South Coast
Air Quality Management District
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Aircraft Emissions Control Technology Forum and Technical Roundtable (February 13, 2008)

Executive Summary

The South Coast Air Quality Management District (AQMD) convened a technical forum and roundtable discussion on the air quality impacts of aircraft emissions and potential strategies and technologies for reducing these emissions on February 13, 2008 at the AQMD headquarters in Diamond Bar, California. Representatives from federal, state and local agencies, academia, and industries representing airlines and aircraft engine manufacturers were invited to this one day forum. The panel of experts gave presentations during the morning session, which was followed by a roundtable discussion and public comment period after lunch. Presentations focused on recent studies of the impact of aircraft on air quality and public health, characteristics of aircraft emissions, existing and future programs and regulations, and potential emissions control strategies.

Highlights of the forum and discussion included:

1. The health impacts due to aircraft emissions, especially the high ultrafine particle number concentrations associated with aircraft engine emissions, need to be further assessed.
2. The importance of monitoring aircraft emissions was highlighted in order to determine the local, regional and global impacts and to focus future control strategies.
3. Effective control strategies include improving aircraft operations both in the air and on the ground as well as new developments in engine technology.

Introduction

Aircraft emissions represent a significant and growing source of air pollution in the South Coast Air Basin (Basin) with adverse impacts on local and regional air quality. Other community concerns include odors and noise. Aircraft engine emissions are regulated at the federal and international level. To date, reduction in airport-related emissions occurs primarily by controlling land-based sources. As the land-based sources are controlled, aircraft emissions will become the primary contributor to airport emissions.

On February 13, 2008, the AQMD hosted a one-day technical forum and roundtable discussion where a panel of experts discussed the contribution of aircraft emissions, the

impact of aircraft emissions on public health, the science of aircraft technology, and potential, existing and future aircraft emission control strategies. Presentations were given during the morning session, and a roundtable discussion followed by public question and comments was conducted in the afternoon.

Panel technical experts included:

1. Howard Aylesworth, Director of Civil Aviation and Environment, Aerospace Industries Association
2. Carl Burleson, Director, Office of Environment & Energy, Federal Aviation Administration
3. Will Dodds, International Coordinating Council of Aerospace Industries Association's Environmental Committee
4. Philip M. Fine, Ph.D., Atmospheric Measurements Manager, AQMD
5. John R. Froines, Ph.D., Professor and Director, Southern California Particle Center, UCLA
6. Betty Hawkins, Managing Director of International Affairs, Air Transport Association
7. Roger Johnson, Deputy Executive Director, Environmental Services, Los Angeles World Airports
8. Zorik Pirveysian, Planning and Rules Manager, Off-Road Mobile Source Strategies, AQMD
9. Philip Whitefield, Ph.D., Professor, Missouri University of Science & Technology

In addition to the above panel members, Elinor Fanning (Southern California Particle Center), Bryan Manning (U.S. Environmental Protection Agency) and Fayette Collier (NASA) joined the afternoon roundtable discussion. The afternoon session was moderated by Dr. Joseph K. Lyou, AQMD Board Member.

Expert Panel Presentation Summary

1. Dr. Chung Liu, Deputy Executive Officer, Science and Technology Advancement, AQMD, opened the morning session by welcoming the panel members and attendees. He provided a short introduction on the South Coast Air Basin (Basin) air quality issues and the need for future regulation of aircraft emissions. Dr. Liu noted that despite significant improvements in the past few decades, the Basin still experiences the worst air quality in the U.S. Therefore, AQMD is investigating control strategies from all source categories, including aircraft, to achieve further emissions reductions. In addition, airport impacts to surrounding communities are also of concern because of increased air traffic. He recognized that AQMD has limited authority to regulate aircraft emissions and must work in concert with the California Air Resources Board (CARB), the United States Environmental Protection Agency (U.S. EPA), the Federal Aviation Administration (FAA), and the aerospace industry to address the air quality impacts of aircraft.

2. Mr. Zorik Pirveysian discussed the regional air quality impacts of aircraft emissions. Mr. Pirveysian highlighted the Basin's disproportionate population-based exposure for fine particulate matter ($PM_{2.5}$) and ozone (due to exceedance of the federal ambient air quality standards) and the corresponding health impacts. Despite past improvements in air quality associated with existing regulations, significant additional reductions are needed to meet the federal ambient air quality standards. The additional NOx reductions are projected to be 30% by 2014 and 76% by 2023. Mr. Pirveysian further explained that the numbers of landings and take-offs for civil and commercial aircraft are projected to increase over the next 20 years, which will adversely affect future regional air quality. He also emphasized that long term emission reductions from aircraft will be critical for demonstrating attainment of the 8-hour ozone standard. New technologies and programs for aircraft will be central to achieving these reductions.

3. Professor John Froines emphasized that ultrafine (< 100 nm in diameter) particles have been shown to be the most toxic and deserve to be studied and potentially regulated. He posed the question as to whether particles be regulated by mass or number. Recent studies suggest reductions in $PM_{2.5}$ mass have resulted in increases in particle number. While particulate matter (PM) has been associated with adverse health outcomes in the past, studies over the past 10 years have shown links to specific cardiorespiratory outcomes, birth outcomes, nervous system outcomes, and cancer. The characteristics of ultrafine particles (especially combustion generated) are thought to be potential drivers for their adverse effects on human health. One of these properties is their high surface area due to their irregular shapes, which provides sites for vapor adsorption. Ultrafine particles can deposit in the nasal pharyngeal region (nose and throat) as well as alveolar region (lower airways), and they can enter cells and affect organelles, including mitochondria. Studies have shown ultrafine particles to be toxic regardless of the sampling location (freeway, source, receptor).

   Professor Froines discussed two studies he led to quantify ultrafine particle concentrations near LAX and its surrounding communities. The studies measured particle number, black carbon, $PM_{2.5}$, carbon monoxide and air toxic gases during two seasons at a background site and a site next to the blast fence at the east end of one of the runways at the airport. The community portion of the study measured particle number and size distributions during take-off at the blast fence and various sites in the surrounding area. Some noteworthy results include: high levels of black carbon were found at the blast fence; aircraft flying overhead influence particle concentrations on the ground directly beneath their landing path; and both particle and vapor phase polycyclic aromatic hydrocarbons (PAH) were not influenced much by aircraft. Particle number concentrations dropped exponentially with distance away from the blast fence. Professor Froines stressed that this research was preliminary and needs to be investigated further. The toxicological properties of aircraft generated particles must be compared to those from other sources.

4. Dr. Philip Fine presented results from several previous airport air quality studies. Researchers reported that concentrations of volatile organic compounds (VOC)

and lead around Chicago O'Hare Airport were not significantly different from typical urban levels. Similarly, concentrations of VOC and PM were not higher than other urban areas at TF Green Airport in Rhode Island, although black carbon levels were elevated at TF Green. For the John Wayne Airport and LAX studies, no increase in PM10 was observed at John Wayne in 1991-1992, and PM10, CO and VOC levels at LAX were slightly higher than the urban background but not above the air quality standards.

Under a U.S. EPA grant, the AQMD conducted an air quality monitoring study at general aviation airports in the Basin. Measurements of PM10, $PM_{2.5}$, lead, hexavalent chromium, ultrafine particles, VOC, carbon monoxide and carbonyls were taken at Van Nuys Airport and Santa Monica Airport, which are both general aviation airports with residences in close proximity. At both airports, there was no significant increase in $PM_{2.5}$ mass. Elemental carbon (similar to black carbon and soot) and ultrafine particles were both elevated very close to the airports (near the blast fence), but the former was not far above the Basin average and the latter returned to background levels at most of the community sites. Lead particulate was found in higher concentrations than the basin average but still well below the federal and state standards. VOCs showed no clear concentration gradient. Future research will be conducted at LAX, with more continuous measurement to aid in source apportionment.

5. Dr. Joseph Lyou gave a short background on environmental advocacy. He stated that a legally binding community benefits agreement is currently in place between Los Angeles World Airports (LAWA) and local governments to assess risks from the airport to the downwind communities. The agreement includes the use of Best Available Control Technology (BACT) at airports. In addition, the upcoming study will investigate airport impacts in much greater detail. In the past, low income communities did not have a history of interaction with LAWA and are now being represented. The downwind communities have a right to know the air quality impacts of LAX. LAWA has identified a contractor and plans to start the pilot study in 2008 with the hope that the results will warrant a full study soon after.

6. Professor Phil Whitefield presented a summary of the Aircraft Particle Emissions Experiment (APEX) studies as well as potential aircraft emissions control strategies. Aircraft emissions are a source of volatile and non-volatile PM, which will increase with increasing air traffic. Dr. Whitefield listed some potential problems with measuring aircraft emissions. One question is which metric should be used to quantify these emissions: number, size, and/or chemical composition. In addition, aircraft emissions are only one of the particulate matter (PM) sources associated with airports. The APEX studies measured aircraft emissions at four airports. Dr. Whitefield indicated that future research will apportion airport-associated emissions to sources within the airport based on the nature of the emissions and amount of emissions per unit of fuel burned. Ground-level aircraft emissions are due to the operation of aircraft in low-thrust mode for idle and taxi. Thrust above 15% lead to reduced unburned hydrocarbon emissions. Engines are designed to operate at highest efficiency during maximum thrust and not during

taxi and idle. Black carbon is the major component of PM at the exhaust nozzle. Unburned hydrocarbons exit the aircraft's exhaust as gases and form particles further downwind. Dr. Whitefield presented data that shows pronounced particle production at 30 meters downwind of the aircraft due to vapors in the exhaust condensing to form particles. This increases the variability in particle numbers emitted from aircrafts while mass emissions do not vary as much. In general, PM emissions are much higher during the warm-up of the engine. Atmospheric conditions also have a large effect on particle emissions. More study on specific engines is necessary because emissions are engine specific. In terms of potential strategies, Dr. Whitefield proposed to focus on minimizing fuel burn during idle and taxi operations (e.g., fuel efficiency improvements, operational controls) as a viable strategy to control PM and hydrocarbon emissions.

7. Mr. Carl Burleson discussed the Federal Aviation Administration's (FAA) priorities in terms of managing growth of air travel and the associated environmental impacts. Over the last several decades, energy intensity per passenger mile of aircraft has declined to near automobile levels due to fuel efficiency improvements. Mr. Burleson stressed that strategies to reduce emissions from airports are currently underway. All criteria pollutants emitted by aircraft have been reduced, except for NOx due to the high engine temperatures. U.S. commercial aviation fuel consumption is down 3% from the year 2000 even though the industry is moving 12% more people and 22% more freight. As a result of this reduced fuel consumption, U.S. aircraft greenhouse gas emissions are down since 2000 while the European Union has experienced a 30% increase. However, the 50 largest airports are located in areas that are non-attainment for ozone and $PM_{2.5}$. Besides air quality challenges, airports present other environmental challenges, including community noise, energy demand, water quality and global climate. Managing aircraft impact on the surrounding environment is difficult because mitigating one impact may worsen another. For example, noise abatement may increase fuel consumption, which leads to an increase in emissions. Therefore, the interdependencies among various impacts need to be considered. In addition, aviation is a global industry, which makes U.S. regulation of aircraft very complex.

   In 2004, the International Civil Aviation Organization (ICAO) adopted a goal to limit or reduce the impact from aviation greenhouse gas emissions on climate change, and it approved emissions trading guidance in 2007. FAA has developed NextGen (The Next Generation Air Transportation System), which is a plan to modernize the National Airspace System through 2025, and is working with the National Aeronautics and Space Administration (NASA) and the National Oceanic and Atmospheric Administration (NOAA) to account for tradeoffs between different control strategies and policies and to fill in knowledge gaps concerning aircraft impacts on greenhouse gas emissions. In addition, Congress passed the Energy Act of 2005, which asked the FAA and U.S.EPA to look at U.S. aircraft impact on air quality and how to mitigate the potential impacts. The following strategies to reduce aircraft impacts are currently being investigated. Optimization of surface operations by reducing aircraft taxi and idle times at airports can reduce local emissions. Continuous descent approach

(already in use 25% of time at LAX) reduces noise, NOx and fuel consumption over the traditional step-down approach. Historically, new technology accounts for 90% of reductions since new aircraft will have reduced emissions. The underlying ICAO principles for standard-setting are technology feasibility, economic reasonableness, environmental benefits, and environmental interrelationships and tradeoffs. ICAO's current standards address CO, NOx, unburned hydrocarbons and smoke. Standards do not currently exist for PM or CO_2. ICAO is currently investigating a new NOx standard that is more stringent than the one adopted in 2005, and FAA is pursuing alternative fuels in parallel. ICAO is working on noise and fuel burn standards for 2010. Greenhouse gas emissions are going to be the most significant future challenge.

8. Mr. Roger Johnson presented the 2005 on-airport emissions from major source categories (i.e. aircraft, ground support equipment, vehicles, APU, and stationary sources) and a proposed study to start in 2008 that will update these emissions by source category as well as model their impacts on the surrounding communities. As the most comprehensive airport study to date, on and off airport sampling, source identification, and chemical dispersion modeling will be performed. The off-airport sampling will take place in the surrounding communities. Dispersion modeling and chemical mass balance modeling will be performed with the monitoring data. Preliminary data has suggested that emissions from other sources (e.g., ships in the marine channels offshore) are affecting the area around LAX more than airport emissions. The goal of the upcoming study is to identify which sources contribute the most to local air quality so that they can be controlled. LAX must address the increased demand in air travel that Los Angeles will experience in the future. However, LAX expansion will increase emissions, especially those due to regional vehicles that travel to and from the airport. Emissions due to LAX can be broken into two categories, those due to on-airport sources and those due to regional ground transportation to and from the airport. On-airport emissions of VOC, NOx, CO, SOx, and $PM_{2.5}$ are dominated by aircraft while regional vehicles are responsible for the majority of total airport-related emissions. Vehicles traveling to and from the airport emit 42% of NOx, 63% of VOC, 73% of CO, and 90% of PM10. When considering both on- and off-airport sources, aircraft still account for 40% of NOx and 83% of SOx emissions. LAX plans to implement emission reduction measures such as completing 100% gate electrification, gate pre-conditioned air (50% now and 100% by 2015), 100% zero emission ground service equipment by 2015 (technology doesn't yet exist for all vehicles), and 100% cargo and maintenance ramp ground power by 2015. However, only 17% of ozone precursors will be reduced from the above measures, so there is a need to focus more on emissions from regional vehicles and aircraft.

9. Ms. Betty Hawkins presented the perspective of the airline industry. The Air Transport Association (ATA) is the oldest and largest U.S. airline association and represents the leading U.S. passenger and cargo carriers. ATA airlines and their affiliates transport 90% of the passengers and cargo in the U.S. ATA has an environmental department, an environmental council and is on the International Noise and Emissions Committee. Airlines are committed to minimizing

environmental impacts, such as climate change and local air quality, but noise issues must be continually addressed and safety remains the primary concern. Airlines are unable to bear the burden of cost for emissions reductions because in most cases they are unable to pass increased costs down to consumers. Since fuel is the most important cost for airlines, they are always striving to increase fuel efficiency, which will in turn reduce both greenhouse gas and local emissions. U.S. airlines have improved fuel efficiency by 103% since 1978, and ATA airlines have committed to an additional 30% fuel efficiency improvement between 2005 and 2025.

ATA is a member of ICAO, which sets uniform global standards for aviation. ICAO emission standards for aircraft engines are then adopted into national regulations by U.S.EPA and FAA. While airlines contribute about 2% of man-made CO2 and less than 6% of local emissions around most airports, aviation and its greenhouse gas emissions are growing. Airlines are constrained by structural limitations such as expensive equipment with long useful life, safety and operational imperatives, and technology lead times. Airlines are considering altering existing aircraft (i.e. engine/airframe modifications and advanced navigation aids) and investing in newer aircraft to increase fuel efficiency and reduce emissions. However, due to recent re-focusing of NASA program research and development, federal funds for technology development are limited. In addition, the Commercial Aviation Alternative Fuels Initiative, which is cosponsored by FAA, ATA and the Aerospace Industries Association (AIA), is investigating environmentally friendly alternative fuels. Airlines are also working on operational changes to reduce fuel consumption, such as weight reduction and shifting, reduced thrust at takeoff, and engine maintenance. Continuous descent arrivals, required navigation performance and area navigation, and transition to automatic dependant surveillance-broadcast are all being considered to shorten flight paths. Modernizing air traffic control will result in 10-15% reductions in emissions by minimizing delays and circuitous routings. A memorandum of understanding existed between the five South Coast airports and AQMD between 2002 and 2005, which resulted in greater than 4 tons/day NOx and hydrocarbon reductions compared to 1997 due to accelerated electrification of airport equipment and early conversion to low sulfur diesel.

10. Mr. Howard Aylesworth presented the AIA's environmental framework of manufacturing commitments. Mr. Aylesworth emphasized that all environmental concerns related to aircraft need to be addressed, including climate change and emissions at altitude, local air quality, aircraft noise, land use, water quality, and population changes. Furthermore, the solution to any one concern cannot constrain meeting other concerns. Of the concerns just listed, it is the manufacturers' responsibility to address emissions at altitude, local air quality and aircraft noise. AIA is focused on technology breakthroughs, aviation system efficiency and lower carbon fuels. Manufacturers are committed to reducing CO2 emissions from new aircraft by 15% or more while continuing to significantly reduce NOx and noise. Manufacturers are also partnering with airlines to achieve their environmental goals and industry and government to transform the air transportation system and qualify alternative fuels for aviation. Most of the

development will be on domestic, single-aisle planes and twin-aisle planes from international destinations. Due to inadequate public sector funding, the penetration of planes into fleets is currently at its maximum rate. Technologies for new aircraft generally result in a 15% CO2 reduction in each new generation along with further NOx and noise reductions. The air transportation system must be updated to eliminate congestion and delay, which result in unnecessary fuel burn that leads to increased emissions. While airlines pay the full cost of excess fuel burn, air traffic service providers and airports are not required to pay. Alternative fuels are also being considered, but there is currently no viable non-carbon fuel substitute. Thus, the goal is the introduction of a lower carbon fuel, such as synthetic biofuel, within ten years.

11. Mr. Will Dodds discussed engine technology development to address air quality concerns. Historically, reducing NOx has been the focus of engine development, but PM is now also being considered. Engines directly emit primary PM in the form of elemental and organic carbon. They also contribute to secondary PM formation from NOx and fuel sulfur emissions. Measuring PM is a challenge, so manufacturers are currently collaborating with PM measurement teams. ICAO is pushing both increased NOx stringency and improved PM measurement capability. In terms of NOx control, the challenge exists in controlling the aircraft engine's combustor temperature, which must operate at extremely high temperatures to get maximum fuel efficiency. Several design requirements must be met when manufacturing the combustor with safety being the highest priority. Current combustor designs balance all requirements. Higher combustor temperature leads to higher NOx emissions. To combat these emissions, lean-staged combustion and rich-quenched-lean (RQL) combustion are new combustion techniques being studied. These methods are complex and may not be feasible for some aircraft due to the many constraints already on their engines. NOx emission reduction may be enhanced due to improved engine performance (i.e. lower fuel consumption). Engine cycle tradeoffs must also be considered since a decrease in NOx may be accompanied by an increase in PM, CO and/or CO2.

Round Table Discussion

Highlights from the roundtable discussion include the following questions and topics and a summary of discussions. The entire roundtable discussion has been recorded and posted on AQMD's webcast page.

Dr. Joseph Lyou moderated the roundtable discussion portion of the forum. He led off by summarizing some important points to discuss during the afternoon sessions. These included:

1. What should be the focus of health impacts studies?
2. How should we address ultrafine particles from aircraft engines?
3. Which operational changes should we prioritize to achieve emissions reductions?
4. What should be the role of local and state agencies?

Health effects

The panel agreed that it is vital that further assessments be conducted on the health impacts due to aircraft emissions, but the question posed was how to accurately do this. The Southern California Particle Center representatives noted that better exposure assessment is necessary as well as discovery of the unique toxicological properties of aircraft-emitted PM. It is known that aircraft emit a large number of particles, and some chemical composition data has been collected. Health effects must be studied during the process and not after chemical characterization.

FAA added that a large scientific knowledge gap exists, and it is important to focus on the right things. Manufacturers would like to know what to fix before fixing it. Furthermore, efforts in California should be integrated with national efforts.

Monitoring

In order for manufacturers to know how to focus their efforts, monitoring metrics must be established. Representatives from academia noted that collaborations are underway to study aircraft as a source of ultrafine particles. The point was made that we must bridge the gap between atmospheric research and engine research. Research is trying to discover particle distributions and particle characteristics that are representative of jet aircraft. Ultrafine particles change on very short time scales, so continuous monitoring will be necessary to study them. In addition, because exhaust gases are converted into ultrafine particles downwind of the aircraft engine, ultrafine particle formation is heavily influenced by ambient conditions. Researchers are looking at the ratios between NOx/CO/PM to determine if aircraft is a source of localized emissions. The upcoming LAX airport study that focuses on exposure to aircraft emissions will have an ultrafine particle research component.

More research is needed to develop aircraft engine test procedures, and data must be gathered on the current fleet of engines to assess the test procedures. Similarities were drawn between aircraft and on-road vehicles in terms of testing ultrafine particle emissions. The European Union has developed a number standard for on-road vehicle engines. AQMD staff suggested that engine manufacturers begin to take particle number measurements during current engine development and testing. FAA is also looking into adding the ultrafine particle measurements to the PM roadmap engine certification procedure.

Aircraft Operational Controls and Strategies

Since there is an increase in commercial aviation, which dominates air travel, a large number of jets will be arriving and departing at traditionally lower traffic airports. Aircraft ground operations will have to be optimized to minimize congestion on runways where emissions are highest. AIA is currently investigating reconfiguration of taxiways to eliminate stopping and starting of aircraft on the ground. FAA announced a project at the John F. Kennedy Airport to start later this year that will precisely track aircraft in order to optimize airport surface operations. Similarly, LAX is analyzing their airfields to determine traffic flow in order to avoid delays that are projected in the future if nothing

is done to account for rising demand. NASA's Airspace Systems Program is a research program that focuses on increasing the efficiency of airport surface operations. A variety of other control strategies to reduce aircraft emissions are currently being evaluated at the national level.

Next Steps for Government Agencies

Engine manufacturers are requesting more support from NASA for research and development while NASA has shifted its funding priorities. NASA is focused on large carrier transports including passengers and cargo because they account for the majority of air traffic and air quality problems. Engine developers need to create a plan to determine which technologies are capable of making breakthroughs and then efficiently developing and demonstrating them. Public research funding is needed to match private sector funding. Since aviation is a federal issue, state and local agencies may be able to leverage PARTNER (Partnership for AiR Transportation Noise and Emissions Reduction) research funding by making supplemental funds available to researchers who are a part of this program. The FAA also invited staff from AQMD to join the advisory board to the PARTNER Center of Excellence, the environmental working group for the NextGen program, and FAA's Environment and Energy Subcommittee that manages FAA's investment in research and development.

Public Comments and Questions

The following is a summary of the public comments and questions received during the forum. Since the comments are paraphrased below, persons interested in the complete discussion should refer to the recorded proceedings on the AQMD webpage.

Public comments focused on odors, ultrafine particles and transportation alternatives. Residents in the proximity of Santa Monica Airport notice odors that they believe to be originating form idling aircraft. These residents would like the federal government to address the odor issue and determine what these substances are. In addition, one resident near Santa Monica Airport measured ultrafine particles and said that they correlated with increases in odors. This resident requested that source apportionment studies be conducted near Santa Monica Airport by placing monitors around the community. She also wondered whether AQMD could sponsor health effects research on ultrafine particles by bringing in medical doctors to evaluate biomarkers and other health outcome indicators.

AQMD staff indicated that further work is needed to understand the health impacts based on particle numbers. Particle mass has been the traditional metric correlated with health effects in epidemiological studies. It is not known if higher particle numbers are the cause of health effects, and they could in fact just as likely be driven by particle size, shape, and/or chemical composition.

A resident inquired as to whether alternatives (i.e., rail) to air travel could be explored to reduce aircraft emissions. She contended that rail to other parts of California and Nevada could alleviate demand for air travel and thus air traffic. Panel experts cited Europe as

having an extensive rail network and yet the highest growth of air carriers in the world. Rail travel in the U.S. is not effective for long distances due to infrastructural and time constraints.

Closing remarks

Mr. Henry Hogo, Assistant Deputy Executive Officer – Mobile Source Division, provided the closing remarks for the Forum. He noted that the staff perspective is that AQMD needs to look at both regulatory and non-regulatory approaches that aim to reduce existing and future emissions in order to attain $PM_{2.5}$ and ozone standards. AQMD staff would like to work with all stakeholders to develop the next AQMP so that the aircraft emissions source category is appropriately addressed. AQMD encourages engine manufacturers to look at reductions of all pollutants (greenhouse gases and criteria pollutants) concurrently as well as investigate both near and long term strategies to reduce emissions.

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