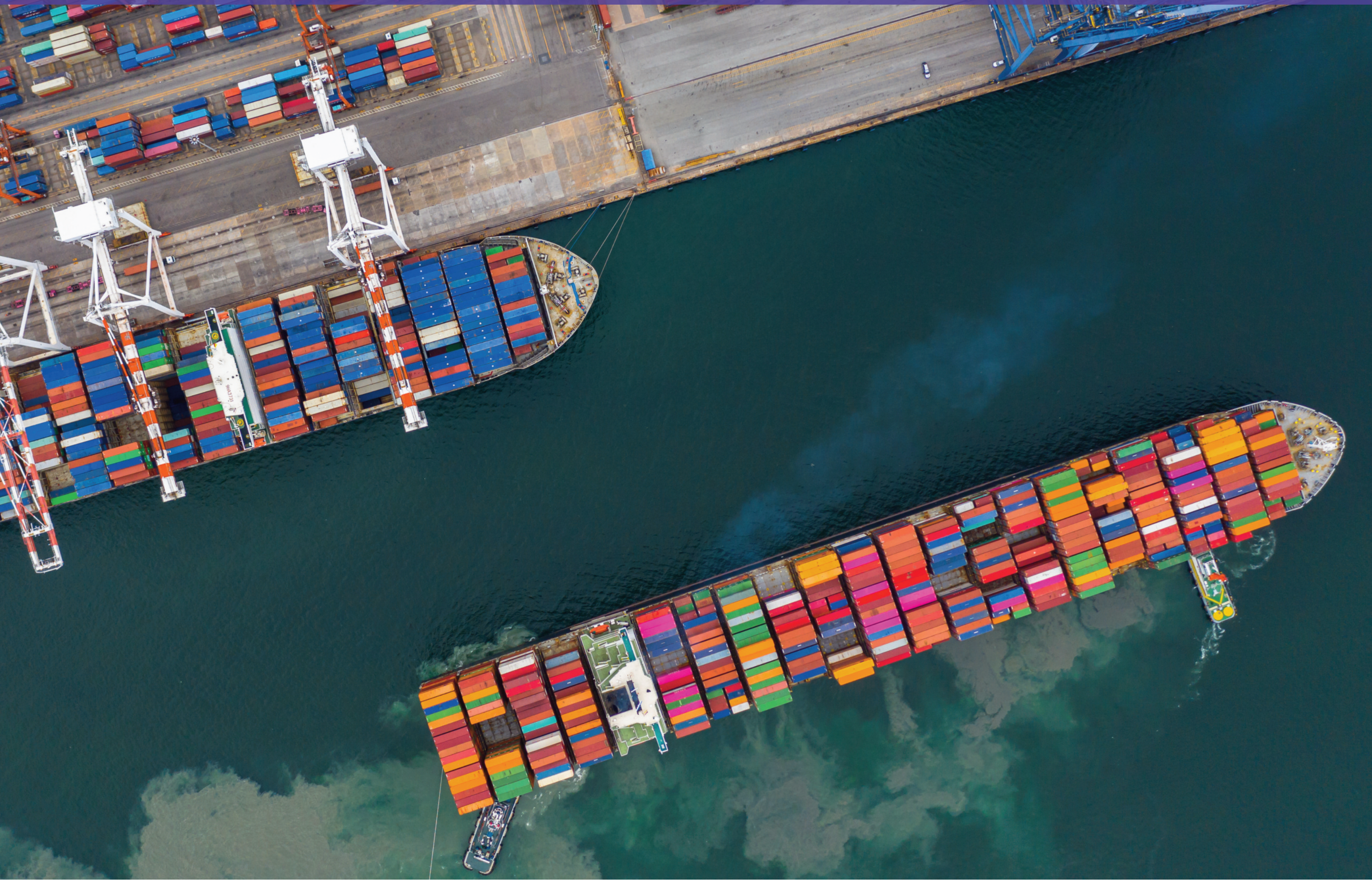
[*Editor's Note*: Since the publication of this article in December 2020, two referenced reports have seen 2021 editions released: (1) U.S. EPA, *Our Nation's Air: Trends Through 2020*, May 26, 2021; https://gispub.epa.gov/air/trendsreport/2021/#home; and (2) AAPCA, *State Air Trends & Successes: The StATS Report*, May 10, 2021.] ; https://cleanairact.org/wp-content/uploads/2021/05/AAPCA-2021-StATS-Report-FINAL-May-2021.pdf.

This article has been selected as part of our "Best of *EM*" issue. It first appeared in the February 2021 issue, which focused on maritime shipping's impacts on air and water quality.



Marine Shipping Exhaust Gas Cleaning Systems, or Scrubbers, Are Anything But 'Clean'

An examination of what exhaust gas cleaning systems are, the problems that stem from them, and what can be done about them.

Exhaust gas cleaning systems, or "scrubbers" are silently contributing to the fouling of our world's oceans and coastlines, under the guise of cleaning the air. Scrubbers are an old technology, well established in the power plant sphere, but new to the marine world. The technology's purpose is to constantly spray an alkaline solution onto the exhaust gases, capturing the harmful pollutants, like sulfur and nitrogen oxides, before leaving the flume. In the case of scrubbers on marine ships, their most popular alkaline solution is the seawater below, and what goes in, must come out.

After "cleaning" their exhaust fumes, scrubbers release the contaminated washwater that was sprayed, and they do so by dumping back into the ocean, and from the modeling from the International Council on Clean Transportation (ICCT), that dumping appears to be in the billions of tonnes. The washwater dumped has a slew of problems: it is acidic and is filled with toxic heavy metals and persistent organic pollutants; components the aquatic ecosystems cannot easily rid themselves of. Nonetheless, scrubbers are installed on thousands of ships, all due to exploiting a loophole from the recent International Maritime Organization (IMO) regulations put onto the world's ships, trying to pull the shipping world away from harmful fuels and toward greener fuels. The loophole is that ships can continue burning the cheaper, more harmful fuel, as long as they have the scrubbers installed. Thus, scrubber installations skyrocketed, and policy hasn't caught up to the demand. However, many ports have taken the initiative to ban the scrubber discharges in their local waters, citing the pollution concerns scrubbers cause. In this article, we lay out the context behind this scrubber wave, and provide evidence through ICCT's current and upcoming work on the topic to explain what can be done to close the loophole.

What Is a Scrubber?

Essentially, the scrubber itself is a column with nozzles in which the exhaust gas from the engines must pass through before exiting the flume. The nozzles spray either saltwater or an alkaline solution onto the gas, capturing the air pollutants. There are three types of scrubbers: open-loop, closed-loop, and hybrid, which operates by alternating between open and closed. The "loop" refers to the complete (open) or restricted (closed) flow of seawater through the system. None of them are emissions-free. Open-loop scrubbers constantly intake large volumes of seawater and discharge overboard acidic washwater at high temperatures containing sulfurs, nitrates, heavy metals, and polycyclic aromatic hydrocarbons (PAHs). Closed-loop scrubbers, on the other hand, recycle the same volumes of the sodium hydroxide solution and emit smaller amounts of washwater, but have a more concentrated, polluted discharge while producing solid waste residuals ("sludge").[1] Open-loop scrubbers are the most popular, making up 80% of the currently installed scrubbers.[2]

Why Are Scrubbers Used?

Scrubber technology has taken the marine shipping sector by storm due to the recent IMO enforcement of a fuel sulfur limit of 0.5%, down from the previous max limit of 3.5%. Starting in January 2020, the sulfur limits for fuel are now 0.5% for ships sailing everywhere outside of the Emission Control Areas (ECAs) and 0.1% inside of ECAs. Ships have been required to switch to the "cleaner" fuels with lower sulfur content. However, IMO also recognizes scrubbers as an equivalent compliance option compared to these low-sulfur fuels, since they are expected to reduce sulfur oxide emissions to the same degree as burning the compliant fuels. In other words, ships can burn the cheaper, viscous heavy fuel oil (HFO), while still complying with the new regulations, causing a boom in popularity right before 2020 (see Figure 1).

What's the Problem?

This boom of scrubber installations has a multitude of concerns attached to it. First and foremost, the claim of being equivalent to burning lower sulfur fuels. A recent study by ICCT[3] on the contents of air and water emissions from scrubbers found that ships using scrubbers achieve lower sulfur dioxide emissions than if they had used lower sulfur fuels, but other air pollutants are higher for ships with scrubbers than using ECA-compliant fuels, such as marine gas oil (MGO). These additional air emissions include

Scrubber installations have skyrocketed, and policy hasn't caught up to the demand.

carbon dioxide, black carbon, particulate matter, and total sulfur emissions (when accounting for sulfur gaseous and particle phases).

Aside from the air emissions, the obvious of the issues stem from the water pollution they produce. Scrubber discharge washwater, from both open- and closed-loop scrubbers, is acidic, high in temperature, and contains pollutants such as nitrates, heavy metals, and PAHs. IMO and the U.S. Environmental Protection Agency (EPA) have set forth guidelines to protect waters from scrubber discharges. However, the guidelines themselves require updating, since compliance with their limits does not guarantee protection. The flaws in the guidelines can be summarized as such: they are voluntarily applied by flag states, they do not cover all pollutants released by the scrubbers, there are inconsistencies in monitoring methods, and the guidelines have not been updated since 2008 when the number of scrubbers installed has increased from 3 ships to over 4,000 in 2020. Other independent sources have also concluded that the scrubber washwater IMO guidelines are problematic.[4-6]

If one were to put aside the unstable guidelines the thousands of scrubbers rest upon, the contents of scrubber washwater and their impacts on marine ecosystems may be the largest red flag. Scrubber washwater discharges may lead to PAH and heavy metal accumulation in the marine trophic chains, impact marine ecosystems, and raise food security risks.[7,8] The acidic washwater is entering areas of threatened coral reefs, perpetuating the human-induced ocean acidification and rising ocean temperature that is named as the main reason for the reef's drastic decline.[9]

And the volumes of washwater entering the ocean are explored by ICCT in an upcoming study on global scrubber discharges. The ICCT found that globally, about 10 billion tonnes of washwater is expected to be discharged only within one year of the regular shipping traffic operation.[10] This number is nearly equal to the total volume of cargo carried by the entire shipping industry.[11] Of these discharges, 80% will happen within 200 nautical miles from the coastline and raises concerns for human health and the marine environment.

Even in widely protected areas, like the Great Barrier Reef, where IMO has set regulations to protect the dwindling area, more than 32 million tonnes of washwater are expected to be emitted within its protective boundaries each year. Since 1995, the Great Barrier Reef has lost half of its corals, while human-induced ocean acidification and rising ocean temperature were named as the main reason for this drastic decline.[9] Similarly, six more Particularly Sensitive Sea Areas (PSSAs) officially designated by IMO for the protection of highly threatened coral reefs will be exposed to 2.9 million tonnes of hot and acidic washwater every year (see Figure 2).

What Can Be Done?

As of this writing, 30 countries have taken it upon themselves to look past the IMO guidelines and establish some form of a ban on scrubber discharges either in ports, freshwater byways, or entire territorial sea areas, primarily noting the unsound knowledge and concerning effects of scrubber washwater.[13] There are small steps to large solutions when it comes to scrubbers. First and foremost, IMO needs to revisit

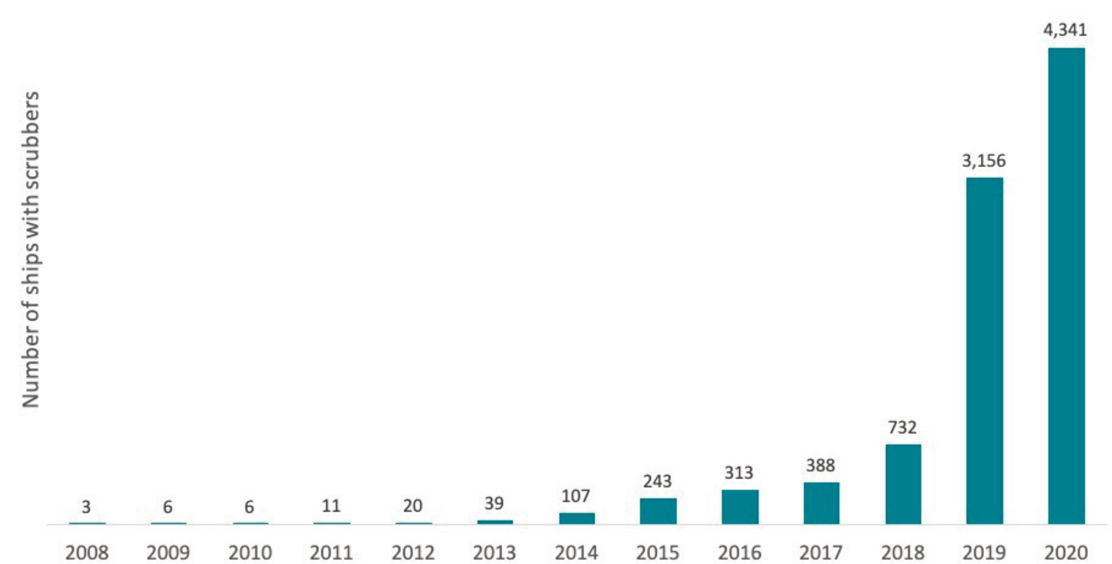


Figure 1. Number of ships with scrubbers by year.
Source: AFI DNV GL, 2020.

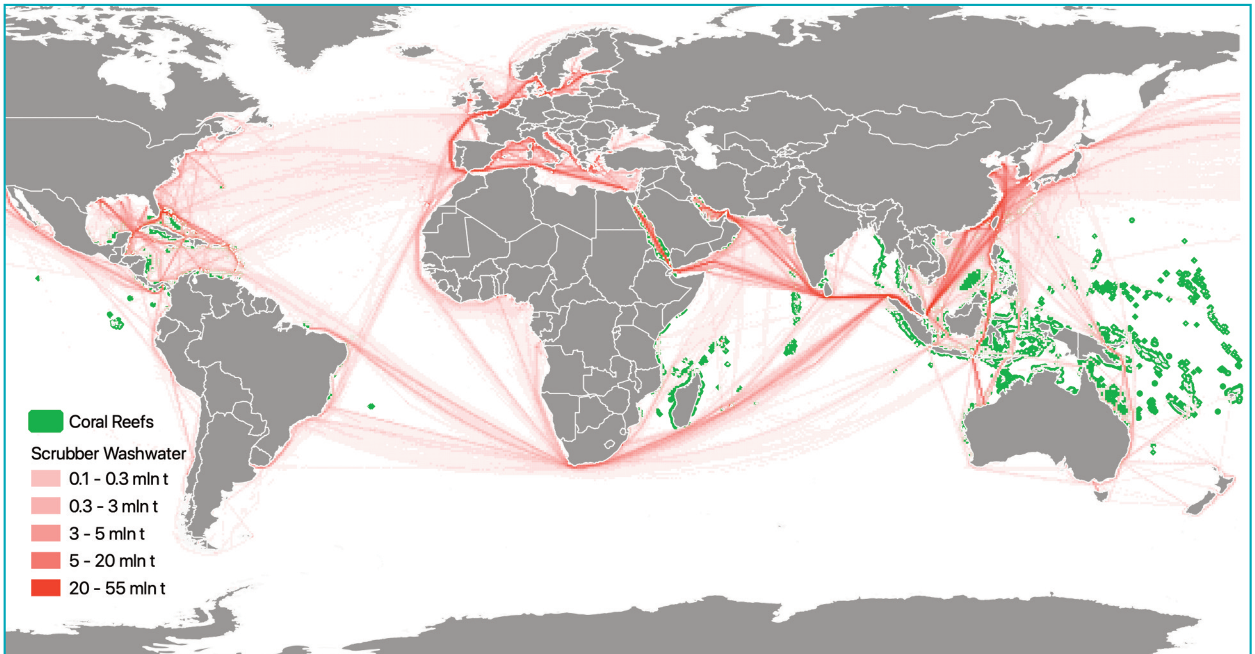


Figure 2. Global scrubber washwater discharges distribution and the global distribution of coral reefs in tropical and subtropical regions.[10] Coral reefs distribution is compiled from multiple sources.[12]

the guidelines they established and have not changed since 2008 when there were merely three ships with scrubbers in the world. The pace of regulation has not caught up with the pace of pollution. Second, there needs to be the recognition that scrubbers are only good at reducing sulfur dioxide emissions, and nothing else, including air and water pollutants. ICCT, along with other independent researchers, have been flagging concerns with the technology that needs to be thoroughly addressed. And lastly, ship owners should take note of the countries already banning scrubbers and realize the potential on the horizon for more bans as governments come to realize they cannot afford to pollute their waters. The scrubber loophole needs to be closed, because if ships are just trading air pollution for water pollution, then the intent of environmental protection using scrubbers is irrelevant. **em**

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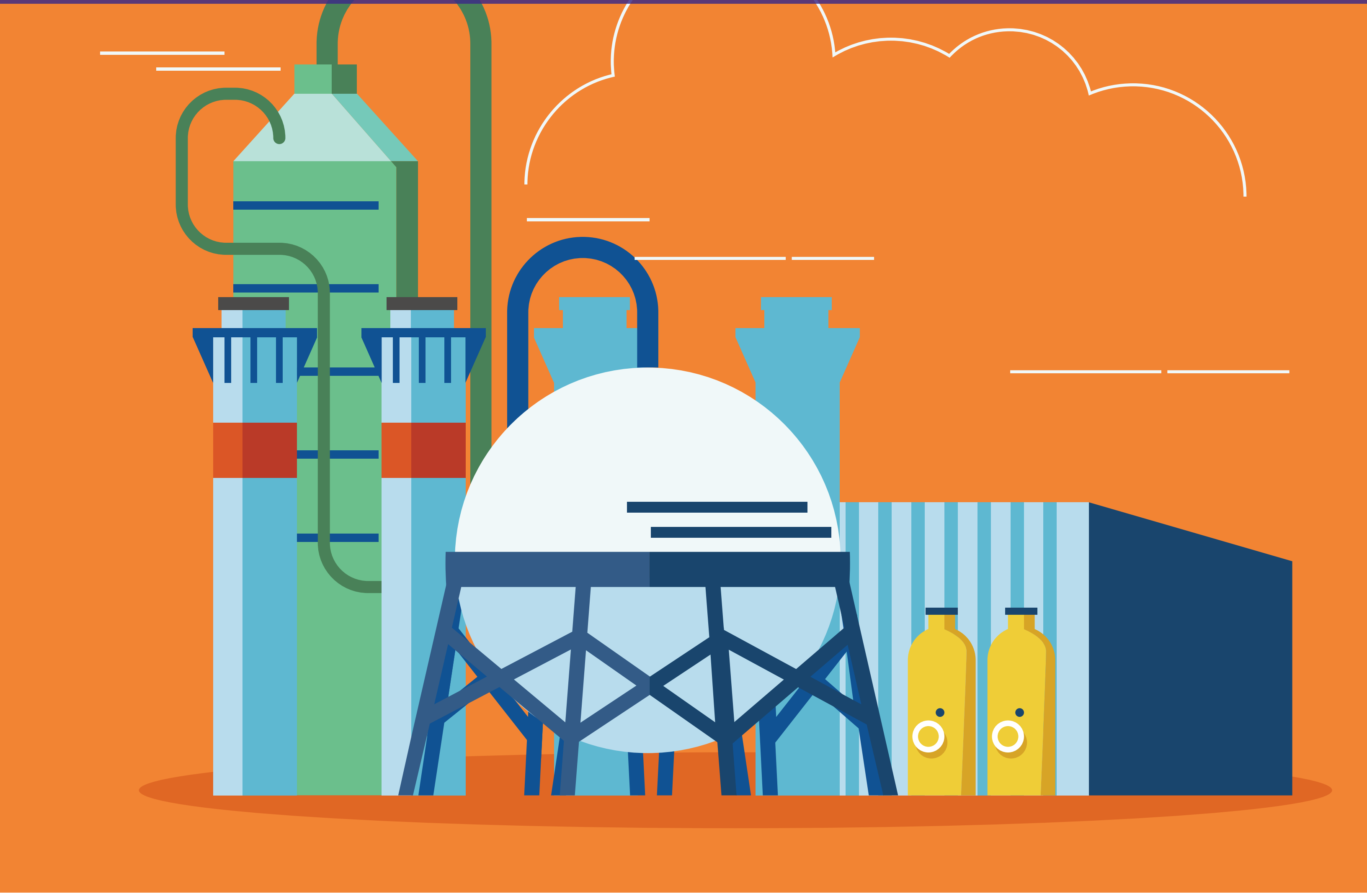
This article has been selected as part of our "Best of *EM*" issue. It first appeared in the May 2021 issue, which focused on the increasing role of renewable energy.



Intermittent Renewables Enabled by a Hydrogen Economy

by Noah D. Meeks and Justin T. Walters

This article considers how clean hydrogen applications could help decarbonize the economy.

Under the United Nations' Paris Agreement, which the United States rejoined in February 2021, nations are committed to pursuing efforts to limit global temperature increases to 1.5 °C. To achieve this goal, global greenhouse gas (GHG) emissions may need to be reduced to 25–30 gigatons of carbon dioxide-equivalent ($GtCO_2e$) per year as soon as 2030 and reach net-zero by 2050.[1] However, global economic activity remains correlated with CO_2 emissions, and as populations are growing and economies (at least pre-pandemic) have been expanding, GHG emissions continue to rise. Despite global consensus on the need to address climate change, effective action remains elusive, indicating the need for an approach that controls emissions while preserving economic opportunity for a growing global population. The optimal approach would preserve desirable attributes of the global energy system while avoiding GHG emissions.

While the rapid and widespread deployment of renewable energy resources is curbing CO_2 emissions, their intermittency presents significant challenges for deep decarbonization of the power generation sector, which is critical for decarbonization of other sectors of the economy. Power markets with the most extensive deployments have already demonstrated that renewables will often be curtailed simply because there is too much generation at one time, or in favor of dispatchable units that have low turndown capability. Hydrogen provides a means of storing that excess generation with maximum flexibility as to end use application, providing maximum value to the power generator. This flexibility also means that multiple end use applications, not just the power sector, can be decarbonized via hydrogen energy.

Decarbonizing Power Generation

Electricity generation is responsible for nearly 40% of global CO_2 emissions. While nuclear-based power generation technologies are potentially deployable on a global scale, their societal acceptance remains a challenge. Advanced nuclear reactors have the potential to mitigate safety, security, and waste concerns, while improving the efficiency and lowering the cost. However, they will still face regulatory hurdles in deployment, especially on a global scale. Because of the challenges with deploying clean, dispatchable generation that is available at any time of day, the intermittent renewable power generators (principally wind and solar) tied to energy storage systems may be used to fully decarbonize power generation. For storage durations greater than tens of hours, hydrogen-based energy storage is projected to be the lowest cost approach.[2]

Decarbonizing Transportation

Transportation—including on-road vehicles, aviation, and maritime—is responsible for greater than 20% of global CO_2 emissions, and transportation has the highest emissions intensity (i.e., emissions per useful energy service) of any major sector. However, long-distance on-road vehicles, aviation, and maritime applications require energy-dense power systems; they require the ability to move heavy loads across long distances with minimal refueling or recharging. Hydrogen (or its derivatives) is well-suited to this application: it is the most energy dense fuel and, combined with the electric motor powered via hydrogen fuel cell, enables the lowest cost and highest performing vehicles.

Decarbonizing Industry

Industrial and chemical processes also have significant carbon emissions, either from the use of fossil fuels for heating, or from use of fossil fuels (including hydrogen derived from fossil fuels) as a feedstock. Clean hydrogen (described in the next section) can be used as both a thermal fuel and a chemical feedstock in a variety of decarbonized industrial and chemical processes. For instance, clean hydrogen may replace hydrogen derived from natural gas in ammonia synthesis or oil refining. Clean hydrogen rather than fossil fuels can be used in some steelmaking processes. Clean hydrogen, rather than fossil fuels, can provide high-quality heat for a variety of industries, including iron/steel, non-metallic minerals, cement, chemicals, pulp and paper, and grain drying.

The Many Colors of Hydrogen

Like electricity, hydrogen is an energy carrier that has no CO_2 emissions at the point of use; the environmental attributes of its generation and transmission are reflected in the overall lifecycle of hydrogen applications. Several terms are used to describe the environmental attributes of hydrogen generation, and colors are often used as shorthand to denote these attributes, as shown in Table 1. "Clean hydrogen" is a general term referring to hydrogen with a limited carbon footprint (CertifHy consortium defines it as <3.64 kg CO_2/kgH_2[3]) produced from any hydrogen and energy sources. "Renewable or green hydrogen" refers specifically to hydrogen generated from renewably powered water electrolysis, whereas "renewables" refers to PV solar, wind, and hydropower.

Today, hydrogen is produced as a commodity for use in specific industrial processes, but not as an energy carrier. Mostly it is produced in large-scale plants, often near the customer, via steam-methane reforming with typical emissions around 10 $kgCO_2/kgH_2$. Water electrolysis currently has limited commercial use in hydrogen generation, but this technology has tremendous growth potential as hydrogen transitions from a commodity chemical to a clean energy carrier. In this technology, electricity is used to dissociate water (9 kgH_2O/kgH_2) into hydrogen and oxygen. Generally, water electrolysis units are available in scales ranging from kW-scale to tens of MW-scale. There are three major types of water electrolysis, which are defined by the ion

Table 1. Colors are used as shorthand for environmental attributes of hydrogen generation.

"Color"	Energy Source	Hydrogen Source
Brown	Coal	Coal
Gray	Natural Gas	Natural Gas
Blue	Natural Gas with CCS	Natural Gas
Turquoise	Natural Gas to solid carbon	Natural Gas
Green	Renewable Power	Water
Red	Nuclear Energy	Water
White	Grid Electricity	Water

transported in the electrochemical cell, as shown in Table 2, and each type has a unique cost/performance profile that makes it relevant for a hydrogen energy economy. Current technology requires very pure water (Type II), but research is underway for the utilization of seawater as a hydrogen source.

The larger cost of water electrolysis is driven by electricity operating costs, particularly the cost associated with procuring low-carbon electricity. The economic viability of electrolytic hydrogen production is governed not only by the capital costs of electrolysis equipment, but also by the cost of deploying and acquiring clean electricity with a sufficient level of availability (i.e., a sufficiently large capacity factor). Because coupling electrolysis cells directly to a variable renewable generation asset limits the capacity factor of electrolysis, it is often desirable to connect to grid electricity, which is becoming increasingly clean.

Water electrolysis is particularly amenable for producing hydrogen on-site, such as may be used for filling vehicles. Not only does this approach leverage the existing electrical infrastructure to save distribution and trucking costs, but it directly produces high-purity hydrogen that is required for most fuel cell electric vehicle applications. (Carbon monoxide that can be present in hydrogen derived from fossil fuels may deactivate the fuel-cell catalysts.) In addition, water electrolysis is a modular technology, which makes it useful for small installations, with the potential for adding capacity over time.

Roadmap for Hydrogen

Once produced in a decarbonized way, hydrogen has two major attributes that enable it to decarbonize multiple sectors: it can be stored and moved, and it has high energy density. The reaction from hydrogen to water releases more energy per unit mass than any other chemical reaction. This reaction has more potential energy density than any other energy storage system and is particularly useful in applications that are energy intensive or require longer duration storage. These include long-distance and heavy-duty transportation (e.g., semi-trucks, yard trucks, ships, locomotives, airplanes, and any vehicle with significant operational time), large energy transmission from areas rich in renewable resources to energy demand centers, and multi-day to seasonal energy storage.

Hydrogen as a low-carbon energy carrier is not a new concept,[4] but is one that is emerging and would truly enable deep decarbonization via intermittent renewables. As curtailment of variable renewable energy resources increases over time, customers who have time-of-use power rates may be incentivized to generate hydrogen when electricity prices are low for local energy storage (for peak-shaving) or local non-power applications. This will preserve the value of renewable energy and create demand by decarbonizing various end uses.

As electrolyzer technology is more consistently deployed at increasing scales, hydrogen for chemical or industrial feedstock may be generated using purpose-built renewable plants, which will likely co-generate both hydrogen and power for the grid, perhaps in varying quantities. This will have the effect of lowering emissions from avoiding natural gas-based hydrogen generation, while providing decarbonized power. It is likely at this scale when hydrogen delivery from the renewable plant to users will occur via local pipeline. Built-for-purpose hydrogen pipelines operate along the U.S. Gulf Coast region, and there is significant emerging research interest in repurposing existing natural gas pipelines to move hydrogen, but t echnical and cost uncertainty around using them for pure hydrogen service.

Finally, the emergence of hydrogen as a decarbonized energy carrier in transportation, power resiliency, peak-shaving, and feedstock markets will provide a basis for its use in large-scale energy storage. The deep decarbonization of power will demand large-scale energy storage and likely demand it over longer durations than conventional batteries will allow. Additionally, the prevalence of hydrogen energy in non-power applications will provide an opportunity to divert that hydrogen into other markets as needed.

Table 2. Comparing types of electrolysis.[2]

Electrolysis Type	Half-Cell Reactions (ion transported in blue)	Capital Cost ($/kW, 2030)	Efficiency (kWh/kgH$_2$, 2030)
Alkaline	$4\ H_2O + 4e^- \rightarrow 4\ OH^- + 2\ H_2$ $4\ OH^- \rightarrow 4e^- + O_2 + 2\ H_2O$	400 – 850	51 – 47
Proton Exchange Membrane (PEM)	$2\ H_2O \rightarrow 4\ H^+ + 4e^- + O_2$ $4\ H^+ + 4e^- \rightarrow 2\ H_2$	650 – 1,500	53 – 49
Solid Oxide	$2\ H_2O + 4e^- \rightarrow 2\ H_2 + 2\ O_2^-$ $2\ O_2^- \rightarrow O_2 + 4e^-$	800 – 2,800	43 – 40

Hydrogen is emerging as a low-carbon energy carrier that is becoming commercially relevant today with multi-day back-up power generation and material handling applications. Both markets illustrate the value that hydrogen energy density brings to commercial applications. Because hydrogen can also be used for large-scale and long-duration energy storage, and used as a clean fuel in power production, utilities will look to couple the market demand for clean hydrogen with the potential for hydrogen to serve bulk power operations. **em**

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This article has been selected as part of our "Best of *EM*" issue. It first appeared in the July 2021 issue, which focused on the COVID-19 pandemic.

Air Quality Impacts from the COVID-19 Restrictions Across the United States

by Brett Gantt, Joe Mangino, David Mintz, and Liz Naess

An overview of the impacts on air quality data as a result of the U.S. government-mandated restrictions imposed during the height of the COVID-19 pandemic.

Shortly after the start of the COVID-19 restrictions across the United States in March 2020, the U.S. Environmental Protection Agency (EPA) began fielding questions from citizens, reporters, and regulators about the impacts on air quality. These questions followed international news reports of dramatic improvements in air quality resulting in rare views of the Himalayas from India and rapid reductions in satellite-derived nitrogen dioxide (NO_2) columns over China. Initial indicators of widespread, reduced mobility and associated vehicle emissions created expectations of significant improvements in air quality in urban areas influenced by these sources.

To help give context to the 2020 air quality as it was occurring, EPA posted on the AirData website a new Daily Air Quality Tracker tool (https://www.epa.gov/outdoor-air-quality-data), which reported daily air quality index (AQI; EPA's tool for communicating daily air quality using color-coded categories that correspond to levels of health concern) values for fine particulate matter ($PM_{2.5}$) and ozone (O_3) against historic values from previous years. This tool allows users to filter the data by pollutant (O_3, $PM_{2.5}$, or both), year, Core-Based Statistical Area (CBSA), and county to quantify how pollution levels in their location of interest differ from typical recent and historic values. A screenshot of the Daily Air Quality Tracker for Los Angeles County, CA, is shown in Figure 1.

As the COVID-19 restrictions continued through spring 2020, the Daily Air Quality Tracker revealed that air quality impacts were not consistent across the United States. These inconsistencies included differing impacts to O_3 vs. $PM_{2.5}$ at the same location and across locations. At the time, it was difficult to assess the reason for these inconsistencies because up-to-date air quality data on a national scale was only available for O_3, $PM_{2.5}$, and PM_{10}. Since then, many studies have begun to report more comprehensively on the air quality impacts of the COVID-19 restrictions. This list includes studies on the impact in individual cities,[1,2] states,[3] and national analyses showing the nonuniform impacts in cities across the United States.[4,5] Other articles have described the complex issues of atmospheric chemistry and natural variability as it relates to quantifying the impact of COVID-19 restrictions on air quality,[6,7] emphasizing that emissions (including long-term trends), meteorology, and chemical transformations in the atmosphere are all important factors.

Methods

To better understand why relatively consistent reductions in vehicular traffic during the restrictions led to differing air quality impacts across the United States, we analyzed 10 years' worth of air quality data (2011–2020) from the NCore Multipollutant Monitoring Network. As described in Weinstock,[8] the NCore Network supports long-term science and policy objectives by providing air quality data for multiple gaseous and particulate pollutants at a broad array of representative urban and rural locations throughout the United States.

Of the many pollutants measured concurrently at the NCore sites, several are relevant for monitoring direct vehicular emissions (carbon monoxide [CO], nitric oxide [NO], elemental carbon) and others (NO_2, O_3, and $PM_{2.5}$) are formed in the atmosphere from vehicular-emitted precursors. The NCore sites also have unique measurements of reactive nitrogen (NOy). This NOy measurement, which includes NO and NO_2, as well as peroxyacetyl nitrates, nitric acid, particulate nitrate, and nitrous acid, helps provide a more complete characterization of nitrogen species involved in O_3 photochemistry than just a NO or NO_2 measurement alone. There are many volatile organic compounds (VOCs), including formaldehyde (HCHO) and benzene measured at some NCore sites that also give an indication of the level of vehicular activity and overall atmospheric chemistry.

For all pollutants, we downloaded the monitor-level daily- and quarterly-averaged concentrations and limited the analyses to daily values between March 15 and May 16, and only for sites that had >75% completeness for the first and second quarters of each year. The March 15–May 16 period was selected to reflect the nationwide reduction below baseline in driving according to the Apple COVID–19 mobility data[9] and includes an equal distribution of days of the week.

The meteorological conditions in spring 2020 played a role in the air quality response.

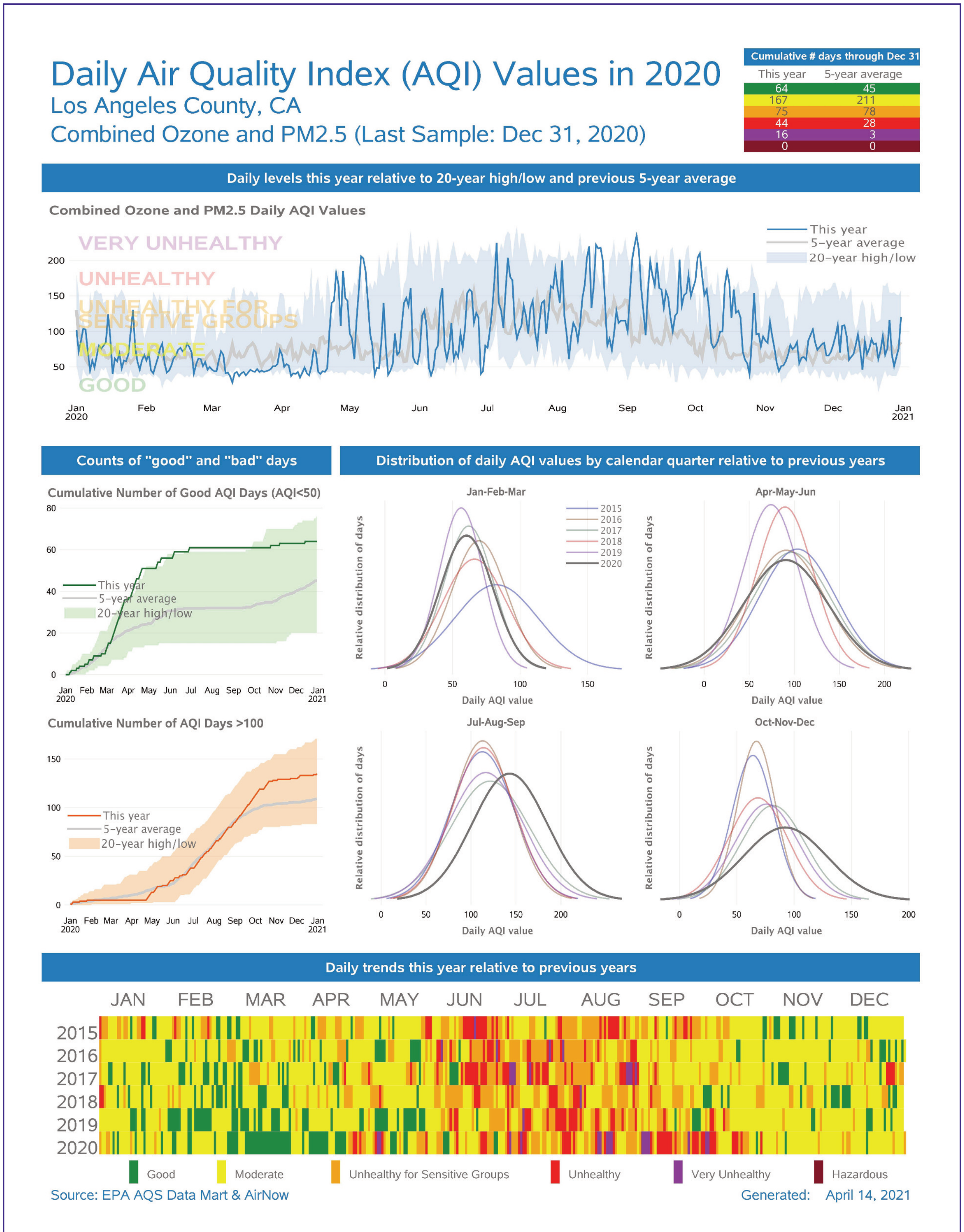

Figure 1. Plots from the Daily Air Quality Tracker (https://www.epa.gov/outdoor-air-quality-data/air-data-daily-air-quality-tracker) showing 2020 O_3 and $PM_{2.5}$ data from Los Angeles County, CA.

Results

The hourly time series plots in Figure 2 show an NCore network-wide average of the air quality changes March 15–May 16, 2020, during COVID-19 restrictions relative to the same period for 2011 through 2019. For 2020, the concentrations were at the low end of the 2011–2019 averages for most hours of the day for NOy, O_3, and $PM_{2.5}$. This was especially true for NOy and $PM_{2.5}$ during the morning rush-hour period (6:00–9:00 a.m.), reflecting the selective reduction in commuting versus overall driving patterns during the COVID-19 restrictions. For $PM_{2.5}$, the reduction in morning rush-hour concentrations was large enough in 2020 to make it the only year of the 2011–2020 period to have morning rush-hour concentrations below the overnight concentrations. The diurnal cycle of O_3 concentration changes was more complex, as the reduced NOy concentrations contributed to slight increases in the morning rush-hour concentrations (presumably due to reduced titration) while also reducing afternoon concentrations.

When looking at individual sites, the maps in Figure 2 indicate that the changes in average daily concentration in 2020 relative to 2015–2019 were dependent on the pollutant, as well as locational (urban vs. rural) and geographical setting. This comparison to the most recent five-year period captured recent historical trends in the pollutant concentrations rather than the long-term reductions that have occurred for many pollutants across the United States. For NOy, there were widespread reductions in 2020 that scaled with location. The rural sites experienced small changes and urban sites experienced larger changes. This was consistent with Chen et al.,[4] which established a relationship between population density and ambient NO_2 changes due to COVID-19. Like NOy, there were widespread reductions in average 8-hr daily maximum (MDA8) O_3 during the March 15–May 16 period in 2020 (relative to 2015–2019) across the NCore sites. The scale of the reduction, however, was quite distinct from the NOy changes due to the chemical and meteorological factors affecting O_3 formation in the atmosphere.

Many of the largest MDA8 O_3 changes in 2020 occurred at the Midwest and Upper South sites, likely due in part to lower than average temperatures in the region in April and May. Several of these NCore sites historically have had high HCHO/NOy ratios, indicating that they are typically NOx-limited with O_3 concentrations that are sensitive to the small (relative to the larger population centers) NOy reductions that occurred in 2020. Despite large NOy changes in the Northeast NCore sites, only small decreases (and some increases) in the MDA8 O_3 were observed in 2020. Unlike the Midwest sites, these sites historically have low HCHO/NOy ratios and likely have lower O_3 sensitivity to the NOy reductions.

The map of 2020 $PM_{2.5}$ concentrations changes shown in Figure 2 has much more variation in directionality than either NOy or MDA8 O_3, including many sites in the Midwest that experienced modest increases. Like O_3, there are many factors that affect $PM_{2.5}$ concentrations, and the lower-than-average temperatures in the Midwest may have resulted in (a) lower boundary layer heights, (b) increased direct $PM_{2.5}$ emissions from residential wood smoke, and (c) reduced nitrate evaporation. Each of these factors can lead to increased $PM_{2.5}$ concentrations, potentially offsetting the reductions in vehicular emissions due to the COVID-19 restrictions.

For the Northeast and California NCore sites, the combination of slightly higher than average temperatures and lower vehicular emissions resulted in reduced $PM_{2.5}$ concentrations due mainly to lower nitrate and elemental carbon. It is worth noting that $PM_{2.5}$ concentrations are typically lowest in April across much of the United States,[10] and the coinciding of the COVID-19 restrictions with this cleaner springtime period may have a minimal regulatory impact on the 24-hr $PM_{2.5}$ National Ambient Air Quality Standard (NAAQS). The opposite is true for O_3, which historically has had the highest daytime O_3 concentrations in April across many regions of the Eastern United States.[11]

Year-to-year changes in the pollutant levels at individual sites can provide additional context for the 2020 COVID-19 restrictions, and the NO_2, MDA8 O_3, and $PM_{2.5}$ mass and speciation time series plots for the Riverside, CA, Raleigh, NC, and New York City, NY, NCore sites in Figure 3 are good examples. For all three sites, the very low 2020 NO_2 concentrations are outliers in the 2011–2020 trend. Despite these consistently sharp NO_2 reductions at the three sites, only the Raleigh site with much lower overall NO_2 concentrations had a noticeable change in the 10-year MDA8 O_3 trend. This large drop between 2019 and 2020 for the MDA8 O_3 in Raleigh was similar to many of the rural NCore sites in the eastern United States that are likely severely NOx-limited. Although the direction of the long-term MDA8 O_3 trend differs for the Riverside and New York City sites, the likely reason that 2020 was not an outlier for either site was because neither site is NOx-limited.

For $PM_{2.5}$, Figure 3 shows that all the sites had 2020 concentrations that were mostly consistent with the long-term trends. At both the Riverside and New York City sites, long-term reductions in $PM_{2.5}$ continued in 2020 such that it was the lowest of the 2011–2020 period. $PM_{2.5}$ chemical speciation data at the two sites indicate that reductions in nitrate were largely responsible for the low 2020 concentrations. For the Raleigh site, $PM_{2.5}$ concentrations decreased slightly during the 2011–2019 period and remained mostly unchanged in 2020. Because the Raleigh site historically has had low nitrate and elemental carbon concentrations during the March 15–May 16 period, the sensitivity of its $PM_{2.5}$

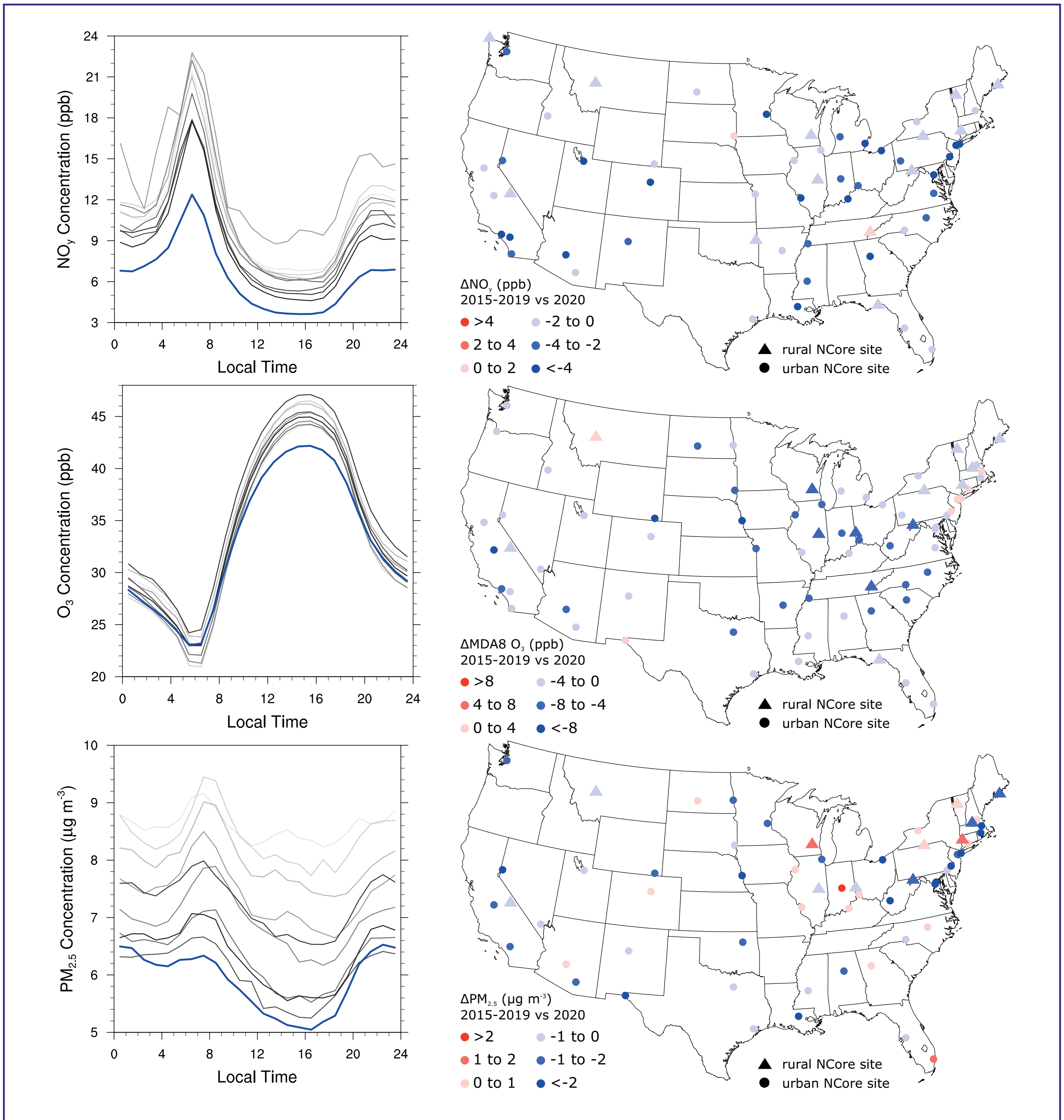

Figure 2. Multi-site average hourly (left) and site-level daily (right) concentrations of NO_2, O_3, and continuous $PM_{2.5}$ for NCore sites, March 15–May 16. The plots on the left show 2011 through 2019 averages in light to dark gray and the 2020 average in blue. The maps on the right show the difference between the 2015–2019 and 2020 averages (8-hr daily maximum for O_3) at each NCore site across the continental United States.

concentrations to vehicular emissions (including the large reductions in 2020) is low.

Conclusions

The COVID-19 pandemic in the United States beginning in mid-March 2020 dramatically changed driving habits and led to large and widespread reductions in vehicular emissions. How these emissions reductions affected air quality in the spring of 2020 across the United States was more nuanced; pollutants directly affected by vehicular emissions (NO_2, CO) had lower concentrations while the pollutants of greater regulatory significance (O_3 and $PM_{2.5}$) had concentration impacts that were a function of meteorology and atmospheric chemistry in addition to emission changes. The

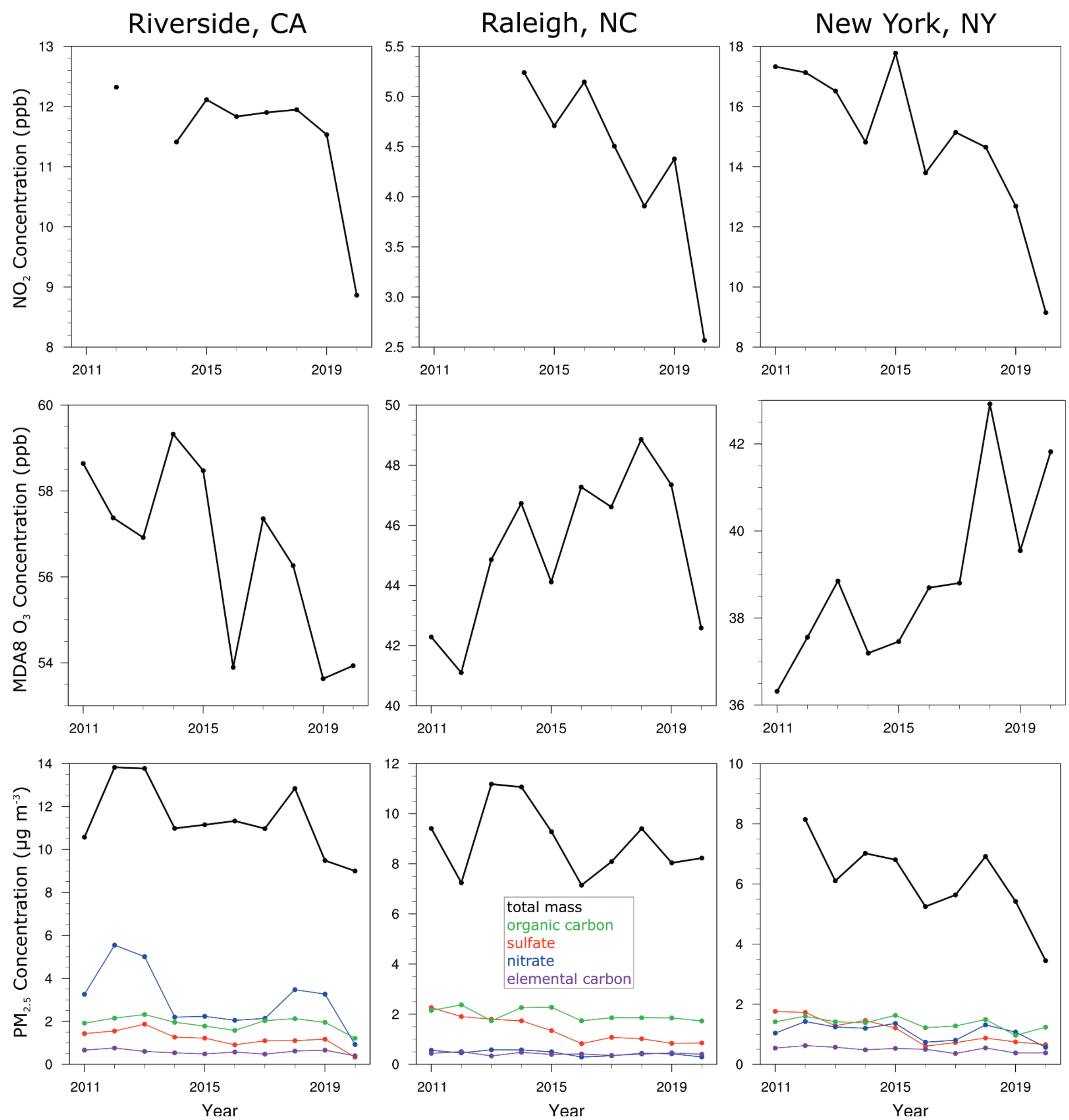

Figure 3. Average daily concentrations of NO_2, 8-hr daily maximum O_3, and daily total and speciated $PM_{2.5}$ mass, March 15–May 16, for the Riverside, CA, Raleigh, NC, and New York, NY, NCore sites from 2011 to 2020. For the $PM_{2.5}$ plots, both continuous and filter-based measurements of total mass were included.

locational (urban vs. rural) and geographic setting played a large role in the magnitude of the impact from the restrictions, with several of the largest urban areas in the United States experiencing small O_3 impacts and modest $PM_{2.5}$ reductions and with rural areas experiencing larger O_3 reductions and little change to $PM_{2.5}$.

Whether the spring of 2020 represents a glimpse of the future air quality in the United States is unclear. Based on our preliminary understanding, the main emission reductions due to the restrictions were from light-duty gasoline vehicles, aircraft in urban areas near large airports, and reductions resulting from reduced commercial activity; other sectors including heavy-duty diesel vehicles, electrical generation, and industrial processes were less affected overall. The meteorological conditions in spring 2020 played a role in the air quality response: lower-than-average temperatures favored lower O_3 concentrations in some areas of the Midwest, while also contributing to higher $PM_{2.5}$ concentrations. The opposite was true for some areas in California and the Northeast, where warmer than average temperatures enhanced O_3 formation and inhibited $PM_{2.5}$ concentrations.

Local atmospheric chemistry was also important: areas that were NOx-limited often experienced O_3 reductions, while areas that were nitrate-dominated mainly experienced $PM_{2.5}$ reductions. For other areas that were not historically NOx-limited or that had low nitrate concentrations, the impacts of the COVID-19 restrictions to O_3 and $PM_{2.5}$ concentrations were relatively modest. Along with additional measurements of VOCs and other pollutants, future analyses of emissions inventory data, chemical transport modeling, and satellite data (see examples at NASA.gov; https://www.nasa.gov/feature/goddard/2020/nasa-funds-four-research-projects-on-covid-19-impacts) will further help to quantify the impact of the COVID-19 restrictions on air quality in the United States. **em**

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NEW FOR 2022! ***Climate Change Perspectives*** is a new bimonthly column that will focus on the latest news and developments concerning climate change.

COP 26 Reflections

by Miriam Lev-On and Perry Lev-On

Back in September 2021, the United Nations published a synthesis of national climate action plans as communicated in countries' Nationally Determined Contributions (NDCs). The NDC Synthesis report (https://unfccc.int/news/full-ndc-synthesis-report-some-progress-but-still-a-big-concern) indicates that while there is a clear trend that greenhouse gas emissions are being reduced over time, these updated NDCs would still lead to a 2.5 °C increase in global warming by 2050. Therefore, nations must urgently redouble their efforts if they are to prevent global temperature increases beyond the Paris Agreement's goal of well below 2 °C (or no more than 1.5 °C) by the end of the century.

By the end of the most recent Conference of the Parties (COP 26), held in Glasgow this past November, 151 countries (https://www.climatewatchdata.org/2020-ndc-tracker) had submitted new climate plans with pledges to reduce their emissions by 2030:

- **91 of the 151 countries,** representing 63.7% of global emissions, have submitted new or updated NDCs with reduced total emissions;
- **27 countries, representing** 3.0% of global emissions, have stated their intention to enhance their ambition or actual actions in a new or updated NDC; and
- **Member countries** have also agreed to provide updated NDCs outlining their increased ambitions ahead of COP 27, which will take place in Egypt in November 2022.

COP 26 Overview

The three main goals emphasized by the United Kingdom as the COP 26 host were:

1. **Emissions' mitigation and attaining global net zero emissions by mid-century to limit global warming to 1.5 °C.**
2. **Adaptation to climate change.**
3. **Adequate financing to enable climate action.**

The key scientific premise on which the Glasgow conference was based was that worldwide greenhouse gas emissions should be reduced by 45% (compared to 2010), so as not to exceed a 1.5 °C temperature rise.

The World Leaders' Summit, which brought together over 120 heads of state and dignitaries, opened the Glasgow conference. It consisted of strong calls for greater ambition, including new NDCs and net zero pledges. There were also new financial pledges, including the first ever U.S. contribution to the Adaptation Fund (the fund finances climate change adaptation and resilience activities in developing countries that are vulnerable to the adverse effects of climate change).

Two notable declarations were announced during the World Leaders' Summit:

- **The Glasgow Leaders' Declaration on Forests and Land Use**, signed by 120 countries, to halt and reverse forest loss and land degradation by 2030, backed by public funds for forest conservation and a global roadmap to make 75% of forest commodity supply chains sustainable.
- **The Global Methane Pledge**, signed by over 100 countries, to commit to collectively reduce global methane emissions by 30% by 2030.

Throughout COP 26, many other declarations and alliances were announced, including:

- A commitment to phase down coal;
- A commitment to increase funding to help poor countries cope with climate change and make the switch to clean energy;
- A U.S.–China agreement to cooperate on addressing climate change over the next decade;
- The Green Grid initiative whose goal is to build out more transmission and infrastructure ready to transmit electricity from renewable energy sources; and
- An agreement by financial organizations, controlling US$130 trillion in assets, to back clean technology and direct finance away from fossil fuel industries.

Many observers were surprised at how much attention the issue of retaining access to coal and natural gas has received. Clearly, there was a lot of interest in how to step down from fossil fuels in a way that would not harm developing economies and would not harm big companies' contribution to the world's economy.

Paris Agreement Rulebook

COP 26 finalized the guidelines for the full implementation of the Paris Agreement. After six years of intense negotiations, parties to the Agreement have reached a compromise on the issue of Article Six (market mechanism) rulebook, which includes:

- A bottom-up, bilateral, or regional cooperative approaches via internationally transferred mitigation outcomes (ITMOs);
- A centralized crediting mechanism to contribute to mitigation and support sustainable development
- Non-market approaches.

Finalization of Article Six will enable the implementation of market-based solutions for addressing the climate crisis. It is

What did the countries agree on at COP 26 in Glasgow?

The main decisions reached by the 197 parties participating in the Glasgow Climate Change Conference include:

- Phasing down of coal use.
- Gradually reducing inefficient fossil fuel, including natural gas, subsidies.

  In this context it must be noted that the term 'inefficient subsidies' was added to the declaration under pressure from India and China. It leaves it to the countries to decide for themselves which subsidies are efficient, and which are not, so the countries will most probably decide according to economic rather than environmental considerations.
- Increasing the target ('ambition') for reducing each country's greenhouse gas emissions by 2030 and presenting the new target to the conference of the parties at COP 27, which will be held at the end of 2022 in Egypt.
- Meeting a global target for adaptation (climate preparedness) in two years, including increased funding obligation for climate change preparation.

Countries are called upon to double funding for climate change preparedness by 2025 and are required to submit their policies on climate adaptation by COP 27.

- Agreeing on the final details for the modalities of implementing the Paris Agreement, including new market mechanisms.

expected to drive investment into greenhouse gas reduction and sequestration projects. Such mechanisms could result in co-benefits for local communities, such as habitat restoration and improved air quality; and allow for countries and corporations to meet climate goals efficiently and cooperatively.

In Summary

Countries participating in COP 26 made progress in several key areas:

- **Adaptation** has been central to the conversations at the meeting, and the texts adopted recognize this relevance.
- The Network that provides technical support for countries to address and manage **loss and damage**, has now been enhanced, strengthening global efforts toward resilience.
- All Parties agreed that much more **financial support** needs to be provided to developing counties, recognizing the need for much more financing for adaptation.
- To address the **emissions reduction gap**, all Parties have collectively agreed to look for ways to increase actions with the overall objective of closing that gap to mitigate the effects of climate change.

Clearly, getting to net-zero emissions and implementing all the other pledges made at COP 26 will not be easy. But the emerging evidence of extreme climate change makes it imperative that the global community makes the next 10 years "count". It should be based on firm commitments to making energy, water, and urbanization sustainable for generations to come. That means leading focused transformations locally and globally.

As was summarized by Patricia Espinosa, Executive Director of the UNFCCC, in her closing speech on November 12, 2021:

> "At COP 26, Parties built a bridge between good intentions and measurable actions to lower emissions, increase resilience and provide much needed finance".

Now we definitely need to cross that bridge….**em**

Dr. Miriam Lev-On is Executive Director, and **Dr. Perry Lev-On** is Managing Director, both with The LEVON Group, LLC. **Dr. Miriam Lev-On** is a long-time A&WMA member and has been extensively involved in the organizing committees for A&WMA's climate specialty conferences over the past two decades.

A Roundup of the Latest U.S. Environmental Protection Agency (EPA) Research

Air Sensor Performance Evaluation Reports Available

EPA researchers published two reports that recommend an approach for testing and evaluating the performance of fine particulate matter ($PM_{2.5}$) and ozone (O_3) air sensors for use in non-regulatory supplemental and informational monitoring (NSIM) applications. The reports—designed to be used by sensor manufacturers, developers, and testing organizations—provide a set of protocols for testing O_3 and $PM_{2.5}$ air sensors, metrics, and target values for the purpose of evaluating sensor performance, and templates for reporting testing results. The testing protocols are entirely voluntary, and testers do not receive certification or endorsement by EPA. Read: EPA Scientists Develop Recommendations for Testing and Evaluating Air Sensor Performance (https://www.epa.gov/sciencematters/epa-scientists-develop-recommendations-testing-and-evaluating-air-sensor-performance).

Wildfire Study Aims to Develop Approaches to Reduce Wildfire Smoke Eexposures

A multi-faceted study by EPA has brought together a large and diverse group of experts, including scientists, public health officials, building owners, and sensor technology innovators to address community health impacts from wildfire smoke. The research includes field and laboratory studies, a prize-based challenge to encourage innovations in the development of indoor air cleaners, an air sensor loan program for air quality advisors, and collaborations with heating and air conditioning experts and a product safety testing organization. For the field research, scientists are partnering with the Missoula City-County Health Department (MCCHD) in Montana, University of Montana, and the Hoopa Valley Tribe in California. The objectives of the study, called Wildfire—Advancing Science Partnerships for Indoor Reductions of Smoke Exposures (ASPIRE) Study (https://www.epa.gov/air-research/wildfire-study-advance-science-partnerships-indoor-reductions-smoke-exposures), are to develop novel solutions and approaches for reducing wildfire smoke exposures.

Interim Guidance Supports Smoke Readiness Plans for Commercial Buildings and Schools

EPA is collaborating with partners to develop guidance to protect those who are in schools, commercial buildings and other public buildings from wildfire smoke exposure. A newly released interim guide provides recommendations and processes for developing a smoke readiness plan for commercial buildings that can be implemented when smoke is forecasted and during smoky days. A final guide is planned for 2022. Read: Guidance Available to Prepare Schools, Commercial and Public Buildings for Wildfire Smoke (https://www.epa.gov/sciencematters/guidance-available-prepare-schools-commercial-and-public-buildings-wildfire-smoke).

Tool Developed for Managing Electronic Waste

Electronic waste is increasing around the world. To help understand and improve the flow of used electronics products from consumer markets to the waste or reuse stream, EPA researchers have developed the Alternative Disposition of Electronics Planning Tool, also called ADEPT, which can be used to make predictions of future waste generation demands and to evaluate different disposal scenarios of used electronics at both state and national levels. Read: Helping Communities Manage Electronic Waste (https://www.epa.gov/sciencematters/helping-communities-manage-electronic-waste). **em**

More Information

For more information about the **EPA Research Highlights** column, contact Ann Cornelius Brown, U.S. Environmental Protection Agency (EPA), Office of Research and Development, Research Triangle Park, NC; e-mail: **brown.ann@epa.gov**.

20 Years of A&WMA's Measurements Conference

by Eric Winegar, Conference Chair

In March, A&WMA will celebrate the 20th anniversary of the Symposium on Air Quality Measurement Methods and Technology—the Measurements Conference—in San Diego after a nearly two-year pandemic break of in-person meetings.

The conference generally follows the format of the International Symposium on Toxic and Related Air Pollutants that originated in the mid-1980s as a meeting for U.S. Environmental Protection Agency (EPA) contractors in coordination with the Air Pollution Control Association, a precursor to A&WMA. By 1986, A&WMA had assumed operational responsibility, and this conference continued annually in the Research Triangle Park (RTP), NC area (close to EPA offices) until 2000, after which it lapsed due to lack of funding support.

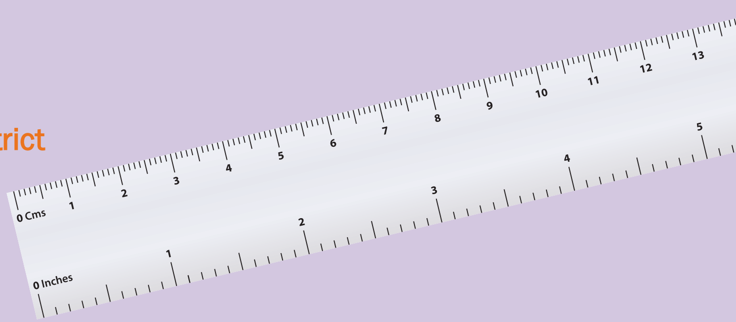
In 2002, the 'next generation' meeting was re-named and reformulated as an A&WMA reoccurring specialty conference that for the past 20 years has alternated between the West Coast and the East Coast on an approximate one-and-a-half-year frequency. The post-2002 West Coast meetings have been held in Long Beach, Sacramento, San Francisco (twice), and Los Angeles, California, and the East Coast meetings have all been held in the RTP, North Carolina area.

The primary goal of the Measurements Conference has been to foster the exchange of new and improved methods and technology for air quality measurements. Two important values have evolved: (1) presenters must describe actual data—that is, no theoretical or laboratory-only data (unless discussing a laboratory method); and (2) presentations must not be specifically commercially-oriented or marketing focused. This latter requirement has arisen from many attendees' preferences that the contents of talks be focused on the science, even if a new instrument or capability is being demonstrated or introduced.

The planned 2020 meeting was postponed twice due to the pandemic and was ultimately held as a virtual meeting in May 2021. The 2022 meeting in San Diego is scheduled for March 8–10. This 20th year anniversary meeting will include two-and-one-half days of parallel tracks of technical presentations. The meeting will start with a keynote presentation by a prominent person in the field. The two main days will include an exhibition, with a variety of vendors, mostly of instrumentation, monitoring equipment, or laboratory services—as of this writing, a dozen exhibitors have already

Notable Members of the Measurements Conference Organizing Committee of the Past 20 Years

Eric Winegar, Sonoma Technology
Ray Merrill, EPA
Ricky Tropp, Desert Research Institute (retired)
R.K.M. Jayanty, Research Triangle Institute (retired)
Hilary Hafner, Sonoma Technology
Phil Fine, South Coast Air Quality Management District
Ian MacGregor, Battelle
Sara Head, Yorke Engineering
Ned Shapely, EPA



signed up for the meeting and there is room for over 20 more. And we are always appreciative of our sponsors who have included major public agencies (e.g., the California Air Resources Board and the South Coast Air Quality Management District) and various instrument vendors.

One of the more notable memories of the past 20 years of meetings was the keynote speech by Mary Nichols, then-Chair of the California Air Resources Board, at the 2013 Measurements Conference in Sacramento. In this talk, she referred to the audience and to our measurement scientist colleagues as "rock stars." Never before nor since have I been referred to in that way (and I would bet this applies to all of my colleagues in this niche of environmental science). Nichols went on to focus on the fundamental importance of the measurement process in air quality science. Indeed, it is safe to say that the act of measurement—making an observation, directly or instrumentally—is at the core of all scientific enterprises, including the environmental sciences.

A key concept in the evolution of the scientific process through the course of history has been the reliance on experimentation—that is, the process of performing a scientific procedure, especially in the laboratory, to determine something. In 1970, with the formation of the EPA, quickly followed by the passing of the U.S. Clean Air Act, the result was a set of regulations that established "hazardous" or "toxic" air pollutants, for which compliance required specific validated methods. Enter SW-846 in 1980, including its similarly purposed *Air Methods Compendium*, with requirements to use validated methods versus ad hoc methods that had been employed in the past. This move emphasized the need to conduct an observation (i.e., a measurement) with proven methods so that the results from one measurement can be compared to another, reflecting the evolution of science from a single-person operation to that of many persons and across organizational boundaries, all as part of the evolution of environmental quality assurance. It is an obvious assumption that having a common method of data collection allows for deeper insights into broad problems when a singular approach is used.

This historical backdrop is the foundation of the Symposium on Air Quality Measurement Methods and Technology:

Air Quality—the arena of interest;
Measurement Methods—collective means of conducting experiments and measurements;
Technology—the means by which the measurements are made; and
Symposium—a time-honored avenue for sharing work that eventually results in examination by one's peers.

As one of A&WMA's premier specialty conferences, we expect this conference to continue past this 20th year into the next 20 years and beyond. We encourage you to get involved, register, and attend this important event. For more information go to: https://www.awma.org/measurements. **em**

What's on Tap for 2022?

Looking to expand your knowledge and professional network? A&WMA offers many opportunities to advance your knowledge and career. Take a course or webinar. Attend one of our targeted Specialty Conferences. Network at a Section or Chapter meeting.

Check out our list of upcoming events...

January 18–21
A&WMA Board, Intercouncil, and ACE Planning Meetings
Virtual

March 8–10
Air Quality Measurement Methods and Technology Conference
San Diego, CA
www.awma.org/measurements

April 6–7
Freight & Environment: Ports of Entry 2022 Conference
Oakland, CA
www.awma.org/ports

April 8–10
Leadership Training Academy
Pittsburgh, PA
www.awma.org/LTA

May 5–6
39th International Conference on Thermal Treatment Technologies and Hazardous Waste Combustors (IT3)
West Palm Beach, FL
www.awma.org/IT3

June 27–30
A&WMA's 115th Annual Conference & Exhibition (ACE)
San Francisco, CA
www.awma.org/ace2022

For a complete list of A&WMA events, go to www.awma.org/calendar_list.asp

A&WMA continues to monitor the COVID-19 pandemic situation very closely and will make adjustments to the events calendar and transition from face-to-face events to virtual events, as needed. Changes to the events calendar will be communicated to members via e-mail. Please be sure to check your e-mail for the latest information from A&WMA.

What's In Store?

Missed out on attending a recent webinar or virtual conference? Be sure to check out the A&WMA Online Store at **www.awma.org/store_home.asp**, via the Association's Home Page, for the latest recorded webinars and conference proceedings. Members receive significant discounts on all products sold through the online store.

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Layout and Design: Clay Communications, 1.412.704.7897

EM, a publication of the Air & Waste Management Association, is published monthly with editorial and executive offices at The Koppers Building, 436 Seventh Ave., Ste. 2100, Pittsburgh, PA 15219, USA.

EM Magazine (Online) ISSN 2470-4741 » EM Magazine (Print) ISSN 1088-9981

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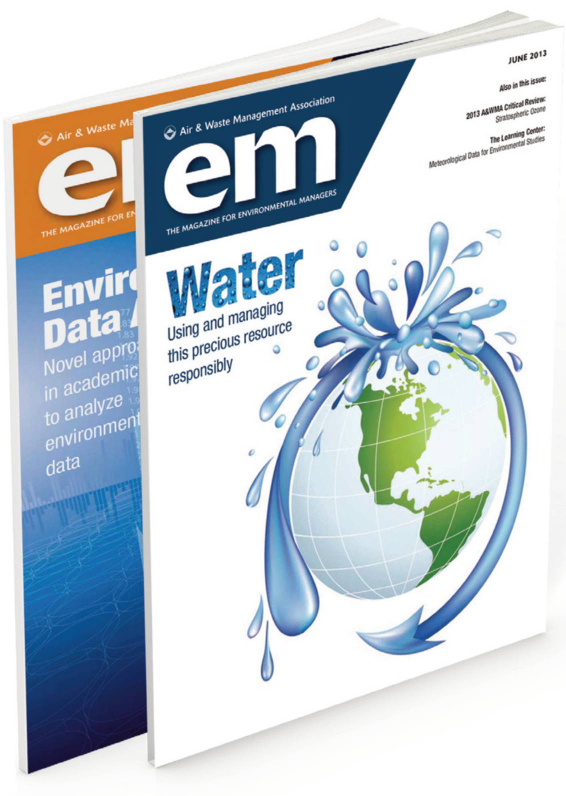

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Topics covered include regulatory changes; research; new technologies; environment, health, and safety issues; new products; professional development opportunities; and more. *EM* covers a wide range of topics, including air quality and air pollution control, pollution prevention, climate change, hazardous waste, and remediation.

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