Ozone-Depleting Substances
New Regulations, New Challenges
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Ozone-Depleting Substances
New Regulations, New Challenges
by Ali Farnoud

This month, EM considers the changes in regulations impacting equipment containing ozone-depleting substances or substitutes. The recently implemented U.S. Environmental Protection Agency regulations were written with the objective of reducing emissions of both ozone-depleting substances and greenhouse gases. The regulations are far-reaching and impact not only industrial, commercial, and residential sources, but also schools, hospitals, and grocery stores.

Cooperation and Progress in Kigali
by Janet G. McCabe

The Future of EPA’s ‘Covert’ Regulation of GHGs
by William H. Haak

Refrigerant Phasedown, Alternatives, and Factors Driving the Future of the Refrigerant Market
by Elizabeth Ortlieb, Ted Atwood, Brian Noel, and Kirk Lowery

Features

Highlights from the Coordinating Research Council’s 27th Real-World Emissions Workshop

Columns

EPA Research Highlights:
Sustainable Materials Management at Your Fingertips
by Aaron Ferster and Michael Nye
A look at the Materials Management Wizard—MWiz—which offers streamlined access to the breadth of EPA’s tools and resources on sustainable materials management.

Departments

Message from the President: Why the Association?
by Scott Freeburn

In Memoriam: Barbara K. Zielinska (1946–2017)

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If our Sections and Chapters are the fundamental service deliverers of the Association, and they do a good job of addressing local needs, what greater value comes from associating on a national or international level? Those of you who have spent more than a little time in the Association will have your own answers to this question, but here are my thoughts.

Federalism
Okay, so this may not be the way most members think of the Association. However, over the past two decades, A&WMA has encouraged its Sections and Chapters to independently incorporate so that, among other things, decisions at one location, are not legally connected to or binding on other elements of the Association. The benefit of this type of organization is that a lot of independent thought goes on every day trying to solve local problems. Since our various parts share similar challenges, the good solutions can be easily and more broadly applied. The Association makes these connections possible through the member directory and other published information. The key is knowing about these efforts.

Doing Big Things
Good ideas abound within the Association. Upon occasion, what is identified as desirable programming is, practically speaking, beyond the resources and ability of a local group to implement. There are many reasons why this might be the case: limited time availability, a lack of topical expertise, and limited physical and personnel resources. Combining resources is why most organizations with a mission are formed. A&WMA is no different. These good ideas, where a larger effort means larger benefits, should be implemented and it is the organizational resources of the Association—staff time, experience, skills, and networks—that can make them happen. Without the Association’s resources, these types of programs would be rare or perhaps be done by another group.

The Annual Conference and Specialty Conferences with national and international reach occur because the Association’s headquarter staff in Pittsburgh, with volunteer help, coordinates them. Many years ago, the Annual Conference was locally produced by the volunteer section, but the level of effort and quality demands outgrew local resources. It is still a challenge for a Section to host the Annual Conference, even at the scaled down volunteer requirements of today’s implementation.

Support and Direction
Few organizations can function without a managed online presence to inform the public, support efficient internal communications, transact business with members and suppliers, and produce goods and services. There is no element of Association activities that is not connected through the website and the useful management software applications used there. A central dedicated effort to keep such fundamental infrastructure working, useful for all members, is as basic to our success as breathing. Along with the online presence, accounting, document production, and management systems are fundamental to our mission and require similar care and feeding. A lean, efficient organization to do these things is a far more practical solution than a far-flung group of volunteer—no matter how dedicated.

The Board of Directors continually looks at how the Association’s business is conducted, especially what is or must be done in Pittsburgh. We seek to know what our members consider priorities and the best way to deliver them. The current crop of products is leaner than it used to be and so is the staff that produces it. It is our current financial reality. New ideas requiring more staff involvement must be self-supporting financially, so that there are the resources to augment the Association staff for the new work. If that seems like a high hurdle, just ask yourself, “How else will it get done?”

Additional information regarding the benefits of the Association can be found in our publication, entitled “38 Reasons to Become an A&WMA Member” (https://www.awma.org/files/Benefits%20Guide%202004-16.pdf). I recommend you read it for your edification and for the time when a colleague asks you why you are a member of A&WMA.

Philosophy
Here is a final question: If it weren’t part of the Association, what would your Section or Chapter be? My guess is that it is unlikely to remain as it is now. Beyond the functional benefits we receive as being part of the Association, A&WMA also stands for something that our current Sections and Chapter reflect. We are the open forum for environmental discussions based in a self-enforced diversity of membership, with all that implies about a diversity of opinion, lack of bias as an organization, being nominally apolitical, and without financial obligations to anyone. This formula has been valued for more than 110 years, and it is not yet out of style. We maintain a commitment to high standards, expect technical and scientific excellence, and produce high-quality products. We are open to anyone that holds similar desires and interests.

I am proud to be part of an Association like that.
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We are grateful to our many organizational members for their support of membership and A&WMA conferences, events, and activities this past year as we continue to strive to provide optimum products and services to meet the needs of our customers.

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Ozone-Depleting Substances
New Regulations, New Challenges

A look at the changes in regulations impacting equipment containing ozone depleting substances or substitutes.
This is likely what many thought when the U.S. Environmental Protection Agency’s (EPA) updated Significant New Alternatives Policy (SNAP) program was promulgated. The original program was designed to reduce the usage of certain refrigerants with high ozone depletion potential (ODP) to help repair the damaged ozone layer. Limiting production and using market forces to substantially reduce these refrigerants was part of the Montreal Protocol that was ratified as part of the U.S. Clean Air Act (CAA) as early as late 1990s.

EM focuses on the SNAP program, recent changes, and its effects, with three full-length feature articles that follow.

In the first article, Janet McCabe describes the connection between the Montreal Protocol and the Kigali Amendment. She discusses the history of the Montreal Protocol, efforts already underway by a few large corporations to reduce the global warming potential (GWP) of the refrigerants, and the mechanism eventually adopted to reduce the production of hydrofluorocarbons (HFCs) as part of the Kigali Amendment.

The SNAP program proved to be an extremely effective yet costly policy. Many facilities across the country were forced to prepare a meticulous plan to replace the ozone-depleting substances (ODS) with substitutes. The massive effort to remove ODS and the additional requirements to standardize the leak repair and maintenance of the refrigerant equipment resulted in significant improvement of the ozone layer.1

The recent update to the SNAP program, however, is different from the previous versions in that the driver behind the program is not protecting the stratospheric ozone, but curbing climate change. The Kigali Amendment, which was signed in October 2016, shifts the direction of the Montreal Protocol toward climate change. Similarly, the new SNAP program promulgated in Section 612 of the CAA, as well as the less costly yet impactful repair and maintenance programs in Section 608, both list President Obama’s Climate Action Plan and not stratospheric ozone protection rules. This issue of EM covers these topics in detail:

Next, William Haak talks about EPA’s authority to use Title VI of the CAA (stratospheric ozone) for regulating refrigerants. He also discusses the recent legal challenges facing the SNAP program (the Mexichem Appeal), and other potential challenges due to the recent change in U.S. administration.

Lastly, Elizabeth Ortlieb and co-authors focus on the refrigerant market and the factors impacting its future. They discuss the phaseout schedule, the additional market forces, and the future cost of purchasing refrigerants.

I thank all of the authors for their contribution to this issue of EM. I also would like recognize the help of Susan Wierman and Brian Noel whose help was instrumental with article solicitation. It was certainly a pleasure working with all of the contributors and coordinating this issue.

All Farnoud works with Ramboll Environ as a Managing Consultant in Air Quality Practice. He is also a member of EM’s Editorial Advisory Committee.

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A look at the Kigali Amendment to the Montreal Protocol, a tremendous step forward in the globe’s efforts to mitigate the widely predicted impacts of climate change throughout the world.
The phrase “May you live in interesting times” has often been attributed to an ancient Chinese curse. Whatever the origin of the phrase,1 we certainly are living in interesting times when it comes to climate change. The body of evidence and the scientific consensus around that body of evidence continues to support the conclusion that the earth’s climate is changing in ways that will cause significant disruption to life on earth, with numerous adverse consequences. In 2015, all countries on earth except for Syria and Nicaragua2 joined together in a commitment to reducing emissions of greenhouse gases, memorialized in the Paris Climate Accord.3 With their reduction goals, the global community was hoping to restrict temperature increases by 2100 to a maximum of two degrees Celsius more than before the global industrial age—and aim for 1.5 °C, if possible.

One category of pollutants that contribute significantly to climate change and that can be a significant part of the solution are hydrofluorocarbons (HFCs)—man-made chemicals that are primarily used in air conditioning, refrigeration, and foam insulation, and are powerful greenhouse gases that can be thousands of times more potent than carbon dioxide in contributing to climate change. In the fall of 2106, countries across the globe came together again to take an important step forward on HFCs.

The Montreal Protocol
In the 1970s and 1980s, scientists around the world were becoming increasingly concerned about the thinning of the protective layer of ozone located in the stratosphere that absorbs radiation from the sun. This ozone blanket protects our planet and the people on it from those aspects of ultra violet light that can cause a variety of very serious health effects including skin cancers,4 cataracts, and harm to some crops and marine life. Ozone in the atmosphere naturally ebbs and flows, but scientists were seeing an alarming decline that exceeded what would be expected through natural fluctuations. These findings prompted 197 countries to join together in the Montreal Protocol on Substances that Deplete the Ozone Layer.5

The Montreal Protocol was the first treaty in the history of the United Nations to achieve universal ratification and it has proven to be successful at stopping and reversing the environmental damage that was happening at a global scale. Actions taken over the past 30 years under the Montreal Protocol and its subsequent amendments have resulted in a 99-percent decrease in ozone-depleting substances (ODS) that harm the ozone layer, and the atmosphere is well on the way to recovery by the middle of this century.6 Because many of the harmful ODS also have higher global warming potential relative to carbon dioxide, reductions in ODS have also been very beneficial for efforts to address climate change. The success of the Montreal Protocol is proof that countries can come together to address and, importantly, solve a critical environmental challenge that has the potential for substantial global public health impacts.

The Kigali Amendment
What’s the secret to this success? Some of the elements that have made the Montreal Protocol successful include a legal framework that takes the long view and has enough flexibility...
Work to address this situation through an amendment to the Montreal Protocol had been underway since 2009. A series of proposals, mostly by the United States, Canada, Mexico, and Micronesia, kept the Parties at the table and working on fundamental issues, including:

1. the level of ambition (the ultimate amount of reductions and the timetable over which phasedown would occur);
2. a flexible approach that would recognize the relative capacities and needs of developed and still developing countries;
3. the amount of financial assistance that would be provided; and
4. designs that would encourage early action and increased ambition.

These features were essential to the Parties reaching an agreement, on October 15, 2016, to make a further amendment to the Montreal Protocol, known as the Kigali Amendment.

The success of the Montreal Protocol is proof that countries can come together to address and solve a critical environmental challenge.

Styrofoam), and fire suppression. Over the decades that the Montreal Protocol has been in effect and working, many of the most damaging chemicals have been phased out completely and others have been reduced substantially. One of the key ways these advances have been achieved is through the development of substitute chemicals that are less damaging to the ozone layer. Many chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) have given way and been replaced by very benign technologies (e.g., water-based). But a generation of substitute chemicals known as HFCs, or hydrofluorocarbons, has also developed. It turns out that these chemicals, while gentler on the ozone layer, are just the opposite with respect to climate change, with global warming potential (GWP) ranging as high as 14,800 compared to carbon dioxide.7

As needs for refrigeration and air conditioning increase across the globe, especially in developing countries where governments are reasonably committed to improving the standard of living of their people, emissions of HFCs are projected to increase by as much as 20 times in the coming decades. According to the United Nations Environment Programme (UNEP), consumption of HFCs is expected to grow at a rate of about 10 percent annually.8 If the current mix of HFCs is unchanged, increasing demand could result in HFC emissions of up to 8.8 gigatons of carbon dioxide equivalent per year by 2050.9 That level of growth will wipe out much of the progress made by eliminating or reducing CFCs and HCFCs.

Over this time period, companies in the United States and elsewhere made great technological strides and commitments to using lower GWP refrigerants in a variety of uses. In September 2014, 22 private-sector companies and organizations made commitments that would avoid the equivalent of 700 million metric tons of carbon dioxide emissions through 2025. For example, Coca-Cola announced a goal that 100 percent of its newly purchased cold drink equipment would be HFC-free. Carrier, a global manufacturer and distributor of high-technology heating, air conditioning, and refrigeration solutions, committed to pursue the commercialization of HFC-free refrigerants in road transportation refrigeration by 2020. Honeywell, a global technology and manufacturing company, committed to transition the majority of its high-GWP HFC production to new low-GWP production, reducing its annual production of high-GWP HFCs by nearly 50 percent on a carbon dioxide equivalent basis prior to 2020. Numerous companies and governments were investing millions of dollars in research and development during this time as well.10

These technological advances provided the underpinning for knowing that a significant phasedown of HFCs could be achieved. In October 2015, the Parties met in Dubai, with high hopes of reaching agreement. Time ran out, however, with significant differences still unresolved. The Parties did something that was both smart and reflected the confidence that an agreement would ultimately be reached using this Framework that had been so successful over the decades. They adopted the “Dubai Pathway,” in which they agreed to...
work together, within the Montreal Protocol, to approve an HFC amendment by first resolving challenges and generating solutions through smaller meetings of countries in 2016 that could problem-solve the remaining issues.\textsuperscript{12}

Patience, perseverance, creativity, and attention to the differing needs of countries resulted in a dramatic and much celebrated conclusion last fall.\textsuperscript{13} Under the amendment, the 197 partner countries committed to cut the production and consumption of HFCs by more than 80 percent by the late 2040s. The ambitious phasedown schedule will avoid more than 80 billion metric tons of carbon dioxide equivalent emissions by 2050—avoiding up to 0.5 °C warming by the end of the century—while continuing to protect the ozone layer. Under the amendment, developed countries will reduce HFC consumption beginning in 2019. Most developing countries will freeze consumption in 2024, with a small number of developing countries with unique circumstances freezing consumption in 2028. The plan also provides financing to certain countries, to help them transition to climate-friendly alternatives.\textsuperscript{14}

The elements of the agreement track the most significant issues raised by various countries: what are the relative expectations for developed countries and countries where basic human needs for refrigeration and air conditioning are still not met? What will countries do if substitutes are not available on the schedule or in the quantities that we currently anticipate? Or if they aren’t as effective as currently predicted? How much money will developed countries commit to help developing countries transition and on what timetable?

\textbf{Continued Success}

The Kigali Amendment is a tremendous step forward in the globe’s efforts to mitigate the widely predicted impacts of climate change throughout the world. It is proof that the Framework established in the Montreal Protocol so many years ago has stood the test of time. Features that have contributed to this success are how it smooths the transition to less damaging chemicals and aids compliance, built-in technology reviews that are transparent and open to all stakeholders, the ability to dial expectations relative countries’ situations, predictable deadlines with long lead times, and an amendment mechanism to assess and adjust ambition (either down or up). Add to the mix a well-seasoned organizational structure allowing countries and stakeholders to work together constructively and the result is good for the planet, good for the health and economic well-being of the American public, and good for American businesses.
A look at efforts by the U.S. Environmental Protection Agency (EPA) to regulate greenhouse gas (GHG) emissions under a statutory provision designed to address ozone-depleting substances.
The Future of EPA’s ‘Covert’ Regulation of GHGs by William H. Haak

The Intersection of GHG and ODS Regulations

The phaseout of ozone-depleting substances (ODS) by EPA under Title VI of the U.S. Clean Air Act (CAA) pursuant to the Montreal Protocol has been a 20-plus-year exercise in American businesses delivering global environmental benefits through technology forcing. The cost has taken the form of untold research and development dollars spent seeking acceptable alternatives to ODS. In addition, ODS phaseout and emerging alternatives have led to massive corporate capital investment into new facilities, new manufacturing equipment, and retrofits to existing facilities to accommodate non-ODS alternatives approved under EPA’s Significant New Alternatives Policy (SNAP) Program.

In September 2016, EPA issued a final rule under SNAP targeting hydrofluorocarbons (HFCs) and HFC-containing blends. These once acceptable ODS alternatives suddenly became unacceptable due to their global warming potential (GWP) and their resultant impact on climate change. Industry’s what amount to non-ODS-related reasons (i.e., the GWP of HFCs and their potential impact on climate change). EPA, in turn, defended its rulemaking by asserting that CAA Section 612 requires the agency to review ODS alternatives and, where an alternative presents a higher overall risk to human health and/or the environment, replace that alternative with a more acceptable option. The court issued its decision on August 8, 2017. The court’s opinion and its impact on EPA will be discussed below.

The Historic Regulation of ODS and Approved Alternatives under SNAP

The Montreal Protocol on Substances that Deplete the Ozone Layer was agreed to in September 1987 and entered into force on January 1, 1989. Designed to phaseout the production, use, and emission of ODS, the United States’ commitment to implementing the Montreal Protocol led to the creation of Title VI of the 1990 CAA Amendments. EPA regulations issued pursuant to Sections 601 through 607 of Title VI established the phaseout schedules for Class I and Class II ODS in accord-

Industry’s reception of the rule was neatly split. In opposition are producers of HFCs and HFC-containing blends who have been making and selling these previously EPA-approved ODS alternatives profitably for years. Joining EPA in support are chemical companies who developed several non-HFC ODS alternatives that are now christened as the new non-HFC ‘go-to’ alternatives under SNAP.

The U.S. Court of Appeals for the D.C. Circuit heard oral arguments on challenges to the SNAP final rule on February 17, 2017. Petitioners Mexichem, Arkema, Compsys, and other intervenors arguing against the rule allege that EPA overstepped its authority under Section 612 of the CAA and SNAP by revisiting previously approved ODS alternatives for dance with the requirements of the Montreal Protocol. Class I substances (primarily chlorofluorocarbons, or CFCs) have a higher ozone depletion potential and were phased-out first. Class II substances are hydrochlorofluorocarbons (HCFCs). HCFCs are being phased-out now—after having served for many years as interim alternatives for Class I ODS.

Under Section 612 of the CAA, the SNAP Program empowers EPA to identify acceptable alternatives to ODS and, thereafter, publish lists of acceptable and unacceptable substitutes by industry and end-use. “Unacceptable” substitutes include alternatives that EPA has determined “may present adverse effects to human health or the environment”. As these lists were developed through the 1990s, they were subsequently
relied-upon by industrial users and chemical industry producers of targeted ODS and acceptable alternatives—to inform both research and development investment into alternatives and capital investment into updating manufacturing capabilities to utilize the acceptable alternatives identified by EPA under SNAP. All told, the total cost of Title VI compliance is estimated to range from hundreds of millions of dollars to tens of billions of dollars.\(^11\)

**HFCs under Attack: The Kigali Amendment to the Montreal Protocol**

With Class I ODS already phased-out and Class II substances nearing phaseout, it appeared to many that Title VI had largely run its course. Late in the second term of the Obama Administration, however, EPA reenergized the mission of Title VI by revisiting several previously approved ODS alternatives with an eye toward the substances’ GWP and their impact on climate change. These high GWP ODS alternatives included HFCs and HFC-containing blends. President Obama’s June 2013 Climate Action Plan included a line item committing the United States to becoming a leader in HFC emission reduction by utilizing EPA’s power under the SNAP Program of Section 612 of the CAA.\(^12\)

The Kigali Amendment to the Montreal Protocol was the driver for EPA’s move to eliminate HFCs and HFC-containing blends through SNAP.\(^13\) Agreed to in October 2016 at the 28th Meeting of the Parties to the Montreal Protocol in Kigali, Rwanda, the Kigali Amendment establishes a 30-year schedule for the phasedown of the production, consumption, import/export, and emission of HFCs as an additional means to combat climate change.\(^14\) The United Nations Environment Programme reports that scientists believe the move could prevent up to 0.5 degrees Celsius of global warming by the end of the century.\(^15\) The Kigali Amendment will enter into force on January 1, 2019—assuming it is ratified by at least 20 parties to the Montreal Protocol. As of this writing (Summer 2017), only four parties had ratified the Amendment.

**The Mexichem Appeal and the Limits of EPA’s Power under CAA Section 612**

In their February 2017 oral arguments before the U.S. Court of Appeals for the D.C. Circuit, the petitioners opposing EPA’s rulemaking focused primarily on the proposition that the applicability of the SNAP Program is narrowly limited to replacing ODS with non-ODS alternatives.\(^16\) In addition to alleging that EPA overstepped its statutory authority under CAA Section 612, petitioners also argued that other statutory alternatives provide EPA with more suitable authority to regulate or prohibit the use of any non-ODS alternative that the agency subsequently concludes poses a risk of adverse impacts on human health and the environment.\(^17\)

In defense of its rulemaking, EPA argued that Title VI gives the agency authority to delist any ODS alternative that may pose a higher overall risk to human health and the environment than some other alternative.\(^18\) EPA also took the position that Section 612 is about regulating ODS substitutes, and that the statute establishes an ongoing obligation for EPA to continually review and revise the list of ODS alternatives as more data inevitably becomes available over time. When the court questioned the agency as to whether it was fair to “pull the rug out from under” those industrial users of, and chemical industry producers of, previously approved HFC ODS alternatives, EPA responded that the regulated community had been on notice since its initial rulemaking on the subject in March 1994 that the list of ODS alternatives was subject to refinement and evolution over time.\(^19\)
Conclusion: The Future of GHGs as ODS Substitutes under SNAP

From a legal academic standpoint, EPA's arguments appeared to be quite sound with respect to the language of CAA Section 612 and the breadth of the agency's powers to list, reevaluate, and delist ODS alternatives. Under a longstanding legal doctrine referred to universally by attorneys simply as “Chevron”, administrative agencies are afforded great deference when reasonably interpreting a statute that they administer. Applying Chevron deference here could lead a court to conclude that EPA acted properly and ODS alternatives can be delisted under SNAP for non-ODS-related reasons.

On the other hand, EPA's efforts to regulate climate change have been subject to increased scrutiny (judicial and otherwise) for more than a decade now. What could be conceived as a “covert” effort by EPA to regulate GHG emissions under a statutory provision designed to address ODS emissions may be subject to less Chevron deference than the agency otherwise might expect. Although it is unlikely that the economic impact on industry would ultimately carry the day for petitioners, a court could give substantial consideration to the huge investment made by the regulated community in reliance on EPA's initial listing of HFCs as acceptable ODS alternatives.

Ultimately, the court's August 8, 2017, decision held that EPA does not have authority under the CAA to delist ODS alternatives for non-ODS-related under SNAP. A split three-judge panel of the court vacated the rule to the extent it compelled manufacturers to replace HFCs, and remanded the rule to EPA for further consideration. The majority opinion placed great weight on a 1994 EPA statement in which the agency admitted that it was not authorized under CAA Section 612 to “review substitutes for substances that are not themselves” ODS. The court then focused on the interpretation and application of the word “replace,” and refused to afford the agency Chevron deference to the extent that EPA's use and application of the word “replace” would have authorized its actions under SNAP. Judge Robert Wilkins dissented from the majority opinion, and wrote that his belief was that Chevron deference supported EPA's interpretation and application of the word.

While EPA's usage of Title VI of the CAA and SNAP to address GHG emissions and climate change mirrored the manner in which the Parties to the Montreal Protocol employed the Kigali Amendment to the same end, the ultimate outcome for EPA was very different. Given the Trump Administration's stance on climate change and early efforts to undo climate-related initiatives undertaken by the Obama Administration's EPA, an appeal of the Mexichem decision by EPA appears highly unlikely (though NRDC and the industry intervenors who sided with EPA may choose to appeal separately). Further, it is a near certainty that the United States will not ratify the Kigali Amendment before it enters into force.

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References
1. Title VI of the U.S. Clean Air Act (CAA) is codified at 42 U.S.C. §7671 et seq.
2. 81 Fed. Reg. 86778 (December 1, 2016).
3. The global warming potentials of HFCs can range from approximately 100 times to 15,000 times greater than carbon dioxide. See Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Table 2.14 (2007).
4. The Natural Resources Defense Council also intervened in defense of EPA's rulemaking.
6. Petitioners also allege, inter alia, that EPA's rulemaking was arbitrary and capricious in that the agency failed to explain the materiality of differences in GWP, improperly used GWP as a measure of atmospheric impacts, and failed to provide an objective standard for comparing ODS alternatives that established an acceptable GWP for an ODS alternative.
10. 42 U.S.C. §7671k(c).
13. Although EPA's move slightly pre-dates Kigali, the agency's action was taken in anticipation of Kigali.
17. For example, the Toxic Substances Control Act at 15 U.S.C. §2601 et seq.
18. EPA's arguments suggest, by logical extension, and in keeping with the technology forcing nature of the CAA, Title VI, and SNAP, that an approved ODS alternative could be delisted even if no readily available safer alternative currently exists.
An overview of key factors impacting the refrigerant market, including EPA’s Significant New Alternatives Policy (SNAP) Program.
At approximately the same time the Montreal Protocol was ratified by the United States in 1989, the U.S. Clean Air Act (CAA) Amendments of 1990 were taking final shape. This was fortuitous timing for protection of the ozone layer, as it afforded Congress the opportunity to incorporate requirements for the phaseout of ozone depleting substances (ODS), as required by the Montreal Protocol, into the final CAA Amendments. For example, the CAA has banned production of certain ODS, such as chlorofluorocarbons (CFCs), since the 1990s. The phaseout timelines illustrated in Table 1 show that the U.S. Environmental Protection Agency (EPA) has used supply controls to limit and phaseout ODS refrigerants since soon after the regulations were finalized. In fact, the origin of these supply controls can be traced back to the Montreal Protocol itself. This method of control is a crucial factor that affects the hydrochlorofluorocarbon (HCFC) refrigerant shortages and price increases the regulated community faces today.

A requirement of the 1990 CAA Amendments that is equally critical to these HCFC concerns is the development of a program to identify safe alternatives to ODS under Section 612 of the CAA. Section 612 authorized EPA to evaluate and regulate substitutes for those ODS refrigerants that were being phased out under the Montreal Protocol. This CAA requirement was embodied in the Significant New Alternatives Policy (SNAP) Program within EPA’s Protection of Stratospheric Ozone regulations in 40 CFR 82, Subpart G.

Under the SNAP Program, EPA reviews several characteristics of proposed substitutes—including but not limited to ozone depletion potential (ODP), global warming potential (GWP), toxicity, and flammability—using a comparative risk framework for specific industrial sectors (e.g., refrigeration and air conditioning, foam blowing agents) and end uses (e.g., residential air conditioning, phenolic insulation board). SNAP Program decisions on substitutes are categorized as 1) acceptable, 2) acceptable subject to use restrictions, 3) acceptable subject to narrowed use limits, or 4) unacceptable.

SNAP’s Shift in Focus

The requirements of the SNAP Program have not changed since the mid-1990s when they were promulgated. However, the decision-making process and determination of acceptable and unacceptable alternatives to ODS have evolved considerably in those 20 years. Not surprisingly, early SNAP designations focused on replacing those ODS having the highest ODP, typically CFCs such as R-11 and R-12, and subsequently HCFCs such as R-22 and R-123. As refrigerant technology continued to evolve, and the phaseout of true ODS refrigerants identified in the Montreal Protocol has been implemented, EPA shifted its focus to expanding the approval of non-ODS substitutes, including some of the most common refrigerants in use today—hydrofluorocarbons (HFCs) such as R-134a and R-410A.

The most recent and substantial shift in the focus of the SNAP Program was heralded by the unveiling of President Obama’s Climate Action Plan, which contains commitments for reduction of HFCs. That plan appeared to set in motion the proposed regulation of substitutes primarily due to their GWP rather than their ODP. The first of these regulations was proposed the following year, and have since been finalized.

An example of a 20-year progression from CFC to HCFC to HFC for one specific end-use is illustrated in Table 2. The combined impact of phaseout and SNAP decisions on the continually escalating price of refrigerant is illustrated in Table 1. This trend may continue as a SNAP determination published in the Federal Register in July 2017 illustrates that the impact of GWP on SNAP decisions still plays a role in SNAP decision-making, regardless of the recent change in administration.

Table 1: ODS phaseout timetable.

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<td>Price (R-410A)</td>
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Notes: a Typical price for 30-lb tank of refrigerant.  
   b 75% reduction in HCFCs based on no production or import of R-142b and R-22, except for use in equipment manufactured before 1/1/2010.  
   c As included under Kigali Amendment to Montreal Protocol, not yet ratified by United States.
Supply Control: A Long-Established Method with Drawbacks

To meet the requirements of the Montreal Protocol, EPA chose an allowance system to phaseout HCFC production and consumption, and since 2003, it has issued annual allowances through a series of allocation rulings. In other words, the agency indeed chose to control supply rather than demand of HCFCs. However, this method has not come without complications that many end users are experiencing today or will experience soon when needing to service equipment using popular HCFC refrigerants. As a case in point, consider how this allowance system has impacted the most commonly used HCFC, R-22.

R-22

In its most recent allocation rule, which was published in October 2014, EPA announced a five-year linear approach for the phaseout of R-22 production for 2015–2019. The rule allocated 13 million pounds of R-22 for 2017. That number drops to 9 million in 2018 and 4 million in 2019. To put that into perspective, 13 million pounds is approximately 5 percent of the projected R-22 service needs of the United States, which means that there is only a 1 in 20 chance the R-22 refrigerant needed to service an existing R-22 unit is newly produced in 2017 and available on the market. The remainder of the refrigerant needed will have to come from existing stockpiles and reclaimed refrigerant. And, the supply gap will only become more pronounced as the production allocations continue to drop until 2019, when less than 1 percent of the refrigerant available for service needs will be newly produced.

On or after January 1, 2020, no new or imported R-22 will be allowed in the United States. Then, the only available R-22 will come from recycle and reclamation, which today accounts for less than 2 percent of needs; or existing R-22 stockpiles, which have experienced an overall decline in recent years. To complicate matters further, when the allocations of R-22 were delegated, there was an overestimate of the rate of R-22 recycle and reclaim, and as a result, a shortage looms. But the market confusion does not stop there. As an illustration, consider the fact that, as recently as 2014, R-22 equipment was readily available for sale in the United States, constituting a sizeable percentage of total equipment sales. This equipment was sold as “dry-charged” (i.e., not filled with refrigerant), even after a ban on producing R-22 charged equipment went into effect as of 2010.

The point is, while rarely admitted, such supply controls have taken for granted that end-users of controlled refrigerants have the needed awareness on this long-planned (nearly two decades prior) and calculated phaseout, let alone that those end-users are prepared and have a plan for transition to alternative refrigerants. Thus, far too many end-users will continue to allow their appliances leak vital, soon-to-be obsolete refrigerant due to limited availability, and then be caught off guard when the supply of these substances dwindle rapidly. Accordingly, the long-established method of supply control has its drawbacks: leakage of refrigerant continues, and low recycle and recovery rates remain. And, even when refrigerant leaks do not surpass EPA mandatory leak repair thresholds included in 40 CFR 82, Subpart F, consumption still exceeds access to outdated refrigerant that is still in service.

Shifting from Supply-Side to Multi-Sided Control

Recently, there has been a shift in the method of control for the phaseout of HCFCs, and it is not nearly as one-sided as it has been in the past. That is, if you look to EPA’s SNAP Program, specifically Rule 20 and Rule 21, you will see evidence of demand controls now being used to phasedown certain refrigerants and phase in others. This multi-sided approach to control may very well help end-users better prepare for the fast changing world of refrigerants. Of course, bear in mind that the SNAP Program simultaneously adds further complexity to the transition.

For example, returning to the case example of R-22 phaseout, many affected stakeholders with R-22 equipment will be faced with the option to either retrofit the equipment to use an alternative refrigerant or replace the equipment entirely.

Table 2: Example 20-year progression from CFC to HCFC to HFC.

<table>
<thead>
<tr>
<th>Rule Date:</th>
<th>1994</th>
<th>1996</th>
<th>2002</th>
<th>2016</th>
<th>2017+</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial Comfort Cooling with Centrifugal Chillers</td>
<td>R-22 is an acceptable substitute for R-12 (N)</td>
<td>R-410A (N) or R-407C (N/R) are acceptable substitutes for R-22</td>
<td>R-410A (N) or R-407C (N/R) for R-22</td>
<td>R-407C and R-410A are Unacceptable (N)</td>
<td>??</td>
</tr>
</tbody>
</table>

Notes: (N) Indicates use in a new equipment
(R) Indicates use in retrofitting existing equipment to use the listed refrigerant
Those who choose replacement, which is the costlier of the two options, must proceed with caution and take into account relevant SNAP rulings. Consider the popular replacement option for R-22 units, the HFC blend R-404A. R-404A may seem like a good choice for the long-term (in certain applications), but such a choice may be misplaced due to recent SNAP decisions, which have begun R-404A’s phasedown ahead of the Kigali Amendment to the Montreal Protocol by listing it as unacceptable in several air-conditioning and refrigeration end-uses.\textsuperscript{14,15} [Editor’s Note: The Kigali Amendment to the Montreal Protocol is described in detail in the article by Janet McCabe elsewhere in this issue of \textit{EM}.]

Thus, replacement options will come with complications and associated costs. One such additional complication is the vacatur of SNAP Rule 20 by the U.S. Court of Appeals for the District of Columbia that occurred on August 8, 2017.\textsuperscript{16} The 2-to-1 decision indicates that EPA cannot utilize the SNAP Program to disapprove of previously approved non-ODS substitutes such as HFCs. While EPA had not commented on the decision at the time this article was written, EPA and/or one or more of its intervenors are expected to appeal this decision to the D.C. Circuit.

Along similar lines, material origins add another layer of complexity that system owners must consider. Tariffs have been applied to many common refrigerant gases (e.g., R-410A and R-134a), which means they spend a longer time in port to be evaluated and as a result their total costs increase.\textsuperscript{17} These market events have an impact on the supply availability options of the approximately 5,000 U.S. distribution locations.

So, what this multi-sided control effort really means is that heating, ventilation, and air conditioning/refrigeration (HVAC/R) management decisions may come with additional complications. In fact, expect faster phaseout of refrigerants, fewer options for replacements, and more rapid financial obsolescence of equipment. Also, with the rapid changes in the regulatory landscape, the useful life of an appliance may be much shorter than its typical depreciation period, so acceleration of appliance depreciation must be considered.

A Farewell to Cold and Cheap Comfort (For the Better)

While the transition away from HCFCs and HFCs is not straightforward, it is clear that the old days of cold and cheap comfort are gone . . . and it is for the better. In fact, there is a strong and unified consensus unique to the HVAC/R industry that the best path forward is to replace the old refrigerant gases with better, more environmentally sound materials that cause fewer problems, like hydrocarbons (HCS) and hydrofluoro-oroolefins (HFOs). In fact, before the Trump Administration had taken office, the HVACR Industry Alliance solicited their support for this shift in a letter to then-Vice President-Elect Mike Pence: “The HVACR Alliance strongly supports Senate ratification of the Kigali Amendment to the Montreal Protocol and urges members of the Senate to align U.S. policy with the direction U.S. manufacturers are heading with regard to [phasing down the use of] HFCs.”\textsuperscript{18}
Specifically, HC materials, which have flammable properties, will become more prevalent, resulting in a need for new regulations to safeguard the workforce. Danielle Wright, Executive Director of the North American Sustainable Refrigeration Council, embraces this next generation of gases, stating: “The global phasedown of HFCs is driving retailers to invest in ‘future-proof’ refrigerant solutions. It is also motivating equipment manufacturers to develop innovative new technologies that are making naturally occurring refrigerants not only a viable option but the optimal choice in terms of performance and return on investment.”

Undoubtedly, the best advice is to stay alert. Many popular refrigerants are already being phased out; some have just begun being phased down; and others have been impacted by increased costs. In the coming years, multi-sided control efforts will radically transform the industry. Amendments to the Montreal Protocol will be signed, the SNAP Program will continue to evolve, more controls will be deployed, and the impact to end-users will be primarily financial. Meanwhile, the HVAC/R industry is attempting to act responsibly to deploy alternative solutions in a timely and cost-effective manner.

With an extensive background in government affairs, Elizabeth Ortlieb is policy analyst for Trakref, a refrigerant management software company. She tracks HVAC/R policy and compliance at the private, local, state, federal, and international levels.

Ted Atwood is a pioneer in carbon management with more than 20 years of experience handling refrigerants in countries such as China, Germany, Eastern Europe, South and Central America, as well as building and operating nine refrigerant recycle facilities in the United States. He is the founder and CEO of Trakref, a software solution provider that helps clients manage their HVAC/R compliance and refrigerant needs.

Brian Noel is a managing consultant at Trinity Consultants with 15 years of air compliance experience, including refrigerant management.

Kirk Lowery is a regional director at Trinity Consultants, who has been implementing refrigerant programs and performing training on refrigerant regulations for more than 20 years.

References
3. 42 U.S. Code Chapter 85, Subchapter I, Part 1 Section 7671c-7671d.
4. 42 U.S. Code Chapter 85, Subchapter I, Part 1 Section 7671k.
5. 40 CFR Part 82, Subpart G, Appendix A–R.
6. 40 CFR Part 82, Subpart G, Appendix L–V.
Highlights from the Coordinating Research Council’s 27th Real-World Emissions Workshop

by Xiaochen Tang, Lawrence Berkeley National Laboratory; Dominic DiCicco, Ford Motor Company; Scott Mason, Phillips 66 Company; Henry Hogo, South Coast Air Quality Management District; Susan Collet, Toyota Motor North America Technical Center; Megan Beardsley and Tom Long, U.S. Environmental Protection Agency; Matt Thornton, National Renewable Energy Laboratory; Tao Huai and John Collins, California Air Resources Board; Shirish Shimpi, Cummins Inc.; Kevin Black, Federal Highway Administration; Radha Purushothaman, Caterpillar Inc.; and Christopher Tennant, Coordinating Research Council (CRC)

The 27th Coordinating Research Council’s Real-World Emissions Workshop was held on March 26–29, 2017, in Long Beach, CA. Co-Chairs, Dominic DiCicco (Ford Motor Company) and Scott Mason (Phillips 66 Company), opened the workshop to more than 240 attendees, representing 12 countries from industry, government, academia, and consulting, which sets a record for the highest attendance for this event. This year’s keynote speakers included Jeff Wrona (General Motors) and Daniel Short (Marathon Petroleum Corporation). The workshop comprised 53 presentations in 9 sessions and 28 posters, as well as demonstrations of analytical and technical services by various vendors. Highlights from the workshop sessions are summarized in the following article.
Emission Rates and Inventory
Session Chair: Henry Hogo, South Coast Air Quality Management District
Emission rates for light- and heavy-duty vehicles have been established based on certification programs for all pollutants, with a specific focus on nitrogen oxides (NO\textsubscript{x}) and particulate matter (PM), with more recent efforts using remote sensing devices (RSD) and portable emissions measurement systems (PEMS). An analysis of newer light-duty vehicles utilizing gasoline direct injection (GDI) engines designed to achieve future greenhouse gas (GHG) reductions has shown a potential to increase PM emissions, especially under cold-start conditions. Early efforts led to additional in-use studies identifying potential pathways for reducing PM, including the possibility for gasoline particulate filters.

Emissions of NO\textsubscript{x} and PM from heavy-duty diesel vehicles have decreased dramatically over the past decade as a result of improved diesel fuel, vehicle emission after-treatment technologies, and regulatory requirements, including California’s bus and truck rule. More recent studies suggest higher PM emission observations in older fleets with diesel particulate filters (DPFs) than newer fleets, leading to a need for additional studies on the potential for compromised DPF systems. Further, emissions inventories and ozone modeling have mostly relied on the certification emission rates, however, consistently higher volatile organic compounds (VOCs)-to- NO\textsubscript{x} ratios observed in ambient monitoring data compared to inventory data implied either an underestimation of VOC emissions, overestimation of NO\textsubscript{x} emissions, or both.

The California Air Resources Board’s (CARB) EMFAC model summarizes vehicle travel and emissions data for mobile sources, and is continuously updated to reflect the latest base emission and deterioration rates, including the effect of after-treatment technologies incorporated into model-year 2010 or newer engines. Recent studies highlight a potential need to revise the model to account for malfunctions affecting PM emissions. Idle emission rates at varying soak times for vehicles equipped with selective catalytic reduction systems, were also updated. Lastly, chassis dynamometer measurements along with other studies were used to update base emission rates and speed correction factors.

Emissions Control Measures: I/M and OBD
Session Chair: Susan Collet, Toyota North America Technical Center
Ambitious governmental targets for light- and heavy-duty vehicle emissions are shown in Figure 1. For light-duty (LD) vehicles, new and innovative technologies are being explored, such as selective catalytic reduction on filter (SCRF) to reduce NO\textsubscript{x} and thermoelectric generators (TEGs) to reduce carbon dioxide (CO\textsubscript{2}).

Regarding heavy-duty (HD) vehicles, CARB is moving forward with parallel efforts to lower new engine emissions and see that those emissions remain low in-use, during warranty, and throughout useful life. To comprehensively improve NO\textsubscript{x} performance in California, a few parallel paths need to be integrated and moved forward together: better hardware and control strategies, consideration of in-use NO\textsubscript{x} performance

Figure 1. Light-duty vehicle emissions legislations for European Union, United States, China, Japan, India, and Brazil.
across duty cycles, expansion of regulatory durability and NOx emission control throughout HD truck useful life, and identification and remediation of high emitters, as shown in Table 1. CARB also sees a need for a more comprehensive, multi-pollutant HD inspection and maintenance (I/M) program to ensure in-use vehicles have regular inspections and effective emission controls.

It is important to have accurate HD NOx sensor monitoring. Artificial neural networks (ANNs) can predict arbitrary functions using input/output data, which is useful not only for on-board diagnostics (OBD) monitoring at highway conditions, but also for NOx production prediction during various modes of engine operation.

### Emissions Modeling

**Session Chair:** Megan Beardsley, U.S. Environmental Protection Agency (EPA)

A detailed emissions model predicted second-by-second fuel use and emissions, based on PEMS measurements of Euro 6 vehicles, as shown in Figure 2. A dynamic evaluation of ozone trends in California’s South Coast Air Basin found that the rate of decrease in ambient ozone levels was steeper than that estimated by air quality models. California’s EMFAC2017 inventory model will include a number of updates, including LD and HD in-use emissions and activity profiles, as well as a new module to estimate GHG emissions.

Data from remote sensing, I/M programs, and tunnel studies were used to evaluate LD vehicles NOx running emissions rates in Motor Vehicle Emission Simulator (MOVES); however, results from this preliminary evaluation were mixed. Telematics data were used to generate light-, medium-, and heavy-average speed inputs and temporal profiles for MOVES by county and road type that, when finalized, will be used to estimate emissions for EPA’s 2014 National Emission Inventory (see Figure 3).

### Fuel Effects/Fuel Economy

**Session Chair:** Matthew Thornton, National Renewable Energy Laboratory

The relationship between driver performance and real-world fuel consumption was examined for vehicles in Singapore, which showed that on-road fuel consumption estimated using OBD data is generally higher than the rated fuel consumption. The impact of driving conditions on the formation of secondary PM emissions from GDI vehicles was examined using fuels with different ethanol content.

Comparison of PM emission trends using Tier 2 and Tier 3 certification test fuels showed higher composite PM emission using the Federal Test Procedure (FTP) on Tier 3 fuel. Another study investigated trade-offs between fuel consumption and engine-based strategies to achieve low-engine-out NOx and improved SCR activity. Another study looked at ultra-low NOx measurement and emission factors for HD compressed natural gas (CNG) vehicles.

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### Table 1. CARB’s regulatory development plan for heavy-duty vehicle emissions.

<table>
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<tr>
<th>Hearing</th>
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<th>Implementation</th>
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<td>2017</td>
<td>Updates to Smoke Opacity Programs</td>
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<td>Warranty Updates</td>
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<td>CA Heavy Duty Phase 2 GHG alignment</td>
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<td>2019</td>
<td>Low NOx Engine Performance Requirements</td>
<td>2023 and onwards</td>
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<td></td>
<td>Low Load Certification Requirements</td>
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<td></td>
<td>In-Use Compliance Program (currently NTE)</td>
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<td>Warranty/Durability/Useful Life Period Definitions</td>
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<tr>
<td>2020</td>
<td>HD Inspection/Maintenance Program</td>
<td>Post 2020</td>
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A predictive model for the correlation of heat of combustion with diesel fuel composition was evaluated and better test repeatability for net heat of combustion was found than that of the analyses for the same fuels performed by ASTM D4809. The session ended with a study looking at the fuel effects on gaseous and PM emissions on spark-ignited direct-injection (SIDI) in-use vehicles. This study investigated how a range of fuel properties in specifically-blended fuels affect criteria pollutants, fuel economy, and GHG emissions.

**HD In-Use Emissions**

**Session Chair: Tao Huai, California Air Resources Board (CARB)**

One research team compared in-use transit bus NO$_x$ emissions and concluded that newer model-year buses significantly reduced tailpipe NO$_x$ emissions under real-world driving conditions due to SCR improvements. A HD chassis dynamometer study was designed to check the zero-mile emission rates for model-year 2010 or newer HD diesel vehicles. CARB developed a HD Truck and Bus Surveillance Program to generate surveillance data to not only refine the mobile source emissions inventory, but also identify engine families for confirmatory in-use compliance testing.

EPA examined the MOVES 2014 model and concluded that the real-world NO$_x$ emissions of model-year 2010 or newer vehicles are higher than the standards and current model estimates. On-board NO$_x$ sensors were evaluated to compare with other on-board laboratory grade measurement systems (e.g., PEMS and Fourier transform infrared spectroscopy [FTIR]).

**Particle Emissions Measurements: Mass and Number**

**Session Chair: Shirish Shimpi, Cummins Inc.**

Focus in this session for the particle mass was on capability of partial flow dilution (PFD) systems to satisfy Tier 3 LD engine regulations and evaluating sampling system parameters. HD engine testing using PFD involved comparing the performance of three PFD units from different suppliers with each other and with the constant volume sampling (CVS) counterpart; differences in PN (particle number) measurement results were within 15 percent.

Recently the measurement of PN in-use emissions has been an area of interest in the European Union and a study evaluated an instrument developed to address the size concerns encountered in-use. Condensation particle counter (CPC) has been the mainstay of PN measurement with one company being the prominent player. Another company has decided...
to supply their own brand of CPC to go with their PN instruments, and the measurement performance was tested both in laboratory and over chassis dynamometer tests.

**LD In-Use Emissions**  
**Session Chair: John Collins, California Air Resources Board (CARB)**  
LD vehicle emissions have been monitored by RSD for about 30 years. When using historical data to evaluate deterioration as a function of vehicle age, special care must be taken to compensate for changes in fleet composition because each RSD sample campaign captures a new cohort rather than following one longitudinal cohort.

A newly developed laser-based RSD method that looks down on the highway rather than across it showed good sensitivity and accuracy, which could allow monitoring of more driving modes than conventional RSD. Both RSD and PEMS measurements have shown that on-road vehicles emit differently on the highway compared with when measured in the laboratory over standard driving cycles. To overcome this discrepancy, certification tests need to be designed not only in a way that the vehicle is blind to the fact that it is being tested, but also to represent the wide range of operating conditions encountered in the real world. To represent on-road conditions while maintaining laboratory accuracy and reproducibility, a method to generate chassis dynamometer cycles from on-vehicle, on-road activity measurements has been developed, although current methods do not yet incorporate road grade.

In addition to aging more slowly, modern technology vehicles have different proportions of emissions from cold-start, warm-start, and hot-running exhaust than older technology vehicles. Counterintuitively, start emissions from lukewarm engines after moderate soak times are on average higher than start emissions from fully cold engines. The California emissions model EMFAC 2017 has been updated to reflect the new emission profiles from modern (LEV II) vehicles. Finally, while primary emissions of PM in the exhaust continue to be reduced, emissions of some volatile and semi-volatile gas phase species can lead to formation of tens of times more secondary PM, which the emission models need to address as another source of PM.

**Method Developments in Emissions Measurements**  
**Session Chair: Tom Long, U.S. Environmental Protection Agency (EPA); Kevin Black, Federal Highway Administration (FHWA)**  
Real-time nonmethane organic gas (NMOG) measurements using FTIR were within 5 percent of the traditional method, which subtracts methane, oxygenates, and acetaldehyde from total hydrocarbons in post-processing. By using gas chromatography-mass spectrometry (GC–MS) to develop new recipes, FTIR can then be employed to perform real-time quantification of new or unexpected exhaust species. CARB has developed a portable roadside plume capture system to screen for high emitting in-use vehicles, which emit disproportionately large amounts of NOx and black carbon (e.g., 48 out of 610 vehicles contributed to 50 percent of total NOx emissions, as shown in Figure 4). Among a variety of alternate particle neutralizers to Krypton 85, it was observed that Po-210 produced a similar PN at high concentrations...
and less error than other alternatives at low concentrations when measured with a scanning mobility particle sizer (SMPS).

While the measurement technologies provide the framework for examining the vehicle activities producing emissions, understanding the pattern of vehicle activities is also important for emission controls. Vehicle activity data describing operating modes, such as idling, accelerating, decelerating, and cruising, can be collected in multiple ways, including telematics (indirect, behavior-based) and traditional “drive cycles” (direct, laboratory-based). Several studies discussed using trip-based real-world activity data to improve our understanding of fleet characteristics and reveal the correlation between idle activity and a vehicle’s vocational use (e.g., passenger, commercial, etc.).
Long, “extended” idling activity can be associated with increased NO\textsubscript{x} emission, where an “extended idle event” was defined as a continuous activity segment within a trip with second-by-second vehicle speed less than 5 mph, total duration more than five minutes, and total distance less than one mile.

**Off Road**

**Session Chair:** Radha Purushothaman, Caterpillar Inc.

Research on emissions reduction technologies and measurement methods for locomotive and marine vessels were included. Different black carbon measurement methods were compared on a large marine engine using three different types of fuels. Fuel used for testing affects the black carbon emission rates and the various measurement methods exhibited low uncertainties, except those instruments requiring high dilution had poor agreement. Various measurement methods were utilized to estimate the NO\textsubscript{x} control efficiency and fuel flow on a locomotive engine with a new SCR based after treatment retrofit system. Initial evaluation performed in the railyard showed a 93-percent NO\textsubscript{x} control efficiency.

Emissions from ocean-going vessels were compared with a scrubber system running on high- and low-sulfur fuel. The scrubber system reduced the sulfur dioxide (SO\textsubscript{2}) emissions by 96–100 percent without a reduction in sulfate PM, thus, using a scrubber with high-sulfur (compared to low-sulfur) fuel led to more sulfate PM formation. Exhaust particles from a large marine diesel engine were characterized across four different fuels with varying sulfur levels. Irrespective of the fuel used, 70–80 percent of the particles formed were volatile, and increasing the fuel sulfur and ash content led to larger particles as well as higher total number of particles.

**Next Workshop**

The 28th Real-World Emissions Workshop is scheduled for March 18–21, 2018, in Orange County, CA.
Barbara Zielinska, Ph.D., Emeritus Member of A&WMA, passed away on July 26, 2017. A member for almost 30 years, Dr. Zielinska was actively engaged in the Association’s leadership, most recently serving as Chair of the Chemistry Committee (2006–2009), Vice Chair (2009–2011) and Chair (2011–2014) of the Basic Sciences Division, and Air Group Coordinator (2014–2016).

Dr. Zielinska was a renowned atmospheric chemist with notable contributions through both research and scientific community service. Her research areas included the collection and analysis of trace atmospheric organic species in both the gas and particle phases; development of analytical methods for primary and secondary particulate organic matter speciation; kinetics and products of gas-phase reactions of organics; measurement methods for volatile, semi-volatile, and particulate-phase compounds in ambient air; and particle-associated and volatile organic compound emissions from various sources, including diesel- and gasoline-powered vehicles, wood combustion, biomass burning, and meat cooking.

Dr. Zielinska earned her M.Sc. from the Technical University of Lodz (1969) and Ph.D. from the Polish Academy of Sciences (1979), both in chemistry. Upon completion of her studies, she became an associate research chemist for the Statewide Air Pollution Research Center (SAPRC) at the University of California, Riverside, where she conducted research on mutagenic derivatives of polycyclic aromatic hydrocarbons under the influence of gaseous atmospheric pollutants. After six years with SAPRC, Dr. Zielinska was recruited by the Desert Research Institute (DRI) as an associate research professor in 1989 and was promoted to professor in 1997. She established DRI’s Organic Analytical Laboratory (OAL) and served as the lab’s director until her retirement in 2015. With Dr. Zielinska’s leadership, DRI grew to become a global leader in organic chemistry analysis.

Dr. Zielinska published more than 125 peer-reviewed papers that spanned a range of topics with implications to atmospheric science, air quality planning and management, and air pollution health impacts. She was particularly well known for her work on polycyclic aromatic hydrocarbons (PAHs), biomass burning emissions, vehicle emissions, and secondary aerosol formation. She was also a national leader in service to the scientific community, including a recent role on the National Research Council’s Committee on Risk Management and Governance Issues in Shale Gas Development and on the U.S. Environmental Protection Agency’s Clean Air Scientific Advisory Committee (CASAC). In 1999, Dr. Zielinska was recognized with DRI’s top honor in recognition of scientific accomplishment, the Alessandro Dandini Medal of Science.
Sustainable Materials Management at Your Fingertips

by Aaron Ferster and Michael Nye

A look at the Materials Management Wizard—MWiz—which offers streamlined access to the breadth of EPA’s tools and resources on sustainable materials management.

Since its establishment more than 45 years ago, a major focus of the U.S. Environmental Protection Agency (EPA) has been to improve the management of materials and safeguard the disposal of waste. With ever-growing sophistication, EPA research has supported industry, community, and individual efforts to lower the environmental impact of what we collectively leave behind.

This march of progress has involved every aspect of society. From the now-ubiquitous municipal curbside recycling programs to extensive assessment and monitoring operations to contain or remove hazardous wastes, protect public health, and revitalize contaminated sites, virtually every individual household, business, and community is aware of actions they can take to reduce, reuse, and recycle.

EPA is committed to advancing the next generation of progress, focused on advancing sustainable materials management. This fundamental change embraces not simply reducing wastes, but realizing efficiencies and lowering production costs across the board. By looking at a product’s entire life cycle—from the selection of source materials through production
and eventual disposal in ways that feed the next generation of new products—sustainable materials management represents a paradigm shift in how society thinks about the use of natural resources and environmental protection.

Moving the concept of sustainable materials management from theory into practice requires innovative new tools and resources that tap the many year’s worth of experience, research, and extensive data that EPA has invested in and compiled, while supporting best practices in waste management over the past four-plus decades.

The recently-released Materials Management Wizard (http://www.epa.gov/sustainability/mwiz), or MWiz for short, is one such new tool that simultaneously offers streamlined access to the rest of what EPA has to offer.

The web application serves as a gateway for exploring the breadth of EPA’s tools and resources on sustainable materials management. It taps a rich repository of EPA-sourced tools and resources designed to support sustainable materials management decisions made by communities, stakeholders, and educators. EPA researchers and modelers developed MWiz as part of the agency’s goal to make visible differences in improving communities across the nation.

From an individual homeowner looking for tips on composting to site managers needing to handle tons of construction and demolition materials, users can tailor MWiz to find just the information they need to make plans and take action.

The tools and resources available through MWiz help:

- Analyze problems,
- Advance the understanding of management options,
- Calculate design parameters,
- Identify costs and benefits,
- Evaluate tradeoffs, engage stakeholders, and
- Support education and outreach campaigns.

How MWiz Works
The MWiz interface is designed as a seamless, two-step process consisting of quick links and guided explorations. The quick links provide a menu of resources based on the primary objective of the user under the four broad categories of Learn, Engage, Act, and Discover. Each category serves as an immediate gateway linking the particular objective to a tailored list of tools and resources.

For example, a user activating the “Discover” box is provided a checklist consisting of:

- I am interested in sustainable materials management and the built environment
- I am interested in sustainable electronics
- I am interested in sustainable food management
- I am interested in sustainable packaging

Each selection provides a list of hyperlinked additional informational and other researches.

The Explore feature provides materials management tools and resources, customized to user specifications. A question-and-answer format interface guides users through selections of one or more corresponding topics. At any point, a simple click of a “Show Results” button yields a customized list of results. Explore is divided into three options based on user preferences and goals: specific materials of interest, objectives, and a general key word search.

In both Quick Links and Explore, you can download your reports in PDF format for future use.

As the advancement of waste management cuts across all of EPA’s work, MWiz is a collaborative effort uniting several different offices within EPA. It was made possible through a cross-agency effort involving EPA’s Office of Research and Development, Office of Policy, Office of Land and Emergency Management, and regional staff.

More Information
For more information on the research discussed in this column, contact Ann Brown, U.S. Environmental Protection Agency (EPA), Office of Research and Development, Research Triangle Park, NC; phone: 1-919-541-7818; e-mail: brown.ann@epa.gov.

Aaron Ferster is communications lead for the U.S. Environmental Protection Agency’s (EPA) Sustainable and Healthy Communities National Research Program, and Michael Nye, Ph.D., is an EPA social scientist who leads the MWiz effort for the Office of Research and Development.

Disclaimer
The views and opinions expressed in this article are those of the author(s) and do not represent the official views of the U.S. Environmental Protection Agency (EPA).
This Month in History (and other fun facts)

Did You Know?

October, which is the tenth month in the Gregorian calendar, received its name from the Latin numeral octo meaning “eight” because in the original Roman calendar it was the eighth month.

October’s gem is Opal, and its flower is Calendula.

October, which is the tenth month in the Gregorian calendar, received its name from the Latin numeral octo meaning “eight” because in the original Roman calendar it was the eighth month.

October’s gem is Opal, and its flower is Calendula.

Croatian: Listopad
Danish: Oktober
Italian: Ottobre
Polish: Październik
Old English: Winterfylleþ

This Month in History

Oct. 1, 1880: First electric lamp factory was opened by Thomas Edison.

Oct. 7, 1958: The U.S. manned space-flight project was renamed Project Mercury. It was originally called Project Astronaut.

Oct. 18, 1954: Texas Instruments introduced the first transistor radio.


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