U.S. National Ambient Air Quality Standards Review
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U.S. National Ambient Air Quality Standards Review
by Anthony J. Schroeder

The U.S. National Ambient Air Quality Standards (NAAQS) are ambient concentration thresholds that the U.S. Environmental Protection Agency (EPA) sets for pollutants that are considered harmful to public health and the environment. EPA is required to review each NAAQS every five years—although in practice reviews often do not occur on that frequency—and revise the standard if needed. The articles in this issue of EM provide an update on the status of the current NAAQS review process and possible future changes to the process.

Features

CASAC Review of the PM and Ozone NAAQS
by James W. Boylan

Impacts of Ad Hoc Changes to the Science Review Process for U.S. Air Quality Standards
by H. Christopher Frey

The National Ambient Air Quality Standards at 50
by Karen Hays, Robert Hodanbosi, and Jason Sloan

Columns

PM File: 2020: A Year to Remember or a Year to Forget?
by David Elam

After what can only be described as one of the most challenging years in history, take a moment to prepare for the new year ahead.

Departments

Message from the President: A Dichotomous Year
by Kim Marcus

Back In Time: A&WMA's Annual Critical Review Turns 50
Timothy G. Townsend
This year, we have all faced many more challenges, uncertainties, and angst than at other any time in the past 75 years. A&WMA’s goal throughout has been to bring certainty to those areas that complement our mission and focus, while acknowledging that there is always room for improvement. Adaptation has allowed us to remain financially solvent, while providing equivalent and meaningful programming and services through new platforms.

In retrospect, the year started well. We held excellent Inter-council and winter Board of Directors meetings in beautiful San Francisco in January. From the restaurant at the top of the San Francisco Hyatt hotel, you could see the expanse of the Pacific Ocean on the other side of the Golden Gate Bridge, Alcatraz, Mount Tamalpais, and the Berkeley Hills, as well as several other incredible cities in the distance. A&WMA’s Board welcomed two new directors, Rashmi Pathak and John Kinsman, and we had a robust discussion about many subjects around member services and engagement. While our discussions focused on becoming more innovative with programming and content, we had no idea of the paradigm shifts heading our way.

Just a few (short) months later, we held our first Virtual Annual Conference & Exhibition with more than 600 attendees, 220 papers, 24 sponsors and exhibitors, and many of the same activities of a face-to-face annual conference. Following on from a very successful Virtual ACE, we held a virtual Science of PFAS conference and a virtual New Source Review workshop that were both huge successes, as have been the many webinars we have organized and held throughout the year. I cannot stress enough how lucky and fortunate we are to have such a wonderful and adaptable headquarters staff.

This has been a dichotomous year—both very long and very short at the same time. I am not sure how that works, but I have heard from many other people who feel the same way. This most unusual year has had its disappointments, but also fantastic positive surprises. For example, I really appreciate and enjoy being able to go to the A&WMA website at any time of the day or week and watch a presentation that I missed from a past conference or webinar.

Many thanks and recognition to the Board of Directors, and especially to those who have completed their terms during the Great Pivot Year: Mike Markey, Corey Mocka, and Rahul Thaker. With this last missive as President my duties transition to Brian Benger, who I am certain based on his sage advice and multifaceted support of the Association will be a prodigious and innovative leader in 2021.

Moreover, my sincerest appreciation and thanks to you the members for participating in content development; webinar/conference attendance; advertising, exhibiting, and sponsorship; and last but not least, for your continued support of this Association as members.

This month in EM, the U.S. National Ambient Air Quality Standards (NAAQS) are the focus. Reviewing the standards on a five-year cycle allows the U.S. Environmental Protection Agency to assess where the United States stands with regard to setting ambient threshold concentrations for carbon monoxide, lead, nitrogen dioxide, ozone, particle pollution, and sulfur dioxide. The three articles published in this issue offer a thought-provoking review of the standards, the impacts of ad-hoc changes to the review process, and how the states and federal government are managing cooperative federalism under the U.S. Clean Air Act.
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A&WMA’s Annual Conference is recognized as the premier international conference for the latest information on air, climate change, environmental management, resource conservation, and waste management with 300+ platform and poster presentations, 35+ panel sessions, and 10+ concurrent tracks each day.

Abstracts are due December 20, 2020 for professional/student platform presentations, technical posters and panels. Student poster abstracts are due January 12, 2021.

Authors of accepted abstracts may use several submission formats, including full-length paper, extended abstract, PowerPoint slides or poster boards. Accepted abstracts for panel sessions require submission of a Panel synopsis. All submissions must follow A&WMA guidelines to allow for review and determination of eligibility for inclusion in the online Conference proceedings. All presenters, including panelists are required to register and pay to attend. Young Professionals (YPs) who are primary authors must submit a full manuscript or extended abstract to be considered for YP best paper awards, see A&WMA’s website for more details.

Abstracts are solicited in one of the broad topic areas listed below or in another environmental area that matches your interest. We are looking for the latest and greatest research, ideas, and solutions in the environmental industry and those that touch on the conference theme Environmental Resiliency for Tomorrow.

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- Air Quality, Measurements, Control, Modeling, Visibility, Data QA/QC
- Bioenergy, Biofuels, Biogas, and Landfills
- Brownfield Redevelopment
- Climate Change—Science, Policy, Regulation, Impacts, Food Security, Mitigation and Adaptation
- Government, Public Sectors and Indigenous Issues
- Environmental Program Administration—Policy, Regulation & Implementation, Permitting, Public Participation, Citizen Monitoring, Odor Issues, and EPA Priorities
- Health, Safety and Environmental Effects and Exposure
- Impacts & Health Concerns—Land Use Policies, Alternative Fuels, and Electric Vehicles
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- Regulatory and Legal Issues
- Sustainability, Resource Conservation, Circular Economy, and Energy-Water-Waste Nexus
- Transportation—Multi-Modal Air and Noise Emissions
- Waste Treatment, Processing, Bioenergy, Waste-to-Energy, Landfills, and Site Remediation

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U.S. National Ambient Air Quality Standards Review

An update on the status of the current National Ambient Air Quality Standards review and possible future changes to the process.
The development of U.S. National Ambient Air Quality Standards (NAAQS)—and the requirement to periodically reevaluate them—are cornerstones of the U.S. Clean Air Act (CAA). The NAAQS, which the U.S. Environmental Protection Agency (EPA) must set for pollutants that are considered harmful to public health and the environment, establish national thresholds that are used to evaluate local air quality within the United States. The NAAQS are not necessarily fixed values, however. EPA is required to periodically review and consider revision of the NAAQS. The Clean Air Scientific Advisory Committee (CASAC), which is appointed by the EPA Administrator, is a part of this review process and recommends to the administrator new or revised standards as appropriate.

The three articles that follow this month focus on NAAQS and aspects of the review and revision process. The first two articles provide information and commentary on the periodic review process itself. In the first article, James Boylan, who is a current member of CASAC, provides an overview of recent CASAC activity, including reviews of the particulate matter (PM) and ozone NAAQS. The author also provides his recommendations for future NAAQS reviews. In the second article, H. Christopher Frey, a former CASAC chair, provides commentary on the recent PM and ozone NAAQS reviews and his recommendations for future reviews.

The third article by Karen Hays and co-authors provides a review of the state of air quality in the United States on the 50th anniversary of the establishment of the EPA. The authors credit the implementation of environmental programs by EPA, state, local, and tribal agencies, driven by the NAAQS, with the noted air quality improvements over the past five decades.

As noted above, the members of CASAC are appointed by the EPA Administrator, which is itself an appointed position, and therefore the makeup and membership of CASAC can be influenced by presidential administrations. And as seen in the first two articles, many people involved in this process, including former and current CASAC members, have strong opinions about the best ways to implement the CAA's requirements for CASAC to complete periodic NAAQS reviews. These differences of opinion can result in differences in the approach taken by CASAC to review standards over time.

Due to the timeline for article submittal and review for this issue of EM occurring prior to the November 2020 elections, we have understandably experienced some level of hesitancy from potential authors in accepting invitations to contribute articles for this topic. Therefore, the EM Editorial Advisory Committee and I sincerely thank the authors who did volunteer to prepare articles for this issue for their valuable contributions to EM.

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A&WMA is an educational organization exempt from taxation under the 501(c)(3) code of the Internal Revenue Service. Contributions to this fund may be deductible as charitable contributions for U.S. federal income tax purposes.
A first-hand commentary on the Clean Air Scientific Advisory Committee’s role in the most recent National Ambient Air Quality Standards reviews and recommendations for how future reviews could be improved.
Section 109(d)(1) of the U.S. Clean Air Act requires “…at five-year intervals… the [EPA] Administrator shall complete a thorough review of the criteria published under Section 108 and the national ambient air quality standards…and shall make such revisions in such criteria and standards and promulgate such new standards as may be appropriate….“ Section 109(d)(2)(A) requires the U.S. Environmental Protection Agency (EPA) Administrator to “appoint an independent scientific review committee composed of seven members, including at least one member of the National Academy of Sciences, one physician, and one person representing state air pollution control agencies.”

Section 109(d)(2)(B) provides that this committee “shall complete a review of the criteria…and the national primary and secondary ambient air quality standards…and shall recommend to the Administrator any new…standards and revisions of existing criteria and standards as may be appropriate….“ For the past four decades, this independent scientific review committee requirement has been fulfilled by the Clean Air Scientific Advisory Committee (CASAC). The purpose of this article is to describe CASAC’s role in the most recent U.S. National Ambient Air Quality Standards (NAAQS) reviews and provide recommendations for how future reviews could be improved.

**Recent CASAC Activity**

Over the past three years, the CASAC has been involved with reviewing the particulate matter (PM) and ozone NAAQS. EPA’s NAAQS review process involves three phases: planning, assessment, and rulemaking. During the planning phase, EPA develops the Integrated Review Plan (IRP), which includes timelines and key policy-relevant issues and scientific questions. The CASAC develops a letter to the EPA Administrator with individual CASAC comments.

During the assessment phase, EPA usually develops three documents: (1) Integrated Science Assessment (ISA), which includes an evaluation and synthesis of most policy-relevant studies; (2) Risk and Exposure Assessment (REA), which is a quantitative assessment focused on key results, observations, and uncertainties; and (3) Policy Assessment (PA), which includes staff analysis of policy options based on integration and interpretation of information in the ISA and REA. CASAC is asked to review draft versions of these documents and respond to a set of charge questions assembled by EPA and used to guide the CASAC review of the documents. The CASAC develops a letter to the EPA Administrator that includes consensus response to charge questions and individual CASAC comments. CASAC does not review the final versions of these documents. Also, CASAC is not involved with the rulemaking phase.

Traditionally, the CASAC works with a special panel of experts to review and evaluate the IRP, ISA, REA, and PA. This CASAC expert review panel typically consists of 20–30 members and works directly with the CASAC to help develop responses to EPA charge questions. However, many of the traditional CASAC roles were transformed with the EPA Administrator’s May 9, 2018 “Back to Basics” memo, which directed EPA to expedite the PM and ozone NAAQS reviews (targeting completion by the end of 2020), identified ways to streamline the review process (e.g., avoiding multiple drafts of documents), and identified a standardized set of charge questions for CASAC. As a result, the PM review panel was dissolved, and the ozone review panel was never formed. This placed the full responsibility of the CASAC review on the shoulders of the seven-member CASAC. The current CASAC members are listed in Table 1. Dr. Kendall did not participate in the PM review based on his timing of joining the CASAC, but he did participate in the ozone review.

**PM NAAQS Review**

EPA’s draft PM ISA was released in October 2018. CASAC met on December 12–13, 2018, and March 28, 2019, to discuss the draft PM ISA. CASAC submitted a letter on the draft PM ISA to the EPA Administrator on April 11, 2019. The letter stated: “Overall, the CASAC finds that the Draft ISA does not provide a sufficiently comprehensive, systematic assessment of the available science relevant to understanding the health impacts of exposure to particulate matter (PM). The CASAC recommends that the following limitations be remedied in a second draft of the ISA for CASAC review:

- Lack of comprehensive, systematic review…
- Inadequate evidence for altered causal determinations…
- Clearer discussion of causality and causal biological mechanisms and pathways… .”

For the causality determinations, “The CASAC finds that the Draft ISA does not present adequate evidence to conclude that there is likely to be a causal association between long-term PM2.5 exposure and nervous system effects; between long-term UFP [ultrafine particles] exposure and nervous system effects; or between long-term PM2.5 exposure and cancer.” Also, CASAC made the following two process recommendations:

1. The CASAC recommends development of a Second Draft ISA for CASAC review.
2. The CASAC recommends that the EPA reappoint the previous CASAC PM panel (or appoint a panel with similar expertise). The panel should be appointed in time to review the Second Draft ISA.

On September 13, 2019, EPA announced the selection of a pool of non-member subject matter experts (consultants) to support the CASAC’s review of the PM and ozone NAAQS.
These non-member consultants were allowed to respond formally in writing to written questions from the CASAC members; however, verbal discussions with them were not allowed.

EPA’s final PM ISA\(^a\) was released in December 2019. The final PM ISA revised the causality determination for long-term ultrafine particle exposure and nervous system effects from “likely to be a causal” to “suggestive of, but not sufficient to infer a causal relationship” and added additional text to the Preface of the PM ISA, as well as text in the health effects chapters to clarify the discussion of biological plausibility (the presence of a potential biological mechanism) and its role in forming causality determinations.

EPA’s draft PM PA\(^a\) was released in September 2019. The EPA staff preliminary conclusion was that the current primary annual PM\(_{2.5}\) standard was not adequate and should be lowered, but the current 24-hr PM\(_{2.5}\) standard, PM\(_{10}\) standard, and secondary PM standards were adequate and should be retained. CASAC met on October 22, 2019, and October 24–25, 2019, to discuss the draft PM PA. CASAC submitted a letter on the draft PM PA to the EPA Administrator on December 16, 2019.

The letter stated: “…some CASAC members conclude that the Draft PM PA does not establish that new scientific evidence and data reasonably call into question the public health protection afforded by the current 2012 PM\(_{2.5}\) annual standard. Other members of CASAC conclude that the weight of the evidence…does reasonably call into question the adequacy of the 2012 annual PM\(_{2.5}\) [NAAQS] to protect public health with an adequate margin of safety. The CASAC also finds, in agreement with the EPA, that the available evidence does not reasonably call into question the adequacy of the current 24-hr PM\(_{2.5}\) standard, PM\(_{10}\) standard, or secondary PM standards and concurs that they should be retained.”

In addition, “The CASAC recommends that the final PM PA provide quantitative uncertainty and sensitivity analyses to provide a clearer technical and scientific basis for data interpretation and policy making.” CASAC concluded with “The CASAC recommends that it be provided an opportunity to review a revised draft of the PM PA based on the final PM ISA.”

EPA’s final PM PA\(^a\) was released in January 2020. The EPA staff final conclusions as to the adequacy of the PM standards were consistent with their preliminary conclusions. Table 2 is a summary of the EPA preliminary/final conclusions and the CASAC conclusions on the adequacy of the current PM standards.

**Ozone NAAQS Review**

EPA’s draft ozone ISA\(^a\) was released in September 2019. CASAC met on December 3–6, 2019, and February 11–12, 2020, to discuss the draft ozone ISA. CASAC submitted a letter on the draft ozone ISA to the EPA Administrator on
February 19, 2020. The letter stated, “The CASAC recommends that the following key points be addressed in the final ozone ISA:

- Critically review, synthesize, and discuss available scientific evidence on how changes in public health effects depend on changes in ambient ozone exposures. This is a crucial scientific topic for informing the ozone PA and should be thoroughly addressed in the ozone ISA.
- Clarify criteria used to select, evaluate, weight, and summarize studies; provide details of how the criteria were applied to individual studies and what the results were; and explain how key conclusions were derived from the results.
- Clarify the meaning and derivation of stated key causal conclusions. Causal determination judgments stated in the draft ozone ISA are ambiguous, and sometimes appear subjective and arbitrary.”

In addition, the letter stated, “On overarching process issues, the CASAC strongly recommends that the EPA consider restoring a traditional interactive discussion process in which the CASAC can interact directly with external expert panels, while also keeping the option of obtaining written responses from external experts to specific questions.” EPA’s final ozone ISA was released in April 2020.

EPA’s draft ozone PA was released in October 2019. The EPA staff preliminary conclusion was that the current primary and secondary ozone standards were adequate and should be retained. CASAC met on December 3–6, 2019, and February 11–12, 2020, to discuss the draft ozone PA. CASAC submitted a letter on the draft ozone PA to the EPA Administrator on February 19, 2020. The letter stated, “… some CASAC members conclude that the draft ozone PA does not establish that new scientific evidence and data reasonably call into question the public health protection afforded by the current primary ozone standard. Other members of the CASAC agree with the previous CASAC’s findings and recommendations in their review of the 2014 PM standards.”

<table>
<thead>
<tr>
<th>Name</th>
<th>Affiliation</th>
<th>Position</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dr. Louis Anthony Cox, Jr. (CASAC Chair)</td>
<td>Cox Associates, Denver, CO</td>
<td>President</td>
<td>2017</td>
</tr>
<tr>
<td>Dr. James Boylan</td>
<td>Georgia Department of Natural Resources, Atlanta, GA</td>
<td>Planning &amp; Support Program Manager</td>
<td>2017</td>
</tr>
<tr>
<td>Dr. Mark Frampton</td>
<td>University of Rochester Medical Center, Rochester, NY</td>
<td>Professor Emeritus</td>
<td>2018</td>
</tr>
<tr>
<td>Dr. Sabine Lange</td>
<td>Texas Commission on Environmental Quality, Austin, TX</td>
<td>Toxicology Section Manager</td>
<td>2018</td>
</tr>
<tr>
<td>Dr. Corey Masuca</td>
<td>Jefferson County Department of Health, Birmingham, AL</td>
<td>Principal Air Pollution Control Engineer</td>
<td>2018</td>
</tr>
<tr>
<td>Dr. Steven C. Packham</td>
<td>Utah Department of Environmental Quality, Salt Lake City, UT</td>
<td>Toxicologist</td>
<td>2018</td>
</tr>
<tr>
<td>Dr. Ronald Kendall</td>
<td>Texas Tech University, Lubbock, TX</td>
<td>Professor of Environmental Toxicology</td>
<td>2019</td>
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<table>
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<tr>
<th>PM Standard</th>
<th>EPA Preliminary/Final Conclusion that the Current Standard is Adequate</th>
<th>CASAC Conclusion that the Current Standard is Adequate*</th>
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</thead>
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<tr>
<td>Annual PM$_{2.5}$</td>
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<td>Yes (5), No (1)</td>
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<tr>
<td>Daily PM$_{2.5}$</td>
<td>Yes</td>
<td>Yes (6)</td>
</tr>
<tr>
<td>Daily PM$_{10}$</td>
<td>Yes</td>
<td>Yes (6)</td>
</tr>
<tr>
<td>Secondary PM$_{2.5}$</td>
<td>Yes</td>
<td>Yes (6)</td>
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Note: *Numbers in parenthesis represent the number of CASAC members drawing each conclusion.*
Second draft ozone PA. In that review, the previous CASAC opined that a primary standard set at 70 ppb [parts per billion] may not be protective of public health with an adequate margin of safety. The CASAC also finds, in agreement with the EPA, that the available evidence does not reasonably call into question the adequacy of the current secondary ozone standard and concurs that it should be retained.

In addition, the letter stated, “On overarching process issues, the CASAC strongly recommends that the EPA consider restoring a traditional interactive discussion process in which the CASAC can interact directly with external expert panels, while also keeping the option of obtaining written responses from external experts to specific questions. The CASAC strongly recommends that the EPA work with experts in causal analysis, biological causation, management science, decision analysis, and risk analysis to improve the causal determination framework.” CASAC concluded with the following statement: “The CASAC recommends that it be given an opportunity to review a second draft of the ozone PA (with an updated Risk and Exposure Assessment) after the final ISA for ozone is released.”

EPA’s final ozone PA was released in May 2020. The EPA staff final conclusions as to the adequacy of the ozone standards were consistent with their preliminary conclusions. Table 3 is a summary of the EPA preliminary/final conclusions and CASAC conclusions on the adequacy of the current ozone standards.

### Table 3. EPA and CASAC conclusions on the adequacy of the current ozone standards.

<table>
<thead>
<tr>
<th>PM Standard</th>
<th>EPA Preliminary/Final Conclusion that the Current Standard is Adequate</th>
<th>CASAC Conclusion that the Current Standard is Adequate*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary Ozone</td>
<td>Yes</td>
<td>Yes (6), No (1)</td>
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<tr>
<td>Secondary Ozone</td>
<td>Yes</td>
<td>Yes (7)</td>
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</tbody>
</table>

*Numbers in parenthesis represent the number of CASAC members drawing each conclusion.

With a CASAC of only seven people, all areas of science were not adequately represented (e.g., epidemiology) or only represented by one person. For example, I was the only person on CASAC that specialized in photochemical modeling for PM and ozone. With the traditional review panel, there are typically multiple people with similar areas of expertise that can meet in small groups of 3–4 people to discuss and debate scientific approaches and interpretation of results. Under the current review scenario, there were certain topics where only one CASAC member was a subject matter expert leading to little debate and discussion on alternative approaches and interpretation of results. Hence, that one CASAC member’s comments on those subjects became the default consensus CASAC comments. For the more controversial topics, I would have liked to have seen additional subject matter experts with differing opinions (e.g., the disbanded PM review panel) directly participate in the discussions with the CASAC rather than simply providing their written and verbal comments via the public comment forum. This would allow for a more comprehensive examination of controversial topics.

I feel strongly that EPA should bring back the traditional review panels for future NAAQS reviews. This panel would provide the seven-member CASAC with additional insight and expertise to allow for a more thorough and in-depth review of the relevant science and policy documents. While the pool of non-member consultants did provide additional insight and useful information for the PM and ozone reviews, it was not an adequate replacement for the traditional review panel. My experience serving on the CASAC sulfur (SO2) review panel (2014–2018) allows me to directly compare the traditional review panel approach to the new non-member consultants approach. While on the SO2 review panel, I learned the importance and value of having multiple nationally recognized experts with differing backgrounds and opinions thoroughly reviewing each document. Although EPA made available non-member consultants to formally respond in writing to written questions from the CASAC members, it was not the same as the traditional review panel which directly participated in the deliberations and drafting of consensus comments.

Second NAAQS review, I would support changing the five-year interval to an eight-year interval.

Due to the time required to perform a comprehensive review of the draft documents, it was a difficult and time-consuming task. Just the time alone to read the draft documents can be substantial: PM ISA (1,879 pages), PM PA (457 pages), ozone ISA (1,411 pages), and ozone PA (926 pages). This task was made even more difficult by not having the assistance of the traditional review panels and the EPA Administrator’s decision to complete both reviews by the end of 2020. While the EPA is required by the Clean Air Act to complete NAAQS reviews for each criteria pollutant every five years, they have historically failed to meet that statutory deadline (e.g., 1997/2008/2015 for ozone, 1997/2006/2012 for PM).
It was unfortunate that EPA did not follow the CASAC recommendations to provide second draft versions of the PM ISA, PM PA, and ozone PA for CASAC to review. Since the EPA Administrator set a deadline for these reviews to be completed by December 2020, second draft versions of these documents were not made available for CASAC review and many of the CASAC comments were not adequately addressed in the final versions of these documents. If EPA had been given adequate time to fully address the CASAC comments and provided CASAC with second draft versions of these documents, some CASAC members may have changed their determination as to the adequacy of the standards.

To further streamline the PM and ozone review processes, EPA developed the draft PA prior to finalizing the ISA and incorporated the REA into the PA. The purpose of the PA is to bridge the gap between EPA’s scientific assessments and the judgment required by the EPA Administrator when determining whether to retain or revise the NAAQS. Therefore, the ISA should be finalized prior to developing the REA and the REA should be a stand-alone document that is reviewed by CASAC and the public prior to the release of the PA. This will allow scientific review of the risk and exposure metrics prior to developing policy recommendations.

In the future, EPA should consider spacing out the PM and ozone reviews, starting the review process sooner to allow for multiple drafts of the ISA and PA documents, providing the REA as a stand-alone document prior to release of the PA, and bringing back the traditional review panels.

References
2. Integrated Science Assessment for Particulate Matter (External Review Draft); EPA/600/R-18/179; U.S. Environmental Protection Agency, October 2018.

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Impacts of Ad Hoc Changes to the Science Review Process for U.S. Air Quality Standards

A commentary describing how a series of ad hoc changes have undermined the integrity of the NAAQS scientific review process.
In the last two years, the U.S. Environmental Protection Agency (EPA) has accelerated the pace of reviews of National Ambient Air Quality Standards (NAAQS) for ozone and particulate matter (PM). The U.S. Clean Air Act (CAA) directs EPA to set NAAQS based on a periodic accurate and thorough review of the latest science. This function is performed by the Clean Air Scientific Advisory Committee (CASAC). Recent changes in the NAAQS scientific review process raise questions about proposed decisions to retain current standards for PM and ozone.

CASAC has seven members, which is not enough to provide the breadth, depth, and diversity of expertise, experience, and perspectives needed for these complex reviews, nor could a group of this size cover the needed scientific disciplines. Recognizing this, and consistent with its charter with the U.S. Congress, for four decades EPA has augmented CASAC by convening expert review panels for each pollutant. The panels included scientists with knowledge of epidemiology, toxicology, medicine, air quality, exposure, risk, statistics, and other fields. For example, a 20-member PM Review Panel was appointed in 2015 to help CASAC review the PM NAAQS.

The panel was dismissed by then-EPA Administrator Wheeler in October 2018. He also announced that he would not form a CASAC Ozone Review Panel, even though EPA had solicited nominations for such a panel three months earlier. Subsequently, during the current PM NAAQS review, CASAC recommended that “the EPA reappoint the previous CASAC PM panel or appoint a panel with similar expertise.” Instead, the EPA Administrator appointed a smaller 12-member “pool” of ad hoc consultants who could respond only in writing to questions posed by CASAC members. Thus, the pool was not allowed to deliberate interactively with CASAC, which is critical to exploring complex scientific issues, as was the case for review panels. The pool was appointed by the Administrator, not the EPA Science Advisory Board Staff Office (SABSO) director. In contrast, CASAC review panels were appointed by the SABSO director based on staff assessment of scientific needs. The pool was appointed to serve both the PM and ozone reviews, whereas established practice would have been to appoint separate panels of typically 15–20 experts each.

These are just a few of a series of ad hoc changes to the process for scientific review of the NAAQS that have been implemented by Administrators Pruitt and Wheeler since 2017. These changes have been described as necessary for EPA to comply with the Clean Air Act requirement that NAAQS be reviewed every five years. EPA has typically not met the five-year requirement. However, even when federal courts have intervened to impose review schedules on EPA, sufficient time was allowed for a thorough scientific review. While the five-year review schedule is a matter of law, it is also a matter of law that there be thorough review of the science. Section 108 of the Clean Air Act requires EPA to set air quality criteria that “shall accurately reflect the latest scientific knowledge useful in indicating the kind and extent of all identifiable effects on public health or welfare.”

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During a one-year period, there was complete turnover of CASAC membership under the terms of a 2017 Pruitt memorandum that banned nongovernmental, but not governmental, recipients of EPA scientific research grants from serving on EPA advisory committees. This ban was later found to be arbitrary and capricious by a U.S. District Court. Recent appointments to CASAC have been based on geographic location and government affiliation, in accordance with the Pruitt memorandum. Notably, there are no epidemiologists on CASAC, even though epidemiology is a key discipline pertinent to review of both PM and ozone NAAQS.

Numerous other changes have been made to the reviews of both the PM and ozone NAAQS. Several EPA staff stand-alone documents were deleted from the review process, including second review drafts of science and policy assessments, and multiple risk and exposure assessment documents. Risk assessment content was subsumed into the draft policy assessments, which underwent only one external review instead of the customary multiple reviews typically needed for complex assessments. This is especially problematic for assessments, such as for PM, that are based on extensive new literature since the last review, and for cases, such as for both PM and ozone, for which new risk assessments have been prepared. Reduction in the number of externally reviewed documents limited scientific review and reduced opportunity for public comment. CASAC and external commenters had asked for, but EPA did not provide, second review drafts of the science and policy assessments. Science and policy assessments were reviewed concurrently, contrary to prior practice to establish scientific criteria before undertaking the policy assessment.

Members of the dismissed CASAC PM Review Panel formed the nongovernmental Independent Particulate Matter Review Panel (IPMRP). The IPMRP elected to continue its work. During a two-day meeting in 2019, the IPMRP deliberated on the strengths and limitations of available scientific evidence. The IPMRP reported its findings to the Administrator in October 2019. The panel published a summary of its key findings in the New England Journal of Medicine in August 2020.

The IPMRP unequivocally and unanimously found that the current PM$_{2.5}$ standards do not adequately protect public health. This conclusion is based on scientific evidence from epidemiologic, controlled human, and animal toxicological studies. The IPMRP found coherent evidence from these multiple scientific disciplines consistent with a causal, biologically plausible relationship with adverse effects at ambient concentrations below the current standards. The epidemiologic evidence is robust across diverse study designs in different populations and locations using a variety of statistical approaches. New studies considering large populations report effects below the current annual standard. The inclusion of large populations is made possible by new air quality modeling tools. The IPMRP found no evidence of an ambient concentration threshold for health effects at the lowest observed levels for either annual or 24-hr exposures. An annual standard in the range of 10 µg/m$^3$ to 8 µg/m$^3$ (compared to the current 12 µg/m$^3$ standard) would protect the general public and at-risk groups. The IPMRP advised the Administrator that at-risk populations and environmental justice need to be considered in choosing a margin of safety. The policy assessment of the EPA staff also favored a more stringent annual PM$_{2.5}$ standard.

The IPMRP found that “arguments in favor of retaining the current standard are specious.” Both CASAC and the Administrator over-emphasize uncertainties in individual pieces of evidence without taking into account robust findings based on multiple studies across multiple lines of evidence. The Administrator pointed to a CASAC statement that the current review merely confirms what was assumed in the prior review. However, the now-available evidence supports lower ranges. The Administrator states that there is lack of “experimental” evidence at the current standard. With regard to toxicological studies based on animal bioassays, the number of animals needed to observe adverse effects at the level of current or alternative standards would be prohibitively high. Moreover, the Administrator has directed that EPA “move away from animal testing.” Thus, it would
appear that EPA is not committed to developing the toxicological data that the Administrator implies are lacking.

Controlled human studies for PM$_{2.5}$ have typically been sub-daily, not for the 24-hr and annual averaging times of the standards, and only for relatively healthy subjects. It would not be ethical to subject at-risk persons to prolonged PM$_{2.5}$ exposure in controlled studies. Both CASAC and the Administrator are imposing a burden of scientific proof well beyond that required by statute, which requires EPA to account not just for known but also anticipated effects. An appropriately constituted review panel is needed to synthesize evidence in arriving at judgments regarding anticipated effects. In addition, the standards should protect not just the general public, but also populations at increased risk of harm because of factors that include proximity to sources, age, and disease status.

With regard to the ozone standard, both the EPA staff, in its policy assessment,\textsuperscript{18} and the CASAC,\textsuperscript{19} have recommended retaining the current standards. Controlled human studies are typically the key foundation of the scientific assessment of adverse effects. Yet, such studies cannot be done on many at-risk subpopulations, such as severely asthmatic subjects. Thus, there is absence of direct evidence for many at-risk groups. The EPA staff assessment addressed airflow limitation from ozone-induced asthma exacerbation. However, CASAC acknowledges that asthma has “important features beyond airflow limitation,” that “key features of asthma pathophysiology can be affected by exposure to ozone,” and that the scientific evidence is based almost exclusively on healthy adults. Thus, whether the current standard is “requisite” to protect public health, as required by the Clean Air Act, is not entirely clear in the absence of more thorough deliberation and inference regarding points raised by CASAC. Such deliberations have historically been made by CASAC in conjunction with review panels that have the expertise to address such matters thoroughly. CASAC and the Administrator did not explicitly consider whether levels lower than the current standard would provide additional margin of safety, particularly for at-risk populations.\textsuperscript{20}

In the last ozone review, there were multiple experts on the CASAC Ozone Review Panel for effects on plants. In 2015, EPA set a secondary ozone standard that was contrary to CASAC’s advice at that time. In 2019, the U.S. Court of Appeals remanded the secondary standard to EPA for further explanation.\textsuperscript{21} The salient end points for the secondary standard are foliar injury, relative biomass loss, and crop yield loss. In the current review, both EPA staff and CASAC recommend retaining the current secondary standard.\textsuperscript{18,19} However, in the current review, CASAC lacked expertise to provide input on these endpoints. Thus, there has not been an adequate CASAC review of the scientific criteria, as required by the Clean Air Act.

Ad hoc changes have undermined the quality, credibility, and integrity of the NAAQS scientific review process. In the
past, the courts have typically deferred to the scientific advice of CASAC except when EPA has explained deviations from such advice to the courts' satisfaction. It is a near certainty that EPA will be sued upon promulgation of final decisions from the current review cycles for the PM and Ozone NAAQS. Will the courts defer to a CASAC that has been deprived of an appropriately constituted review panel? Will the courts consider that a particulate matter panel dismissed by the EPA arrived at very different scientific conclusions than the reconstituted CASAC? Only time will tell.

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**References**


H. Christopher Frey is the Glenn E. Futrell Distinguished University Professor at North Carolina State University. He was chair of the U.S. Environmental Protection Agency’s (EPA) Clean Air Scientific Advisory Committee (CASAC) from 2012 to 2015, during which time he chaired the CASAC Ozone Review Panel. He was a member of the CASAC Particulate Matter Review Panel from 2015 to 2018. He chaired the Independent Particulate Matter Review Panel in 2019. E-mail: frey@ncsu.edu.
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 (PM₁₀ and PM₂.₅), ground-level ozone (O₃), lead (Pb), nitrogen dioxide (NO₂), and sulfur dioxide (SO₂)—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 SO₂ from emissions and also reduce emissions of other pollutants.⁷ These emissions reductions contribute

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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 precursor emissions have declined 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.”⁻³

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, NO₂, O₃, and SO₂. Fine and coarse particulate matter (PM₁₀ and PM₂.₅) 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).

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

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

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trillion British thermal units (Btu) in 1970 to 97.6 thousand trillion Btu in 2018; and

• Vehicle miles traveled were up 195%, from approximately 1.1 trillion miles in 1970 to nearly 3.26 trillion miles in 2018.

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 CAAs 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.

Karen Hays is the Chief of the Air Protection Branch for the Georgia Environmental Protection Division and the 2020 President of the Association of Air Pollution Control Agencies (AAPCA). Robert Hodanbosi is the Chief of the Division of Air Pollution Control for the Ohio Environmental Protection Agency and is the incoming 2021 AAPCA President. Jason Sloan is the Executive Director for AAPCA. E-mail: jsloan@csg.org

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.

References
1. 42 U.S. Code §7401(a)(3) – “that air pollution prevention (that is, the reduction or elimination, through any measures, of the amount of pollutants produced or created at the source) and air pollution control at its source is the primary responsibility of States and local governments.”
2. EPA chart of the primary and secondary NAAQS by pollutant: https://www.epa.gov/criteria-air-pollutants/naaqs-table.
3. EPA defines the NEI as: “a comprehensive and detailed estimate of air emissions of criteria pollutants, criteria precursors, and hazardous air pollutants from air emissions sources … released every three years based primarily upon data provided [to the Emissions Inventory System] by State, Local, and Tribal air agencies for sources in their jurisdictions and supplemented by data developed by the US EPA.”
6. Greenbaum, D. The Clean Air Act: Substantial Success and the Challenges Ahead; Annals of the American Thoracic Society, October 3, 2017; https://nepis.epa.gov/Exe/ZyNET.exe/P1007IQM.txt?ZyActionD=ZyDocument&Client=EPA&Index=2000%20Thru%202005&Docs=&Query=&Time=&EndTime=&&SearchMethod=1&TocRestrict=n&Toc=&TocEntry= &QField=QFieldYear&QFieldMonth=QFieldDay&UseQFieldId=1&SearchMethod=1&ToRestrict=n&Toc=With&ToEntry= QFieldOp=0&ExtQFieldOp=0&Xm1Query= &File=Dr3A%5CZYFILES%5CINDEX%20DATA%5C00THRU05%5CTXT%5C00000024%5CP1007IQM.txt&User=ANONYMOUS&Password=anonymous&SortMethod=hr&MaximumDocuments=1&FuzzyDegree=0&ImageQuality=75gB8/75gB8/x150y150g16/i425&Display=hp%20&SearchBack=ZyAction&Back=ZyAction&SearchDesc=Result%20page&MaximumPages=1&Entry=November%202000, and EPA Clean Air Technology Center Products (https://www.epa.gov/catc/clean-air-technology-center-products).

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Beneficial Use of Residues and Byproducts from the Forest-Based Supply Chain

A look at the productive utilization of residues and processing byproducts of harvested wood, which is crucial for improving both the economic and environmental performances of the forest-based supply chain.

A “carbon pool” refers to a reservoir of carbon, which has the capacity to accumulate or release carbon over time. Forests are a substantial carbon pool that could potentially contribute to the mitigation of climate change impacts globally. Sustainably managed forests provide wood as a renewable feedstock for a versatile range of applications, while maintaining the capacity to continuously sequester and store carbon from the atmosphere. After wood is harvested from the forest, the carbon storage capacity is further extended when the harvested wood is used to produce long-lived products, such as timber frames in buildings.

Forest harvest residues refer to the parts of the felled trees that are normally not removed from the forest during harvesting. The composition of forest harvest residues varies, dependent upon the intended uses of the harvested wood. When harvesting industrial roundwood (large logs) as shown in Figure 1, the tree stems (trunks) are typically removed from the forest after cutting, leaving the upper logs, branches, and different cut-offs on the floor of the forest as the residue. In other cases, the smaller branches, cut-offs, and bark are also collected and removed from the forest to produce fuelwood, briquettes, pellets, or wood chips. Wood
processing residues refer to the sawdust, wood slabs, and chips generated during the subsequent processing of the harvested wood into products such as lumber or paper.

Cellulose, lignin, and hemi-cellulose are the main structural components of tree wood. When harvested wood is used to produce paper, the wood pulping process at the paper mill separates the cellulose fiber that is then used to manufacture the paper. Also separated are the two major byproducts, lignin and hemicellulose, and these byproducts have generated extensive interest stemming from their valorization.

A proper management of forest residues and the processing byproducts is crucial for improving both the economic and environmental performances of the forest-based supply chain. Currently, common management strategies are oriented toward energy generation, including producing fuel pellets and lignocellulosic ethanol from residues. Fuel pellets, as shown in Figure 2, are favored in many energy policies as an alternative to fossil fuels due to the renewable nature of the carbon content. Fuel pellets have become an important energy source globally. For example, in 2018, the global consumption of fuel pellets was more than 52 million tons, with the European Union (EU) accounting for more than half of the total consumption.

The production pathways for bioethanol from crops and forest residues are different. For crop-based bioethanol, the steps include saccharification of starch into glucose, which is subsequently converted into ethanol through fermentation. For lignocellulosic feedstocks such as forest residues, an additional step is required to extract the lignin (i.e., via the organosolv process) before the cellulose could be further saccharified into glucose for fermentation. From the standpoint of climate change impacts, bioethanol derived from lignocellulosic feedstocks is considered a preferred alternative to starch/sugar-based bioethanol that is commonly produced from starchy crops (e.g., corn and sugar cane). The life-cycle climate change impacts for lignocellulosic bioethanol over crop-derived bioethanol are lower by approximately 68%.

During the pretreatment of lignocellulosic feedstock for the production of bioethanol, lignin is first separated and typically combusted on-site as a fuel to generate electricity and heat for the bioethanol process. This reduces the demand for external energy sources (e.g., nature gas or electricity from grid) at the bioethanol refinery.

Bioethanol, both the crop-derived and lignocellulosic types, is used as a renewable fuel for motor vehicles. Bioethanol is typically a “blended fuel” component; that is, the bioethanol is typically blended 10–15% with gasoline to produce “E10” and “E15” blended fuel. Production costs are inherently high for emerging technologies, including lignocellulosic bioethanol. Hence, strong, and consistent policy incentives (e.g., subsidies, mandates) are crucial for successful commercial evolution. Multiple policies have been implemented to support the production and use of renewable energy and fuels, including the Renewable Fuel Standard (RFS) in the United States and Renewable Energy Directive (RED) in EU. However, the number of commercial-scale producers of lignocellulosic bioethanol is still limited, mainly due to the high operational cost associated with
specifically the pretreatment step (i.e., lignin removal). The RFS, when first implemented, proposed an ambitious mandate for promoting cellulosic biofuels in the US. However, the continuous reductions in the mandated RFS target (owing largely to pressure from conventional fuel producers) over the past few years have discouraged investment, which eventually led to a pause in production of lignocellulosic bioethanol by POET-DSM, one of the largest commercial producers of lignocellulosic ethanol in the world.

Alternative Strategies
In addition to the bioethanol used in blended transportation fuels, forest harvest and processing residues can also serve as the feedstock for producing drop-in biofuels, which are renewable biofuels that are functionally equivalent to petroleum fuels (e.g., gasoline, jet-fuel, and diesel), and thus, can completely replace (i.e., 1:1 replacement ratio) conventional petroleum fuel. This also represents another opportunity to decarbonize the transportation fuel market, given their compatibility with the existing fuel distribution infrastructure and vehicle powertrains.

One major pretreatment technology is fast pyrolysis in which forest residues are heated to a high temperature (e.g., 500 °C) under a rapid heating rate (e.g., 1,000 °C/sec) in the absence of oxygen. The resulting intermediate product, bio-oil, could be further upgraded to produce drop-in biofuel via hydrotreating. The world’s largest commercial fast pyrolysis plant, the Ensyn plant near Ottawa, Canada, shown in Figure 3, currently produces 3 million gallons of bio-oils per year.

Another pretreatment technology currently under development is hydrothermal liquefaction (HTL), which decomposes forest residues in water with moderate temperature (e.g., 280–370 °C) and pressure (e.g., 10–25 MPa). The resulting bio-oil is subsequently upgraded by hydrotreating (i.e., a reaction with hydrogen to remove oxygen and other heteroatoms), which produces various drop-in biofuels that are functionally equivalent to petroleum fuels. Pacific Northwest National Laboratory (PNNL) hosts an engineering-scale HTL system, which has a feed flow rate of 12 liters per hour and a bio-oil yield of 32%. Compared to the pyrolysis process, HTL avoids the drying step and the resulting bio-oil contains less oxygen and moisture, hence resulting in a higher energy content.

Both pretreatment technologies could be integrated into the conventional supply chain of petroleum refining, where the bio-oils could be co-processed with petroleum-based streams in the hydrotreaters. Consequently, co-processing bio-oils with petroleum fuel production could reduce the climate change impacts of resulting fuels. In addition, because the co-processing step utilizes the existing unit with minor modifications (e.g., hydrotreater in this case), within the petroleum refineries, the capital cost for co-processing fuel production can be greatly reduced, which addresses one of the critical challenges that hamper the scaling up of biofuel industries in general.

As mentioned earlier, lignin is typically used as a fuel for generating energy on-site through combustion. Although this management strategy offsets external energy demand, the monetary gain from lignin utilization as fuel is small in this case, due to the currently low market prices of electricity and natural gas. As a result, research and development efforts have been invested in repurposing lignin as a sustainable feedstock for producing high-value biomaterials. One promising example is to convert the lignin into lignin-containing cellulose nanocrystals (LCNCs), which could potentially become a higher value-added use with reduced climate change impacts compared to combustion of lignin for energy.

One of the key technical barriers hindering the scaling up of lignocellulosic bioethanol production is the high energy consumption required at the pretreatment stage to separate lignin from the wood feedstock. To minimize the energy consumption in the lignin separation step, recent studies have identified an alternative lignin-separation approach that uses a mild solvent (eutectic type), such as lactic acid, to dissolve the lignin.

Hemicellulose is another versatile wood-processing byproduct that could serve as a feedstock for manufacturing many value-added biomaterials, such as food additives (e.g., dietary fiber),
coating gels, and adhesives.  

Apart from using lignin as a renewable fuel replacement for fossil fuel, most of the relevant technologies for lignin and hemicellulose valorization are still at the laboratory/bench-scale of operation. Accordingly, their climate change benefits cannot be accurately evaluated until sufficient production data have been accrued.

A Systems Approach
Many of the abovementioned strategies, when operated independently, may face different challenges, such as limited feedstock supply, energy-intensive pretreatment, and costly treatment of byproducts. Many of these challenges, however, could be mitigated when a systems approach is taken to integrate multiple facilities through the concept of industry symbiosis (IS). IS refers to the exchange of products, materials, waste, and/or energy among multiple industrial facilities to create synergic opportunities for reducing costs, improving resource use efficiency, and mitigating environmental impacts.

A general illustration of an industry symbiosis system involving multiple forest-based products is shown in Figure 4. It is noteworthy that the system includes the forest management, which involves the consideration of carbon sink and emissions from maintenance and harvesting. The IS system could potentially reduce the negative impact on forest management, by enhancing the reuse and recycling of wood products and thus decreasing the demand for tree harvesting.

A specific example of IS in the forestry industry is located in Kouvola, Finland, where the IS system has evolved physically around a pulp and paper mill with the involvement of three chemical plants, one power plant, and one municipal sewage plant. The power plant utilizes the wood residue and sludge from the paper mill to generate heat and electricity to support the operation of the mill and the town. The chemical plants supply chemicals to the paper mill while utilizing the carbon dioxide and purified water from the mill operation. The municipal sewage plant conveys its sewage sludge to the on-site wastewater treatment system of the mill for co-management with the mill’s own wastewater sludge. The mill’s

A proper management of forest residues and the processing byproducts is crucial for improving both the economic and environmental performances of the forest-based supply chain.
onsite wastewater treatment system also manages the wastewater from the power plant and chemical plants. Compared with conventional, stand-alone production systems, the IS system showed 5–20% reduction in most environmental impact categories. For example, the comparative results for climate change impacts, precipitation acidification potential, and particulate matter emissions were reduced by 12%, 5%, and 5%, respectively in IS system. In addition, fossil energy use was reduced by up to 28%.

Another example is the planning of an IS system in Central Germany that would produce high-value-added bioproducts such as polylactic acid (PLA) and cross-laminated timber (CLT). The proposed scenario involves the cascade use of wood-based feedstocks for producing chemicals, engineered wood products, and energy production. The infrastructure for heat, steam, and electricity is shared among different facilities. Compared with fossil-based, stand-alone productions, the IS system can demonstrate 25–130% reductions in most of the environmental impact categories; for example, the climate change impacts and eco-toxicity potentials could be reduced by 75–80%.

Summary
Sustainably managed forests provide harvested wood, one of the most used commodities in the world, while maintaining the capacity to continuously sequester and store carbon from the atmosphere. When roundwood (logs) are harvested from a forest, the branches and treetops are typically left behind as “forest residue.” Subsequently, when the harvested wood is processed into a product, for example, lumber or paper, the resulting residues are referred to as “processing residues” or “processing byproducts.” At a lumber mill, for example, slab wood and bark are processing residues. At a paper mill, the processing byproducts are lignin and hemicellulose. This article has focused on the productive utilization of residues and processing byproducts, as this is crucial for improving both the economic and environmental performances of the forest-based supply chain.

The traditional utilization strategies convert residues and processing byproducts into bioenergy (e.g., wood pellets) and biofuels (e.g., lignocellulosic bioethanol), which could lead to a significant reduction of climate change impacts. Although a mature market has been established for wood pellets as fuel, the development of the lignocellulosic bioethanol market is largely stagnant due to the lack of a consistent policy support. Recent development has also focused on higher value-added applications, such as converting the processing byproduct, lignin, into lignin-containing nanocrystals (LCNCs). Given the nascent status of these technologies, an accurate analysis of the corresponding climate change impacts remains challenging until data from commercial scale operations is available. Industrial symbiosis (IS) has the potential to overcome many of the challenges associated with the forest-based supply chain and, hence, could further improve the viability of beneficial uses of forest residues and processing byproducts.

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After what can only be described as one of the most challenging years in history, take a moment to consider the below five steps to prepare for the new year ahead.

2020 seemed to be full of promise. How could you not be optimistic about a year that shared the number associated with perfect vision? But things changed rapidly as our understanding of COVID-19 developed. Instead of the clarity that the new year promised, uncertainty prevailed as governments around the globe took steps to contain the pandemic. Many of us in the environment, health, and safety (EH&S) profession have been classified as “essential workers.” While we may have continued to work, the nature of our work has certainly changed. We have faced travel challenges, disruptions in supply chains that have affected how we deliver our services and products, and we have negotiated new ways to manage our lives and personal and professional relationships.

While we might like to forget the problems of 2020, that would be a mistake. Instead, we need to sort through the challenges the year presented and take time to record accomplishments. As the year ends, this is an excellent time to reflect on the challenges we have faced, anticipate what those challenges might mean for our future, and take five key steps to prepare for the coming year.

1. Review our projects and prepare or update project summaries. We have addressed the importance of creating project summaries in past columns. In short, we want to make sure we capture what we accomplished, the challenges we faced, the benefits we produced, and how we managed change. Even a cancelled or postponed project offers insights that we can document in project summaries. Preparing carefully crafted project summaries is an excellent way to lay the foundation for a new proposal or prepare for a performance review, a job interview, or a new project.
2. **Review and update our base resume or curriculum vitae.** It is easier to prepare a targeted resume for a specific opportunity or position when there is plenty of material to use. Accordingly, a detailed resume, coupled with project summaries, provides the foundation for development of a targeted resume that illustrates the challenges we have overcome, the results we have achieved, and the benefits we have produced.

3. **Manage our social media presence.** Equipped with updated project summaries and resumes, we can tackle updating our LinkedIn profile and profiles that we may maintain with trade associations and professional societies. This is also a good time to review our connections and news feeds and make appropriate adjustments. It is also a good time to consider how we can improve our visibility in the EH&S community by sharing information in blog posts and at virtual conferences. If you have been troubled about presenting before a live audience, virtual formats can provide you a less intimidating opportunity to share your knowledge.

4. **Review continuing education or professional development requirements.** As EH&S professionals, we are subject to a range of credentialing requirements. Although renewal cycles can take place any time during the year, the end of the year provides an excellent opportunity to review completed continuing education and develop a plan for addressing any gaps that would jeopardize our credentials. Further, this is a good time to explore adding credentials, particularly credentials that share professional development requirements with credentials we may hold.

5. **Plan to connect with colleagues, trade organizations, and professional societies.** For most of us, the pace slows toward the end of the year, providing us the opportunity to reconnect in authentic terms with colleagues and to consider how we participated in trade organizations and professional society meetings in a virtual world. Maintaining our connections with colleagues, trade organizations, and professional societies, while exploring potential new relationships, allows us to remain abreast of developments in our field, adapt as market conditions change, and share our perspective for the EH&S market.

For many of us, 2020 ranked as one of the most challenging years of our careers. Let’s capitalize on those challenges by remembering what we have learned, documenting it, sharing it, and preparing for growth. These five simple steps will provide the clarity and confidence we need to navigate what is likely to remain a challenging world through 2021. Let’s make 2020 a year to remember.

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**References**


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**In Next Month’s Issue…**

**Community-Based Air Quality Assessment**

Community-based air quality assessment includes monitoring, exposure assessments, and planning at community levels. Air quality monitored at the community level empowers local communities in decision-making processes to help reduce emissions, reduce exposure, and develop local mitigation. The January issue explores the air quality assessment work done at community levels.

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David L. Elam, Jr., CIH, CMQ/OE, PMP, Vice President and Project Director, TRC. E-mail: delam@trcsolutions.com.
We conclude our year of honoring A&WMA’s Critical Review for Waste Electronic and Electrical Equipment,” by Dr. Timothy G. Townsend. One of the great technological advancements of the 20th century was the worldwide development of information access and communications through electronic technology. With the introduction of new technologies inevitably came the issue of the management of discarded hardware. The growth of waste and recyclable material from the electronics and electricity age has been remarkable. The contemporary electronics and electrical waste (e-waste) management scope includes televisions, personal computers, printers, computer mice, keyboards, and cell phones.

By the mid-2000s, the tonnage of e-waste in the United States had reached approximately 2 million tons, of which approximately 1.5 million tons were incinerated or moved to landfills. The remainder was recycled. Although this total represented only 1% of the total U.S. solid waste stream, it nevertheless was an important component of potentially hazardous waste material entering the environment. The rising concern and interest in the state of the art of reuse, recycling, and disposal of e-wastes motivated Dr. Timothy Townsend’s preparation of the 2011 Critical Review. In this narrative, Dr. Townsend noted that electronic equipment generally has a relatively short life before becoming outdated with the rapid evolution of technology. Thus, his review covered the range of challenges posed by the logistical, environmental, and societal challenges of managing discarded equipment that has reached its end of life.

The review covered the technologies for secondary use of older equipment, the approaches to recycling valuable metals and plastics from equipment before disposal, and the ultimate disposal of remaining material through landfills and incineration. The review also discussed the hazards to human and ecosystem health associated with disposal processes.

The review’s author, Timothy G. Townsend, Ph.D., P.E., is a professor of environmental engineering in the Department of Environmental Engineering Sciences at the University of Florida in Gainesville, FL. His research interests include landfill design and operation, bioreactor landfill technology, construction, and demolition debris management, discarded electronic devices, treated wood disposal, leaching characterization of solid wastes, and special waste management. He is a licensed professional engineer in Florida and a current Associate Editor of JA&WMA.
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