Excerpts from ORD's Clean Air Multi-Year Plan

The following pages contain excerpts from EPA's Office of Research and Development (ORD)'s Clean Air Multi-Year Plan describing the transition from a PM-focused research program to an air research program. These excerpts focus on the shift towards multi-pollutant research and explain the reasoning behind this shift. Additionally, selections from the text outlining major policy challenges and science needs in the Clean Air Program are included.

I. INTRODUCTION

A. Program Purpose

Air pollution continues to have adverse impacts on the human and environmental health of the United States, despite clear evidence that overall air quality has improved.[1] The *EPA Strategic Plan 2006-2011* (Strategic Plan) identifies Clean Air and Global Climate Change (Goal 1) as a primary goal for environmental protection with its first objective being Healthier Outdoor Air, and its second objective, Healthier Indoor Air.[2] EPA's Strategic Plan Goal 1 also establishes an objective to provide and apply sound science to support the goal of clean air by conducting leading-edge research to support regulatory decisionmaking. This research provides the scientific foundation to develop regulations and advanced tools and models to implement air quality standards and controls by the States, EPA Regions, and tribes. At the same time, the research program strives to develop better ways to track progress in achieving health and environmental improvements under this goal. The Clean Air Research program targets this first objective by providing the science needed to review, attain, and maintain ambient air quality standards required to protect public health. This research, together with the rest of the Clean Air Research program, has the added benefit of addressing risk reduction from a number of toxic air pollutants, and increases in the number of Americans experiencing healthier indoor air in homes, schools, and office buildings. Although the Clean Air Research program considers within its overall goal the reduction of air pollution impacts on ecosystems and visibility, research specific to the protection of public health remains the top priority of the Office of Research and Development's (ORD's) clients.

In 2007, the White House Office of Management and Budget (OMB) found that reductions in hospitalizations and emergency room visits, lost work and school days, and premature deaths account for the greatest expected benefits of air pollution regulation. Between 1996 and 2006, OMB attributed an annual savings of $63 to $430 billion to the development and implementation of air pollution regulations–most notably from control of particulate matter (PM).[3] The benefits of air pollution regulation accounted for ~94% of estimated benefits from all EPA regulations and ~63 to 88% of estimated benefits across all federal agencies, while costing an estimated $25 to $28 billion to implement over this same period.

ORD has developed multi-year plans (MYPs) in a number of program areas to describe the research ORD proposes to accomplish over the next several years. The MYP is intended to provide a vision of the research program and the programmatic rationale for its intended directions. In addition, the MYP provides an up-to-date, structured listing and description of the significant expected outputs from its research, which serves to communicate across ORD and

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[1] These data are summarized in the Air Quality Criteria Documents for PM (10/29/04 - http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=87903) and Ozone and Related Photochemical Air Pollutants (01/31/05 - http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=114523). Risks from Hazardous Air Pollutants possess even greater uncertainty (http://www.epa.gov/ttn/atw/nata/natsa4.html). Additional information on trends in air quality and emissions can be found at the Office of Air and Radiation site: http://www.epa.gov/air/airtrends.

[2] EPA Strategic Plan 2006-2011 (Goal 1: Clean Air and Global Change; Objectives 1.1, 1.2, 1.6; p. 11) – http://www.epa.gov/ocfo/plan/2006/goal_1.pdf.

[3] Draft 2007 Report to Congress on the Costs and Benefits of Federal Regulations – Tables 1.1 and 1.2; pp. 7-8; - http://www.whitehouse.gov/omb/inforeg/2007_cb/2007_draft_cb_report.pdf.

with stakeholders, clients, and reviewers. Multi-year planning permits ORD to consider the strategic directions of the EPA and how research can evolve to best meet the EPA's mission of protecting public health and the environment.

This MYP supports the goal of Clean Air by defining the research needed to answer key questions regarding the development and implementation of National Ambient Air Quality Standards (NAAQS)–primarily targeting PM and ozone as high-risk pollutants. In addition, it also supports, although secondarily, the goals of managing hazardous air pollutants (HAPs)This MYP includes a major shift in the Clean Air Research program by combining several program areas that previously had targeted air pollutants individually (e.g., PM, ozone, HAPs)Although it is essential to provide support for the various NAAQS pollutants that continue to be regulated individually, a multipollutant research program better reflects the complexity of real-world air pollution problems and parallels the evolving scientific and regulatory context. The Clean Air Research program uses the science-based framework, shown in Figure 1, developed by the National Academy of Sciences' (NAS's) National Research Council (NRC) in 1998 and modified by the Air Quality Research Subcommittee (AQRS) of the Committee on Environment and Natural Resources (CENR) in 2007 to identify those pollutants and sources responsible for the greatest health risk. Critical components of this research are used to develop an understanding of how pollutants from sources impact ambient concentrations, how these concentrations relate to exposures, and, in turn, how exposures relate to health outcomes. This information provides the fundamental linkages for evaluating health impacts, ascertaining which sources are most egregious in terms of health risk, and in developing effective mitigation strategies.

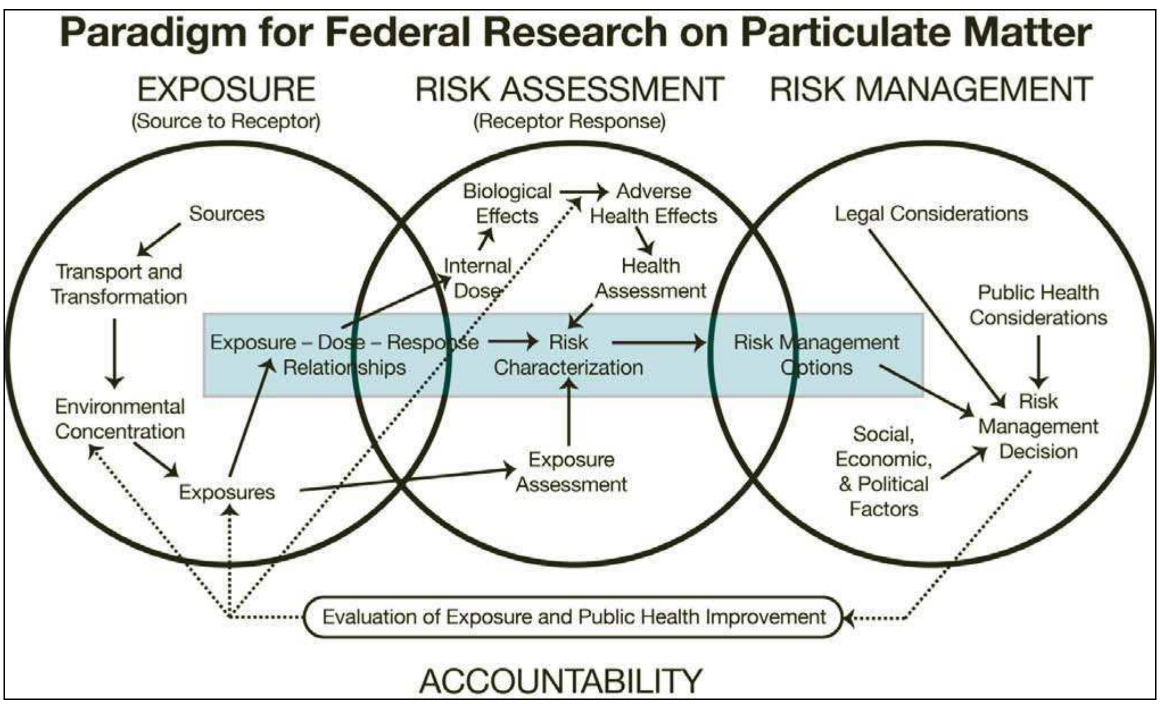

Figure 1. Paradigm for Federal Research on Particulate Matter[4]

[4] From http://www.esrl.noaa.gov/csd/AQRS/reports/pmplan.pdf

The transition to an air research program emphasizing both "source to health outcomes" and multipollutant approaches reflects the recommendations of EPA advisory boards and the reorganization of the Office of Air Quality Planning and Standards (OAQPS). The NRC, over the period of 1998 to 2004, developed for EPA, under a Congressional directive, a series of documents to guide PM and copollutant research. The last report (April 2004) recommends that EPA adopt a broader multipollutant research perspective, and increase its efforts to link observed heath outcomes with specific components and sources of PM.[5] This approach was endorsed by EPA's Board of Scientific Counselors (BOSC) in 2005.[6] Likewise, following the lead of a related NRC report entitled "Air Quality Management in the United States," the Clean Air Act Advisory Committee (CAAAC)[7], consisting of representatives from EPA, State and local agencies, tribes, industry, and environmental and research organizations, also strongly endorsed a broad air quality, rather than a pollutant-by-pollutant, approach for more effective air quality management. Finally, in keeping with the CAAAC recommendation, OAQPS, which is a main client of the ORD Clean Air Research program, has reorganized away from pollutant-specific groupings to a more sector-based structure to improve HAPs control and air quality assessment. Based on the combination of guidance from external advisory boards and the evolving needs of our clients, the focus of the Clean Air Research program was adjusted to support this more realistic, yet complex air pollution approach.

B. Program Design

In support of the broader EPA and ORD Strategic Plans, this MYP provides a focused strategy for Clean Air Research for ORD laboratories and centers and identifies linkages to other relevant MYPs such as the Human Health Research program (HHRP) and the Human Health Risk Assessment (HHRA) program. It provides a "roadmap" built on the progress that ORD has made since 1998 when PM rose to prominence via Presidential and Congressional mandate.[8] The roadmap, however, is intended to be sufficiently flexible to facilitate responsiveness to unforeseen changes and developments in the complex scientific landscape ahead.

The development of this roadmap is reflected in the diagram illustrated in Figure 2, which outlines the progression of scientific research from the recognition of need to use the new information with its impact on human and environmental outcomes.

The fundamental problem-driven question that drives the Clean Air Research program is "How can we reduce health risks associated with exposure to air pollution?" The ability to adequately address this overarching question requires that ORD maintain and continue to develop its core research capabilities across a diverse range of scientific disciplines, including: cell, animal, and human toxicology; epidemiology and biostatistics; human exposure; source emissions characterization and analysis; source apportionment; ambient measurements; atmospheric chemistry; air quality modeling and forecasting; and technology evaluation and assessment.

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[5] National Academy of Sciences (NAS) National Research Council (NRC): Research Priorities for Airborne Particulate Matter: http://books.nap.edu/catalog.php?record_id=10957.
[6] BOSC Report on the PM-Ozone Program Review: April 2005 - http://www.epa.gov/osp/bosc/pdf/pm0508rpt.pdf.
[7] http://www.nap.edu/catalog/10728.html.
[8] "*Particulate Matter Research Program: Five Years of Progress*" released in February, 2004, which summarized the achievements of EPA's research program in advancing our understanding of both health/exposure and air quality issues through early 2003 (http://www.epa.gov/pmresearch/pm_research_accomplishments/).

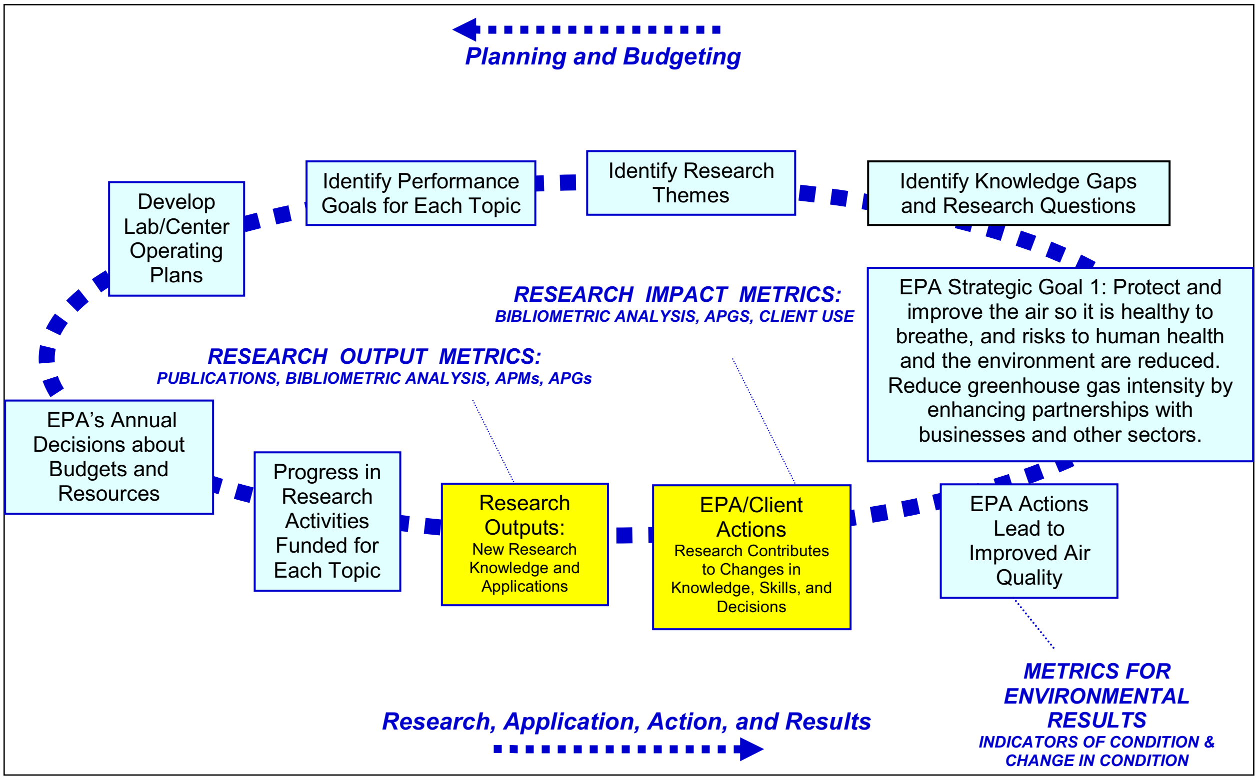

Figure 2. Logic Diagram.

These fundamental capabilities are leveraged within the Clean Air Research program and ORD to maximize project output, science relevance, and resource efficiencies. The goal is to not only address research questions of immediate importance to reducing air pollution health risks, but provide the foundation to anticipate and solve future environmental problems.

ORD structures its research agenda to address its clients' needs and the research priorities identified by the science community. As detailed below in the research plan, key long-term science goals (LTGs) are established from which critical questions are fashioned to frame the research over the next several (~5) years. Researchers work with their Laboratory/Center (L/C) representatives to develop annual performance goals (APGs) that collectively achieve the LTGs over a period of years. More specific annual performance measures (APMs) collectively provide the comprehensive body of research to support a given APG. As such, the APMs are the science building blocks that describe the products expected from the relevant scientific research. Thus, to reflect the overall program investment and to be effective, this MYP places considerable emphasis on the planning and the integration of research. Importantly, however, some latitude for novel and creative initiative is built within the program in an effort to link fundamental science and breakthroughs with known, pressing air pollution problems.

The plan and its science are reviewed at several stages along its development. A Research Coordination Team (RCT) comprised of senior scientists and managers from each ORD Laboratory and Center and multiple representatives from interested client Offices and Regions reviews the priority structure and overall framework of the various LTGs and APGs. The RCT also reviews the APMs and the descriptors that accompany them to gain insight into the plan and its anticipated products. Indeed, the APMs in many cases arise from discussions with members of the RCT in the early stages of MYP development.

To ensure the utility and recognition of delivered products, each APG has a designated ORD lead and a client (partner)-advocate who communicate throughout the life of the. This regular discourse is designed to ensure progress, the communication of findings, and appropriate distribution of the anticipated product to the client/partner office and broader community. Finally, the MYP has been reviewed by ORD's Science Council and an external review panel (i.e., BOSC) for scientific soundness. However, it is important to appreciate that the MYP is regarded as a "living document" meant to serve as a roadmap with important science milestones, while maintaining sufficient fluidity to absorb the newest findings and the ability to evolve from there. Naturally, as workforce and fiscal resources are increasingly constrained, the final MYP reflects primarily the highest research priorities, with the intent of achieving the most effective program possible within ORD's direct and leveraged resources. As described below, the program design and implementation considers major policy challenges, external program reviews, the capabilities of the ORD laboratories and centers, partner needs, ORD partner capabilities, and all available resources.

1. Major Policy Challenges and Science Needs

The Office of Air and Radiation (OAR) is responsible for multiple policy areas regarding the "air" environment and, as such, comprises several offices with specific, yet wide-ranging functions: OAQPS–ambient air regulation and rule implementation; the Office of Transportation and Air Quality (OTAQ)–fuels and mobile sources; the Office of Radiation and Indoor Air (ORIA)–indoor environments; the Office of Atmospheric Programs (OAP)–air quality through market systems, ecosystem protection, and climate; and the Office of Policy Analysis and Review (OPAR)–policy and rule analysis. Facing an array of complex policy decisions that rely on the latest and most robust science, OAR is a major user of clean air research. As a result, representatives of OAR are members of the RCT and provide invaluable advice to ORD as it develops its research agenda. Because the EPA Regions, States, and tribes are critical to rule implementation, they themselves frequently have specific and immediate needs (some research, some advisory) that ORD is challenged to address.

With finite resources, priorities or scaled emphases across needs are requisite if adequate and timely progress (products) is to be achieved. As already noted, program priorities are established within the RCT where partner needs and the appropriate science support can be negotiated collectively toward consensus products. Although resources are critical in the final program development, prioritization uses broad criteria, such as the likely magnitude of public health impact, the narrowing of the greatest uncertainties affecting decision-making, and the anticipation of information needed to support future OAR decisions or directions. The goal is to achieve a research program structure that best meets these criteria. Because PM and ozone score highly among these criteria and are NAAQS pollutants, they remain central to ORD's Clean Air Research program (for both standard setting and implementation) and garner considerable attention among other NAAQS and air toxic pollutants.

The challenges and needs of ORD's clients/partners in the program offices and as users in the field are many and multifaceted, and, therefore, this MYP cannot possibly address every research issue identified as a need. Instead, OAR's highest priority regulatory and policy challenges related to air quality that require the most significant research investment are highlighted below. Within the challenges and needs expressed below, an attempt was made to reflect the perspective of the user including those at the Office, Regional, State, or local levels.

a. NAAQS Setting and Implementation. The protection of public health (including susceptible populations) through the development and attainment of appropriate, protective air quality regulations is fundamental to the tasked mission of OAQPS. Clearly, meeting these regulations in the most cost-effective and efficient manner is in the best interests of public health, the environment, and the economy. There are six NAAQS that undergo repeated, periodic review to meet the statutory requirement of the Clean Air Act (CAA), yet the estimated impacts of reductions in ambient PM and ozone continue to drive the bulk of the public health benefit. The other NAAQS also factor into the overall air pollution burden, but their risks appear less substantial because of less exposure risk and/or ambient reductions, with lead recently gaining renewed emphasis because of public interest and health impacts at levels not previously appreciated. The uncertainties across the NAAQS are similar in magnitude and potential public impact, and, as a result, the uncertainties underlying the standard setting process for PM and ozone (with their potential impacts) sustains these two pollutants at the highest priority. Between these two NAAQS themselves, the risks and benefits associated with PM and its reduction in ambient air has retained the highest ORD interest and, hence, emphasis on PM.

More specific challenges related to the review of the PM and ozone NAAQS that require research support include:

- uncertainties surrounding the $PM_{2.5}$ standards,
- uncertainties surrounding the PM_{10} standard (*vis a vis* coarse PM),
- level and form of the ozone and PM standards,
- uncertainties regarding co-pollutants in PM-associated health effects,
- the potential for interactions between PM and ozone in health outcomes,
- definition / characterization of populations that may be susceptible to pollutant effects, and
- potential for an alternative to the mass-based PM standard through identification of hazardous components.

More specific challenges related to NAAQS implementation that require research support include:

- continuing nonattainment problems (post-sulfur/nitrogen controls),
- uncertainties around predicting impacts of control strategies on air quality,
- development of improved methods to effectively and rapidly measure pollutants,
- uncertainties around the input variables for refinement of air quality models,
- uncertainties around which sources contribute to ambient levels of PM, and
- development of improved emission inventories.

Much of the current Clean Air Research program focuses on these challenges. As will be detailed below under LTG 1, providing the research that underlies the development and implementation of the NAAQS is at the core of the research program. As the program evolves, as described in this document, these research activities are being leveraged to expand both the level of understanding of these NAAQS and the broader array of air pollutants and their effects alone and as mixtures.

b. Mobile and Stationary Source Air Toxics. The 1990 CAA requires EPA to reduce emissions and exposures to 188 specified HAPs (also known as air toxics). Air toxics emissions arise from major stationary sources, smaller (area or point sources), on-road (cars and trucks), and non-road sources (trains, construction equipment, barges, airplanes, etc.)Through implementation of the Maximum Achievable Control Technology (MACT) program, many stationary sources have installed available technologies to address risks of the 188 air toxics. The key challenge now facing the EPA is to determine if there are unacceptable remaining ("residual") risks after these technologies have been installed. There is need for refined emission inventories of HAP emissions to support these residual risk determinations and to better estimate potential community exposures. Because air quality monitoring of the HAPS is more limited than with the NAAQS, the quality of the National Air Toxics Assessment (NATA) for the various HAPs is highly dependent on these inventories to model potential exposures.

One of the more significant challenges to upgrading the current emission inventory is the assessment of those sources emitting pollutants over a wide geographic area rather than from a single point source (e.g., a smoke stack). These sources can range from landfills to refinery leaks. It will be critical to get a better handle on these emissions and understand the associated public exposures to address such risks through residual risk standards or other regulatory designations (area source standards). The NATA focus at present is on 177 HAPs thought to be of greatest risk (by virtue of estimated exposure or compound toxicity) and on diesel exhaust emissions. The hazard and dose-response analyses to support assessment of noncancer and cancer risks from exposure to HAP compounds are being developed by the Integrated Risk Information System (IRIS) program (in the HHRA program) using published data. Nevertheless, there is significant need for information (e.g., mode of action, models) that can be used more broadly to reduce uncertainty in risk assessments related to HAPs in the ambient environment.

Research among the HAPs is targeted in certain areas and otherwise leveraged from the NAAQS program. The Health Effects Institute (HEI) provides a significant research base among selected HAPs as to their risk as point sources or local "hot-spots." [9] Other research utilizes source-based approaches to conduct health research (e.g., diesel) or emission assessments (including methods development) as described above. As these provide insight into the PM issue, their investigation has importance across client information needs. The use of specific HAPs as models that relate to PM or its effects is also supported; however, specific study of HAP toxicity or its dose-response for IRIS is generally not part of the sponsored program.

c. Near-Road/Traffic. Emerging information linking human proximity (living, working, or school environments) to roadways with a range of adverse health effects has led to growing public concern. These concerns have been communicated through OTAQ, ORIA, and OAQPS, as well as from the EPA Regions as an area of great uncertainty, despite its priority. In fact, concerns over potential health impacts from exposure to emissions near roadways have affected several

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[9] HEI publications on air toxics: http://pubs.healtheffects.org/topics.php?topic=1&sort_by=pubdate&order=desc.

transportation projects across the country, as well as a variety of policy decisions. Among these are findings with respect to "conformity" of transportation plans and projects with State Implementation Plans (SIPs) for attainment of the NAAQS and local decisions regarding the location of schools and other projects (e.g., freight terminals) as required under the National Environmental Policy Act (NEPA). These policy decisions are being made even though the scientific uncertainties for the linkages to exposure, hazardous agents, and adverse health effects vary greatly.

Near-road concerns cross a number of priorities among program clients. Mobile source emissions comprise several HAPs (e.g., benzene, aldehydes, butadiene) as well as several NAAQS (carbon monoxide, nitrogen dioxide, PM, lead). Most importantly, the emergence of traffic as a source signal in the PM arena presents this source category as ideal for study. As discussed further below, this source category has been selected as a prototype for multipollutant study.

d. <u>Moving Toward a Multi-pollutant Program to Support Air Quality Management Decisions.</u> Fundamental to a multi-pollutant approach to air quality management is the recognition of the demands on the science to unravel the complex nature of the contributing sources, the atmospheric chemistry, the human exposure/environmental deposition, and, of course, the associated health and ecosystem impacts. A venture into such a broader based perspective has begun with the recent review of the nitrogen oxides (NOx)/sulfur oxides (SOx) NAAQS (2007), where the ecological impacts of these pollutants were considered together. With NOx/SOx, the common theme of acidity and enhanced nutrients in the environment were used for the combined assessment. However, if a multi-pollutant framework is to be more widely embraced for the purpose of air quality management (human as well as environmental health), there is a real need for research to develop analytic approaches to assess multi-pollutant human and environmental health impacts, especially through multimedia pathways, with emphasis on indicators, benchmarks, and interaction-based algorithms. To achieve such a goal, the air pollution sciences will need unprecedented integration and will demand novel tools for assessment to aid interpretation, develop implementation plans, and assess their effectiveness (outcome). Adding to these needs as we move ahead in the 21st century, the challenge is heightened by the NAS recommendation that future policies for air pollution control be integrated with climate change criteria.[10]

OAQPS envisions the goal of a multi-pollutant approach to air quality as leading to a more effective means of achieving environmental benefits and recently has undergone a reorganization to reflect this multi-pollutant and sector-based (source) perspective. The office also has begun to evaluate the technical issues associated with multi-pollutant approaches[11] In this regard, a National Air Pollution Assessment (NAPA)–the next phase of NATA (for the year 2008)–is being developed to include both air toxics and NAAQS pollutants in the context of exposure and health risk and will further expand to include ecosystem and multi-media impacts. In addition, as OAQPS moves toward more comprehensive, "sector-based" approaches for addressing sources, there is a need to understand the amount and species of pollutants emitted from entire sectors and the technological options that are most cost effective in reducing highest source risks. This will

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[10] NAS "Radiative Forcing of Climate Change: Expanding the Concept and Addressing Uncertainties," Oct., 2005.
[11] The Multi-Pollutant Report: Technical Concepts & Examples: http://www.epa.gov/air/airtrends/studies.html.

require new tools and models that can be used by decision makers to evaluate sectors in an integrated manner.

Presently, the Clean Air Research program has a number of largely disconnected efforts regarding multi-pollutant research. These include varied efforts in atmospheric modeling, exposure measurements, and source characterization (methods and health). As described below in LTG 2, ORD multi-pollutant efforts are adopting a source-to-health outcome paradigm, with near-road impacts as the prototype for development of its research framework.

e. Assessing Health and Environmental Improvements Attributable to EPA Actions. There have been marked reductions in several of the NAAQS pollutants over the last two to three decades. Sulfur dioxide reductions and controls in combustion emissions have led to major environmental improvements with reduced acid rain and deposition, but the benefits of reductions in other pollutants have been more difficult to demonstrate in terms of health or ecology. Because of the tremendous complexities involved in attributing changes in health or ecological status to changes in air pollution alone, OAR has been challenged to find acceptable methods to show the benefits of its decision making. As such, OAR has communicated the need for tools to measure the impacts (in terms of benefits or reduced risk) of its decisions–an issue also known by the term, "accountability." CAAAC has called for an "overarching accountability framework" that includes a systematic effort to track air quality achievements and evaluate air program results. According to CAAAC, the EPA needs to move beyond the current approach of relying predominately on air quality measurements and develop and apply the capability and capacity to monitor, assess, and report on how changes in emissions impact air quality, atmospheric deposition, exposure, and effects on human health and ecosystems. There is also interest in ensuring that use of a specific technology or combinations of technologies to reduce air emissions in response to a particular regulatory requirement does not result in other unintended environmental emissions or releases of concern.

Currently, there exists no formally sponsored ORD effort to address these needs largely because of the complexity of the task and the many factors that exist as potential confounding. The HHRP has initiated a cross-program discussion in an attempt to meet this need across program areas, but, to date, this generic program has lacked the resources to be implemented. The Clean Air Research program has been working with OAQPS to develop a framework tailored to its needs, which builds on pilot activities such that a broader model can be built and substantiated. This concept is being incorporated into the design of all planned Clean Air Research program undertakings.

f. Indoor Air. People spend upwards of 90% of their time indoors. Understanding the infiltration of outdoor air with its diverse pollutants into the indoor environment is further complicated by contaminants from indoor sources. The public looks to ORIA for advice on indoor air problems, as well as overall guidance on the issue. ORIA, in consultation with ORD, generated a document entitled *Program Needs for Indoor Environments Research*, which included some key research needs related to chemical and biological indoor contaminants to support future OAR guidance and policy related to indoor exposure risks and guidance. Ideally, characterization of indoor pollutant exposures, arising from either indoor sources or infiltration from sources outdoors, provides the foundation for development of methods and strategies for controls and minimization of risk. Among the issues in the public eye are those related to asthma induction or exacerbation (from contaminants or biological allergens), especially in children. On a different note, there is also a growing movement related to green building design that increasingly will require information that can be used to perform unbiased analyses of building materials selection and installation procedures. For those buildings already in existence, the development of mitigation strategies with assessments for their effectiveness are of great interest, especially those that examine the effectiveness of EPA's Indoor Air Quality *Tools for Schools* guidance already in place (notably for schools located near major roadways). As such, in the implementation of the near-road research program, the Clean Air Research program is attempting to address selected information needs (e.g., school infiltration, effectiveness of solid and vegetative barriers).

g. Ecological Research. The impact of air pollution on the ecosystem has long been appreciated, especially with regard to acid deposition. To that end, the work of ORD has contributed significantly to the steady reduction and ongoing assessments of that environmental stressor. Given the need to review the secondary NAAQS that address welfare (notably ecological) impacts of air pollutants, OAR continues to request support for data collection in the field and associated assessments. With the passage of the Clean Air Interstate Rule (CAIR) and Clean Air Visibility Rule (CAVR) in 2006, OAR's requests are underscored by the desire to develop measures for eco-accountability. As such, identification of indicators and profiles of wet and dry sulfur deposition are voiced as priority needs by OAR. New technologies also have been requested to facilitate these assessments and to address related contaminants such as nitrogen deposition from atmospheric ammonia. With the recent Supreme Court decision on carbon dioxide (CO_2) and growing climate and global change concerns, there likely will be an amplified cry for tool development and broad based assessments related to the interface of land and water. However, ORD's investments in these activities are limited and have been diminishing because of increasing annual fiscal constraints.

h. Global Climate Research. The recent Supreme Court decision on CO_2 and climate has expanded greatly OAR's interest in quantifying climate impact on health, air quality, and other socioeconomic and environmental systems. The linkages between air quality and climate are of growing importance, but little is understood. OAR has increased interest and need for enhanced models to incorporate better chemical, transport, and meteorological parameters both regionally and globally. The interactions between climate change and air pollution loom as a major issue of the 21st century, crossing all offices and program areas. OAQPS, in particular, has the challenge of trying to forecast the impact of longer ozone seasons (compounded by enhanced PM by transformation) and perhaps higher ozone levels on exposed human populations and ecosystems. The Clean Air Research program is partnering with the Global Change Research program to frame the nature of the issues and define specific research issues that can be integrated into both programs to maximize effectiveness. At present, these activities are limited to assessments and the development of a research framework.

i. Research to Support the Regions, States, and Tribes. The implementers of rules and policy decisions are faced with many technical issues. They rely on tools and models developed by ORD, as well as the latest technologies for monitoring and analyses. Cost efficiencies and quality assurance are major concerns when applying technological changes especially for rule changes. ORD must communicate these technology advances and assist in their field applications. The

Regions, States, and tribes also have unique and often immediate needs because of their specific geographies, socioeconomics, etc., that deserve attention from ORD. Assistance in the way of advice and consultation frequently is provided and opportunities for real-world field testing opportunities for ORD research activities is constantly sought. Nevertheless, the balance between long-range policy targeted research and crisis or problem-solving research can, at times, be strained and, thus, requires continual communication and nurturing.

II. THE CLEAN AIR RESEARCH MULTI-YEAR PLAN

A. Changes from the Previous MYP

This MYP combines and integrates three previous MYPs and research strategies (PM, ozone, and HAPs) into a single plan to better coordinate and leverage research across all themes. Earlier MYPs approached each program area separately with little cross-theme coordination and integration. Budgeting (both proposals and tracking) was also separate. As already noted, the science and regulatory programs are evolving toward a multi-pollutant perspective that better reflects the realities of human exposures and offers the potential for more effective control and public health protection.

At the core of this MYP is a major shift in ORD's approach to research in the air pollution sciences. Previously, each MYP relied on several loosely connected L/C-focused LTGs addressing a wide range of specific science supporting regulatory functions. The present MYP is shaped around two overarching LTGs that continue to support the regulatory requirements of the program office while developing the science to link health effects to air pollution sources and components. The latter approaches air pollution from its origin as source emissions, through atmospheric transport and transformation, to exposure, dose, and human health outcomes. It emphasizes science planning coordination to leverage across programs and achieve efficiencies in both science and budget. To this end, this MYP has adopted a two-pronged approach:

1. Continue to support the needs of EPA, and state and local governments, developing the underlying science for developing health-based standards to regulate air pollution regulations and developing tools to implement strategies to meet those standards to protect public health and the environment; and
2. Pursue scientific advances that will lay the foundation for the next generation of air pollution standards and management strategies.

B. Long-Term Goals

This dual approach is reflected in the adoption of two LTGs for this research plan:

LTG 1. In accordance with EPA's legislated mandate for periodic NAAQS assessments and assessment of HAP risks, advances in the air pollution sciences will reduce uncertainty in standard setting and air quality management decisions.

(*Short title*: Reduce uncertainty in standard setting and air quality management decisions due to advances in air pollution science.)

LTG 2. Air pollution research will reduce uncertainties in linking health and environmental outcomes to air pollution sources to support effective air quality management strategies.

(*Short title*: Reduce uncertainties in linking health and environmental effects to air pollution sources.)

The first LTG (LTG 1) supports the following two research themes:

1) Developing the NAAQS and other air quality regulations; and
2) Implementing air quality regulations.

The second LTG (LTG 2) is oriented toward three research themes

3) Launching a multi-pollutant research program,
4) Identifying specific source-to-health outcome linkages, with initial emphasis on "near roadway" impacts, and
5) Assessing the health and environmental improvements due to past regulatory actions.

LTG 2
Air pollution research will reduce uncertainties in linking health and environmental outcomes to air pollution sources to support effective air quality strategies.

This goal represents a major strategic change in the ORD's Clean Air Research program. It envisions an approach to air pollution research that attacks the problem from a multi-pollutant perspective, encompassing all aspects of air pollution from source to health outcomes. It brings together three themes that are complementary and support one another and yet relate and expand the two themes comprising LTG 1 (Figure 5). Following the two themes of LTG 1, the themes of LTG 2 include: 3) launch a multi-pollutant research program to better reflect the nature of real world air pollution; 4) develop a source to health outcome approach to more effectively address air contamination, starting with the near-road issue; and 5) develop a framework for assessing the health and environmental impacts of EPA regulatory activities (i.e., accountability). For each theme, Table 3 aligns the APGs abbreviated as underlined phases within the narrative below.

Implementing LTG-2 within the program promotes leveraging of ORD research activities to include under-funded goals within a broader framework, and more a logical orientation of the Clean Air Research program with the recent reorganization of our major client office, OAQPS.

Theme 3: Develop a multi-pollutant approach to research

Air pollution is a complex mixture comprising hundreds of primary emission products and secondarily transformed pollutants dispersed in ambient air. As such, in developing a multi-pollutant research activity to address associated risks, there must be consideration of the inherent toxicity of each constituent of the mixture, the likelihood of exposure to these constituents, and, even more challenging, the potential interactions among these constituents (which, in the end, may result from unique characteristics of toxicity or exposure because of these interactions).

From a health perspective, noncancer effects are seemingly dominated by just a few pollutants (e.g., PM, ozone, CO, aldehydes) and, likewise, cancer effects involve specific classes of polycyclic organic compounds, and select metals and organic vapors. Indeed, PM is itself a complex mix with health impacts (both noncancer and cancer) that, to date, are best described as associated with PM mass. However, it remains difficult to attribute health effect observations completely to any single pollutant or class of compounds. Further, the evidence available to evaluate hazard and dose-response is highly variable among pollutants, with human evidence rarely available for the hazardous air pollutants whereas substantial human evidence is typically available for the criteria air pollutants, resulting in greater uncertainty in characterizing potential health risks from exposure to the HAPs. Additivity, antagonism, and potentiation have all been observed with air pollutant mixtures, but because the phenomena are poorly understood, regulation is, at present, best achieved by single pollutant regulations.

Like PM itself, the chemistry of the general air pollution mix is more complex than the mere listing of the panoply of pollutants in ambient air. Many reactive gaseous and particulate components emanate from varied sources, which, through complex atmospheric chemistries, alter the atmospheric profile by consuming existent pollutants or creating new ones. Questions exist as to how PM as a complex mix in and of itself should be treated. Total mass is the default, but as a measure composite mass is not necessarily robust across all health outcomes and end points. Hence, questions are raised relative to what is known about the toxicity of mixtures. Co-pollutants may interact chemically or may act through the exposed host altering his/her sensitivity; much remains unclear. If PM (as a collage of primary source emissions and secondary transformation products) and ozone (a gaseous product of atmospheric transformations) have the most impact on health outcomes, what might be the most effective strategy to minimize public health risk? Currently, measurement of PM only by mass regulates all contributors equally. In contrast, ozone is measured as a singular end product even though there are uncertainties remaining as to which source emissions are most significant in its formation. These enigmas beg the question, Can air pollution controls be better focused on sources from which the emissions are ultimately the most toxic?

The challenge is to design a research paradigm to foster a logical and relevant transition from a single-pollutant research focus to a multi-pollutant approach, with the goal of controlling at the source to optimize health risk reductions. Initially, ORD must develop an integrated multiple pollutant research strategy (APG 16) that complements the goals and needs of ORD clients. Traditionally, systematic approaches to the assessment of pollutant mixtures have either started with a mixture and attempted to assess the driving components and/or interactions, or started with the component parts and built toward the mixture. Both approaches have merit and weaknesses and work best when used in a complementary, strategic manner. New “systems” approaches offer some guidance but, as yet, have had limited influence on the air pollution sciences. Part of any strategy, however, must involve deductive and inductive components. To the former, the Clean Air Research program will include multi-city/multi-pollutant studies (APG 19) to establish a matrix of diverse source exposures from which component-driven health impacts might be discerned. Epidemiological and toxicological studies will determine whether adverse health outcomes are associated with the various exposure scenarios and PM source-derived components. These data and findings can be compared with toxicology studies of defined laboratory source emissions, as well as controlled exposures to concentrated air particulates or other pollutants. Research will also be conducted to determine which sources and components humans are actually exposed to across cities. Integrating information from studies of specific sources and a hierarchy of associated toxicological potential, along with studies from cities with differing source profiles, will refine the assessment of risk and the criticality of pollutant type, character and source (integrated with findings from Theme 4).