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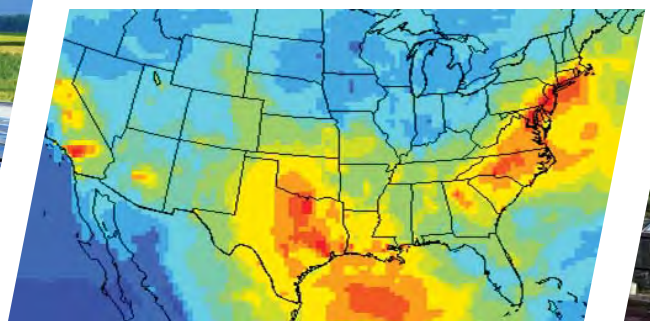
United States
Environmental Protection
Agency

Air, Climate, and Energy

STRATEGIC RESEARCH ACTION PLAN 2016-2019



Office of Research and Development
Air, Climate, and Energy

EPA 601/K-15/005

Air, Climate, and Energy

Strategic Research Action Plan 2016 - 2019

U.S. Environmental Protection Agency
September 2015

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List of Acronyms

ACE	Air, Climate, and Energy
AIMS	Atmospheric and Integrated Modeling Systems
BenMAP	Benefits Mapping and Analysis Program
CAA	Clean Air Act
CDC	Centers for Disease Control
CIVA	Climate Impacts, Vulnerability, and Adaptation
CMAQ	Community Multi-scale Air Quality model
CO	Carbon Monoxide
CSS	Chemical Safety for Sustainability
EM	Emissions and Measurements
EPA	Environmental Protection Agency
GHGs	Greenhouse Gases
GIS	Geographic Information System
HAPs	Hazardous Air Pollutants
HHRA	Human Health Risk Assessment
HSRP	Homeland Security Research Program
IRIS	Integrated Risk Information System
MA	Climate Impacts Mitigation and Adaptation
MARKAL	Market Allocation model
MDST	Modeling and Decision Support Tools
MOSES	Multicenter Ozone Study in Elderly Subjects
NAAGS	National Ambient Air Quality Standards
NMP	NAAQS and Multipollutant
NO_2	Nitrogen Dioxide
O_3	Ozone
ORD	Office of Research and Development
Pb	Lead
PEP	Protecting Environmental Public Health and Well-being
PM	Particulate Matter
R-LINE	Research Line
SEE	Sustainable Energy Evaluation
SEM	Sustainable Energy and Mitigation
SHC	Sustainable and Healthy Communities
SO_2	Sulfur Dioxide
SSWR	Safe and Sustainable Water Resources
STAR	Science to Achieve Results
USGCRP	U.S. Global Change Research Program
VG	Village Green

Executive Summary

This *Air, Climate, and Energy (ACE) Strategic Research Action Plan, 2016 to 2019* outlines a research approach to address the U.S. Environmental Protection Agency's (EPA's) objectives and mandates to take action on climate change and improve air quality. We have made great gains over the past 45 years in combating air pollution and, as a result, the air is much cleaner. However, that progress is now threatened by climate change and is complicated by the life cycles of new energy technologies which have both benefits and potential adverse effects. To tackle these increasingly complex 21st century problems, innovative thinking and sustainable solutions are needed to ensure a healthy and prosperous environment. To address these challenges that cross science disciplines and media – air, water, and land – we need science-supported models and tools that allow us to make more informed decisions and understand the potential consequences of those decisions.

The ACE research program integrates air and climate science with better understanding of how energy science and engineering interconnect these domains. The ACE research program was developed with considerable input from Agency partners and outside stakeholders and interacts with the five other national research programs of EPA's Office of Research and Development to address cross-cutting issues.

The ACE research program is structured to provide research results that fulfill EPA priorities and mandates, meet partners' needs, fill knowledge gaps, and complement broader efforts across the federal government, as well as research being conducted by the larger scientific community. The ACE research objectives are:

1. Assess Impacts—Assess human and ecosystem exposures and effects associated with air pollutants and climate change at individual, community, regional, and global scales;
2. Prevent and Reduce Emissions—Provide data and tools to develop and evaluate approaches to prevent and reduce emissions of pollutants into the atmosphere, particularly environmentally sustainable, cost-effective, and innovative multipollutant and sector-based approaches; and
3. Prepare for and Respond to Changes in Climate and Air Quality—Provide human exposure and environmental modeling, monitoring, metrics and information needed by individuals, communities, and governmental agencies to take action to prepare for and mitigate the impacts of climate change, and make public health decisions regarding air quality.

To achieve these objectives and address their scientific challenges, ACE research projects are organized into five interrelated topics: (1) Climate Impacts, Vulnerability, and Adaptation; (2) Emissions and Measurements; (3) Atmospheric and Integrated Modeling Systems; (4) Protecting Environmental Public Health and Well-being; and (5) Sustainable Energy and Mitigation. Each topic includes specific near- and long-term goals designed to yield solutions to address climate change and improve air quality. This *ACE Strategic Research Action Plan, 2016–2019* (ACE StRAP), describes those topics and the overall structure and purpose of the ACE research program. The research results and innovative tools will support EPA's work to protect air quality and to meet broader EPA legal and statutory mandates in the face of a changing climate.

Introduction

Protecting human health and the environment from the impacts of climate change and air pollution in a sustainable manner are critical 21st century challenges. These challenges are complicated by the interplay between air quality, the changing climate, and existing and emerging energy options. The U.S. Environmental Protection Agency (EPA) Office of Research and Development's (ORD) Air, Climate, and Energy (ACE) research program provides the essential and innovative science and engineering needed to address climate change and improve air quality.

The ACE Strategic Research Action Plan, 2016-2019 (ACE StRAP) outlines a four-year strategy for delivering the research results and solutions needed to: support EPA's mission to protect human health and the environment; fulfill the Agency's legislative mandates; and advance the cross-Agency priorities identified in the FY 2014-2018 EPA Strategic Plan (EPA Strategic Plan). The ACE StRAP is built on the needs of Agency partners and stakeholders and the application of cutting-edge science.

To help the program meet its ambitious objectives, the ORD has developed this StRAP, building upon the vision outlined in the original ACE StRAP released in June 2012, *Air, Climate, and Energy Strategic Research Action Plan, 2012-2016* (2012 ACE StRAP).[1] The 2016-2019 StRAP has been developed in collaboration with EPA Program and regional partners and ORD labs and centers involved with ACE, and through interactions with external stakeholders. The ACE StRAP aims to help ORD managers and scientists to better:

- Integrate ACE research
- Prioritize research to focus on key areas where ACE will lead science
- Demonstrate how research will be translated and actively delivered for use in Agency decision making
- Evaluate the impacts of ACE outputs on partner needs
- Explore and incorporate collaboration and leveraging opportunities across the national research programs and with external stakeholders.

The ACE StRAP is one of six research action plans, one for each of EPA's national research programs in ORD. The six research programs are:

- Air, Climate, and Energy (ACE)
- Chemical Safety for Sustainability (CSS)
- Homeland Security Research Program (HSRP)
- Human Health Risk Assessment (HHRA)
- Safe and Sustainable Water Resources (SSWR)
- Sustainable and Healthy Communities (SHC)

EPA's six strategic research action plans lay the foundation for EPA's research staff and their partners to provide focused research efforts that meet the Agency's legislative mandates, as well as the goals outlined in the EPA Strategic Plan. They are designed to guide an ambitious research portfolio that delivers the science and engineering solutions the Agency needs to meet its goals while also cultivating an efficient, innovative, and responsive research enterprise.

The ACE StRAP specifically outlines the research approach to achieve EPA's objectives to address climate change and improve air quality. It highlights how the ACE research program integrates efforts across ORD to provide an overall research portfolio aligned around the central and unifying concept of sustainability.

[1]See http://www2.epa.gov/research/air-climate-and-energy-strategic-research-action-plan-2012-2016.

Environmental Problems and Program Purpose

Integrating Air, Climate, and Energy Research: Turning Challenge into Opportunity

Ambient air pollution can have significant adverse consequences on human health and the environment. Research conducted and supported by ORD has demonstrated that exposure to air pollution can cause a range of human health and environmental welfare effects. These include, but are not limited to, respiratory and cardiovascular dysfunction that can lead to disease and mortality in humans as well as deposition-driven eutrophication and acidification in the environment. Research has informed and enabled the nation's efforts to curtail air pollution emissions and greatly improve air quality over the last 45 years. While we have seen enormous public health and economic benefits, approximately 127 million people in the United States are still living in counties that do not meet current national ambient air quality standards (NAAQS) for one or more criteria air pollutants.[2] Continued improvement in understanding of emissions, atmospheric processes, exposure, and effects is critical to ensuring continued improvement in air quality now and into the future.

Climate change is beginning to roll back some of these achievements, and is impacting human health and the environment in other, potentially serious ways. Climate change is leading to higher concentrations of some air pollutants and increasing stressors such as heat and allergens that may worsen health outcomes. Simultaneously the presence of some air pollutants in the atmosphere is affecting the rate of climate change itself. Furthermore, the warming climate is causing an increasing range of major and adverse effects on air quality, water resources, agriculture, wildlife ecosystems, contaminated sites and waste management practices, as well as the built environment (i.e., energy, infrastructure, and communities).

Researchers have shown that the emissions of greenhouse gases (GHGs) into the atmosphere are resulting in a change in the global climate. Even as initial steps are taken to reduce these emissions, the rate of responses of the atmosphere and oceans means that climate-driven impacts will continue to worsen for some time. In the absence of continued and expanded emission reductions, there is clear scientific evidence that the public health and welfare of current and future generations are at risk.

The nation will not successfully address climate change and continue improvement in air quality without a solid understanding of energy. The current mix of sources and technologies for energy production and use has major environmental impacts on air quality and climate. Not only does the current energy mix generally represent the major source of air pollution emissions, including GHGs, it also impacts water quality and demand and affects ecosystems and the services they provide. Meanwhile, the energy system is undergoing a substantial transition toward natural gas, renewable resources, and increased electrification as technologies emerge and evolve and as policies are introduced to reduce GHG emissions. Understanding of this evolution is crucial to developing and implementing future approaches to address climate change and improve air quality.

[2]Criteria pollutants are those pollutants for which NAAQS have been established. These pollutants include: particulate matter (PM), ozone (O_3), nitrogen dioxide (NO_2); sulfur dioxide (SO_2); carbon monoxide (CO); and lead (Pb).(http://www.epa.gov/air/airpollutants.html).

The challenges that span the nexus of air, climate, and energy, as well as the major related research needs identified by EPA partners and stakeholders guide both the **Problem Statement** that governs EPA's strategic research, as well as its **Program Vision**. The ACE team will continue to build on its foundation of past accomplishments to deliver the knowledge, tools, and data needed to meet them.

Problem Statement

Protecting health and the environment from the impacts of climate change and air pollution in a sustainable manner are central 21st century challenges. These challenges are complicated by the interplay of air, the changing climate, and emerging energy options.

Program Vision

EPA's Air, Climate, and Energy research program provides cutting-edge scientific information and tools to support EPA's strategic goals of protecting and improving air quality and addressing climate change.

The ACE research program examines the interplay of air pollution, climate change, and today's dynamic energy sector to develop innovative and sustainable solutions for improving air quality and addressing climate change. The results of research efforts support policies that have far-reaching positive impacts across the nation, including reducing health risks from air pollution, preparing for the impacts of climate change, and advancing more resilient and sustainable communities. Integrating the science and engineering issues inherent in the complex interactions of air quality, climate change, and energy into a seamless research program presents a substantial challenge to any research organization. From an EPA research perspective, however, it also presents an opportunity. Combining air, climate, and energy research activities enables the development of sustainable, integrated solutions that have synergistic benefits for public health, the environment, and the economy.

Program Design

This *Strategic Research Action Plan, 2016-2019*, provides both a vision and an actionable blueprint for advancing clean air, climate, and energy science. The ACE StRAP focuses research on meeting the priorities and legislative mandates of EPA. ACE works closely with its Agency partners and stakeholders, including sister federal agencies, nonprofit organizations, industry, and colleagues across the scientific community, to identify and conduct research to address the highest priority issues.

Building on the 2012-2016 Research Program

This plan builds upon and continues to advance the research outlined in the 2012 ACE StRAP. Guided by the previous plan, ACE researchers moved the state of the science forward and provided benefits to public health and the environment, as seen by the following examples:

- Exposure and health scientists advanced the science to enable the policy decision to lower the NAAQS for $PM_{2.5}$ based on clear benefits to public health.

- Researchers demonstrated the significance of vehicle and roadway emissions and developed models to show how roadside vegetative and noise barriers can reduce exposures for people living near heavily travelled corridors.

- Researchers developed more advanced modeling systems that have begun to tackle the complex interactions between air quality, environmental effects, and climate change from community to global scales.

• Researchers are working with various tools to study the possible environmental impacts of different scenarios of future energy technologies and changes in land use to provide insights into the consequences of future decisions on climate and air quality.

• Investigators have brought together technological advances, communities, entrepreneurs, and regulators to evaluate and deploy air quality sensors to forge a new future for community science that can enhance the amount and quality of air quality data available for consideration by communities, regulators, and scientists. These technologies are used by industries for cost-effective detection of leaks and fugitive emissions, and are providing communities with the knowledge to take local action to protect their air quality. This burgeoning area will continue to revolutionize monitoring science in the next decade.

The ACE regional and program office partners have expressed a need to build on much of the research originally envisioned and conducted under the 2012 ACE StRAP. With the dramatic improvement in the Nation's air quality, the partners' emphases have shifted toward implementing air quality standards, climate change, and the transition of the national energy portfolio toward greater reliance on natural gas and renewable energy. In response, the 2016-2019 ACE StRAP envisions a shift in relative priorities among air, climate, and energy research consistent with the mission and strategic directions of the Agency. This shift places a greater emphasis on the research that supports implementation and evaluation of existing policies and regulations, as they account for the current and expected impacts of climate change. The program will be more oriented toward identifying solutions to problems and improving the essential understanding of health and environmental responses, with less emphasis on problem identification. The ACE research projects are structured to anticipate a growing emphasis on climate change, which continues to require multidisciplinary approaches. The updated plan presented here organizes research into five related topics:

1. Climate Impacts, Vulnerability, and Adaptation
2. Emissions and Measurements
3. Atmospheric and Integrated Modeling Systems
4. Protecting Environmental Public Health and Well-being
5. Sustainable Energy and Mitigation

Specific examples of the evolving research are described in the Research Topics section.

EPA Partner and Stakeholder Involvement

Communication with EPA program and regional office partners occurs through a variety of formal and informal avenues. Monthly and quarterly updates provide a solid basis for communicating new or evolving needs as well as research progress. More formally, the program and regional office partners annually provide ACE with the research topics they need to meet their goals over the coming years. The ACE planning team incorporates this information into the draft research portfolio for the upcoming 1 to 2 years. The draft portfolio is presented to the ACE partners through a formal webinar and subsequent discussions. An annual formal two-day, project-level program review brings together all interested partners for more in-depth discourse and feedback on short- and long-term goals and outputs across the breadth of the ACE program. Finally, the ORD Assistant Administrator meets with the relevant partner Assistant and Regional Administrators to discuss research accomplishments and priorities.

ACE interacts primarily with the Office of Air and Radiation, the Office of Enforcement and Compliance Assurance, and the regional offices on issues related to air quality. On topics related to energy and climate change, ACE works most frequently with the Office of Water, the Office of Air and Radiation, the Office of Solid Waste and Emergency Response, and the regional offices. In addition, ACE involves the Office of Policy and the Office of Children's Health Protection in planning and communicating the program's research.

The ACE program receives guidance from stakeholders outside the Agency through various approaches. EPA's Science Advisory Board provides periodic review and feedback on strategic programmatic directions while the Board of Scientific Counselors has been established to provide ongoing management review. Less formal and indirect guidance is provided through interagency venues such as the Committee on Environment, Natural Resources, and Sustainability, and the U.S. Global Change Research Program (USGCRP). National and international science meetings and interaction with experts from across diverse disciplines also provide insights into pressing science and emerging environmental issues.

Through these interactions, ACE has developed a defined vision for future research. The ACE program is designed to leverage its activities not only across ORD, but notably with its program and regional office partners, and with science partners in other agencies and research organizations.

Integration across the Research Programs

EPA's six research programs work together to address science challenges. Coordination efforts can range from formal integration efforts across the programs, to collaboration among EPA scientists working on related issues.

To formally integrate research on significant cross-cutting issues, EPA developed several "Research Roadmaps" that identify ongoing relevant research and important science gaps. The Roadmaps coordinate research efforts and provide input that helps shape the future research in each of the six programs. Figure 1 illustrates the role of the roadmaps. Roadmaps have been developed for the following issues:

- Nitrogen and Co-Pollutants
- Children's Environmental Health
- Climate Change
- Environmental Justice

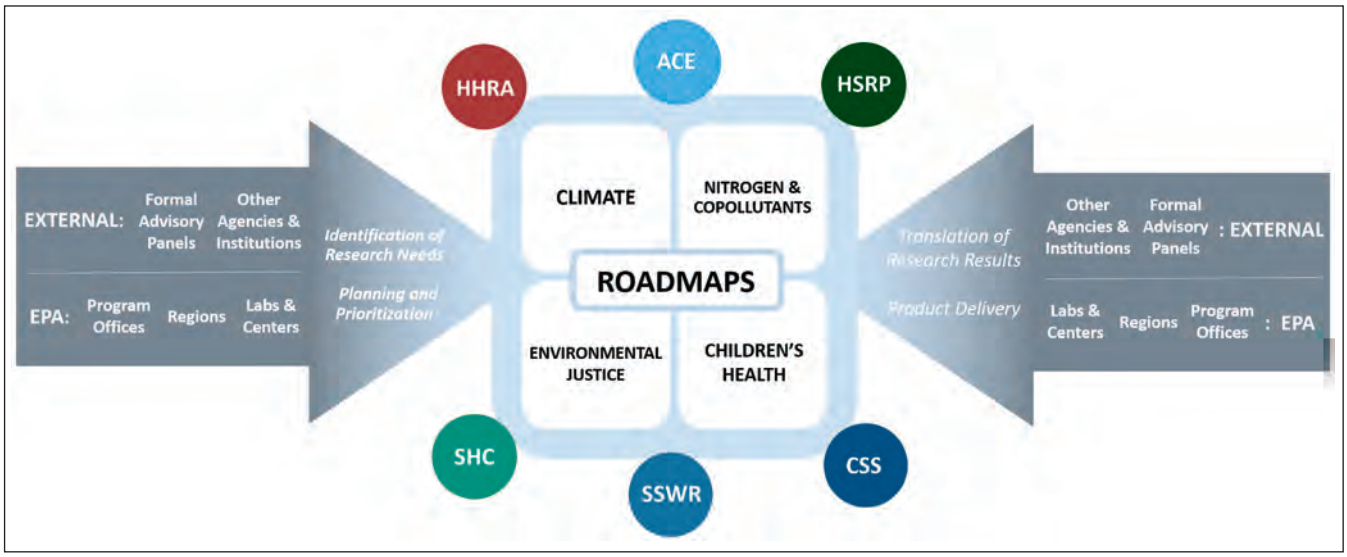

Figure 1. Cross-Cutting Research Roadmaps.

The ACE research program is the lead national program for the Climate Change Roadmap and provides the foundation for research on climate impacts, vulnerability and adaptation (see Topic 1, below). The impacts of climate change are expected to have dramatic effects on the nation's water infrastructure, watersheds and ecosystems, and communities. These effects will worsen current multimedia problems such as acidification and eutrophication of aquatic ecosystems, energy needed to maintain water and drinking water quality, and water demands for energy. The Climate Change Roadmap focuses on coordinating and integrating research across the ORD programs. Examples include climate change research with the Safe and Sustainable Water Research program on watersheds, community resiliency with the Homeland Security Research Program, and health impacts with the Sustainable and Healthy Communities program. The Climate Change Roadmap also highlights opportunities for integration, and connections to external groups, particularly through the federal climate research coordinating body, the USGCRP.

Table 1. Air, Climate and Energy (ACE) research program contributions to critical needs identified by ORD Roadmaps. Checkmarks indicate a larger contribution of ACE activities and interest in the identified science gaps of the roadmaps than a single checkmark; a blank indicates no substantive role. ACE is the lead research program for ORD's Climate Change Roadmap.

ORD Roadmap	ACE Topic Area				
	Climate Impacts, Vulnerability, and Adaptation	Emissions and Measurements	Atmospheric and Integrated Modeling Systems	Protecting Environmental Public Health and Well-being	Sustainable Energy and Mitigation
Climate Change	✓✓✓	✓✓	✓✓	✓✓	✓✓
Environmental Justice	✓✓	✓		✓✓	
Children's Environmental Health				✓✓	
Nitrogen & Co-Pollutants	✓	✓✓	✓✓	✓✓	

The Nitrogen and Co-Pollutants Roadmap guides integration between ACE and the SSWR program to address the issues of nitrogen and co-pollutants, both of which require study of atmospheric and aquatic systems. EPA/NIEHS Children's Environmental Health and Disease Prevention Research Centers (CEHCs), several of which focus on environmental justice and socioeconomic factors, funded through the SHC program, are firmly rooted in the long history of research tying air contaminants to health effects including asthma and respiratory infection. The Children's Health and Environmental Justice Roadmaps help ACE integrate relevant research in these areas with SHC and SSWR.

Additional opportunities for integration are being identified based on feedback from program and regional office partners and ORD scientists, as well as through guidance, innovation, and initiative of individual researchers who identify integration opportunities. Additional opportunities for integration and leveraging with ACE research across the research programs include:

1. SHC and SSWR– Life cycle assessment
2. CSS – High-throughput approaches to evaluate the toxicity of individual and mixtures of air pollutants
3. SHC – Public health impacts of air pollutants and at-risk populations and lifestages, especially asthmatics; development/application of air quality modeling tools
4. HHRA – Multimedia assessment of air pollutants; advancing cumulative risk assessment methods to address multipathway/multipollutant exposures and associated health and welfare effects; incorporation of ACE research into Integrated Science Assessments and Integrated Risk Information System (IRIS).

Research to Support EPA Strategic Plan

EPA's 45-year record of success in protecting public and environmental health from air pollution has relied on building a strong scientific foundation to inform policy decisions. Today, improving the Nation's air quality remains a major EPA priority, especially for those who reside in communities unable to fully meet air pollution standards or who may be at increased risk for health or sociodemographic reasons. Even more pressing is the Agency priority to address climate change, which has significant negative implications for human health and the environment. Climate change can directly affect human health through extreme high temperatures, and will indirectly affect health by increasing incidences of water-borne and vector-borne disease and changing allergen profiles. Increases in extreme weather events will place additional stresses on human health and the environment. Many of the gains of past air quality management decisions will likely be at least partially reversed by climate change. Even the indoor environment is stressed by climate change where pollutant penetration, indoor generated biological or other contaminants, and ventilation/heat issues pose evolving challenges to human health in the built environment.

In support of EPA's mission to protect human health and the environment, the EPA Strategic Plan identifies strategic goals and cross-cutting strategies (Table 2). The ACE research portfolio is designed to address the current and future needs of EPA partners as they develop and implement policies to achieve Goal 1, "Addressing Climate Change and Improving Air Quality." This requires close communication with Agency partners, as well as staying abreast of advances in the science. The increased focus on implementing air quality standards has led ACE to increase emphasis on monitoring and

sensors, air quality models, and emissions and emission inventories. The Agency's actions to develop policies to reduce GHG emissions and prepare for the impacts of climate change has resulted in a greater focus on understanding the effects of climate change on air quality, water quality, and, ultimately, human health and the environment. Looking ahead to anticipate our partners' needs under Goal 1, the ACE portfolio incorporates research to gain insights into potential benefits of multipollutant air quality management approaches and to understand how the energy system may evolve as technologies and policies change to address climate change or reflect technological advances.

Table 2. EPA Strategic Plan (FY2014-2018) Goals and Cross-Agency Strategies

EPA Strategic Plan (FY2014-2018) Goals and Cross-Agency Strategies
EPA Strategic Goals
Goal 1: Addressing Climate Change and Improving Air Quality
Goal 2: Protecting America's Waters
Goal 3: Cleaning Up Communities and Advancing Sustainable Development
Goal 4: Ensuring the Safety of Chemicals and Preventing Pollution
Goal 5: Protecting Human Health and the Environment by Enforcing Laws and Assuring Compliance
Cross-Agency Strategies
• Working Toward a Sustainable Future
• Working to Make a Visible Difference in Communities
• Launching a New Era of State, Tribal, Local, and International Partnerships
• Embracing EPA as a High-Performing Organization

In all of these areas, the Agency's priorities are focused on making a difference in communities. Communities challenged socioeconomically or co-located with heavy industry are of particular concern, as are tribal communities. Partnerships with the EPA regional offices and communities that involve collaborative research on real-world problems can provide results that are immediately useful. Hence, ACE pursues diverse approaches to address air quality-climate challenges, building from fundamental laboratory science to the community and national level, in an integrated effort to achieve and maintain air quality standards and other strategies to protect public health and ensure the resilience of the built and natural environments.

Statutory and Policy Context

The ACE research program has been designed to support the overall priorities of the Agency and the legislative mandates of its program offices, primarily the Clean Air Act (CAA). The CAA provides the legislative authority for efforts to improve and maintain air quality, and is also the basis for reducing GHG emissions through initiatives such as the Clean Power Plan[3], issued by EPA to cut carbon pollution from power plants. By informing decisions under the CAA, ACE research fosters innovative approaches based on sound science to ensure clean air in the context of a changing climate and evolving communities and energy options.

Under the CAA, the Agency is required to set and periodically review air quality standards to protect the public health and environmental welfare of the Nation. EPA establishes NAAQS for pollutants that cause serious health and welfare effects and are widely distributed across the country. To date, the Agency has

[3]See http://www2.epa.gov/cleanpowerplan/clean-power-plan-existing-power-plants

set NAAQS for six common air pollutants: particulate matter, ozone, sulfur dioxide, nitrogen dioxide, carbon monoxide, and lead. Of these, particulate matter and ozone appear to account for the majority of adverse health effects resulting from ambient air pollution. In addition to the NAAQS pollutants, the CAA requires EPA to regulate emissions of hazardous air pollutants or air toxics that are known or suspected to cause cancer or other serious health or environmental effects.

The CAA also provides the statutory authority for EPA to regulate GHG emissions, following the 2007 U.S. Supreme Court decision and the Administrator's issuance of the *Endangerment and Cause or Contribute Findings for GHGs*[4] in 2009. In addition, the Clean Water Act, Safe Drinking Water Act, and Resource Conservation and Recovery Act provide further context for actions to prepare for and adapt to the impacts of climate change. Additional policy context is given by the President's Climate Action Plan as well as Executive Order 13563, "Preparing the United States for the Impacts of Climate Change[5]."

To provide the scientific foundation for EPA's efforts to meet its legal, statutory, and policy requirements in a changing climate, the ACE research program will inform climate mitigation and adaptation choices towards sustainable, resilient solutions with maximum benefits for the Nation's people and environment.

Research Program Objectives

The ACE research program is structured to provide research results that fulfill EPA priorities and mandates, meet the needs of our partners, fill knowledge gaps within broader efforts across the federal government, and complement research being conducted by the larger scientific community.

The program is strategically divided into three broad research objectives that flow from the organizing frameworks depicted in Table 1, Figure 2, and the Agency priorities noted in the text above. The research supported through the ACE program addresses challenges specific to EPA priorities and emphasizes efforts to focus on the highest priorities identified by our partners and stakeholders. Figure 2 is a conceptual framework illustrating the intersection of air, climate, and energy. The Research Program Objectives are shown in the gray diamond. The five Research Topics shown in the base of the figure (discussed in more detail below) collectively encompass the research to address the Research Program Objectives. Important social factors that influence, and are influenced by, air quality, climate change, and energy outline the five research topics.

Together the research objectives provide a platform that encompasses the breadth and diversity of the science research issues and questions arising within the Agency's air-climate-energy domain. They are:

Objective 1: Assess Impacts

Assess human and ecosystem exposures and effects associated with air pollutants and climate change at individual, community, regional, and global scales;

Objective 2: Prevent and Reduce Emissions

Provide data and tools to develop and evaluate approaches to prevent and reduce emissions of pollutants into the atmosphere, particularly environmentally sustainable, cost-effective, and innovative multipollutant and sector-based approaches; and

[4]See http://www.epa.gov/climatechange/endangerment/

[5]See http://www.gpo.gov/fdsys/pkg/FR-2013-11-06/pdf/2013-26785.pdf

Objective 3: Prepare for and Respond to Changes in Climate and Air Quality

Provide human exposure and environmental modeling, monitoring, metrics and information needed by individuals, communities, and governmental agencies to take action to prepare for and mitigate the impacts of climate change, and make public health decisions regarding air quality.

Consistent with the principles and characteristics of all ORD research programs, the ACE research objectives and challenges outlined below are unified through a call for sustainable and innovative solutions to environmental problems. Sustainability and innovation will be reflected in activities that cut across the ACE research objectives and will be integrated at the program level.

Each research objective contains broad science questions to enable staff to apply their expertise and innovation to shape specific research activities to meet the overall strategic aims of the program.

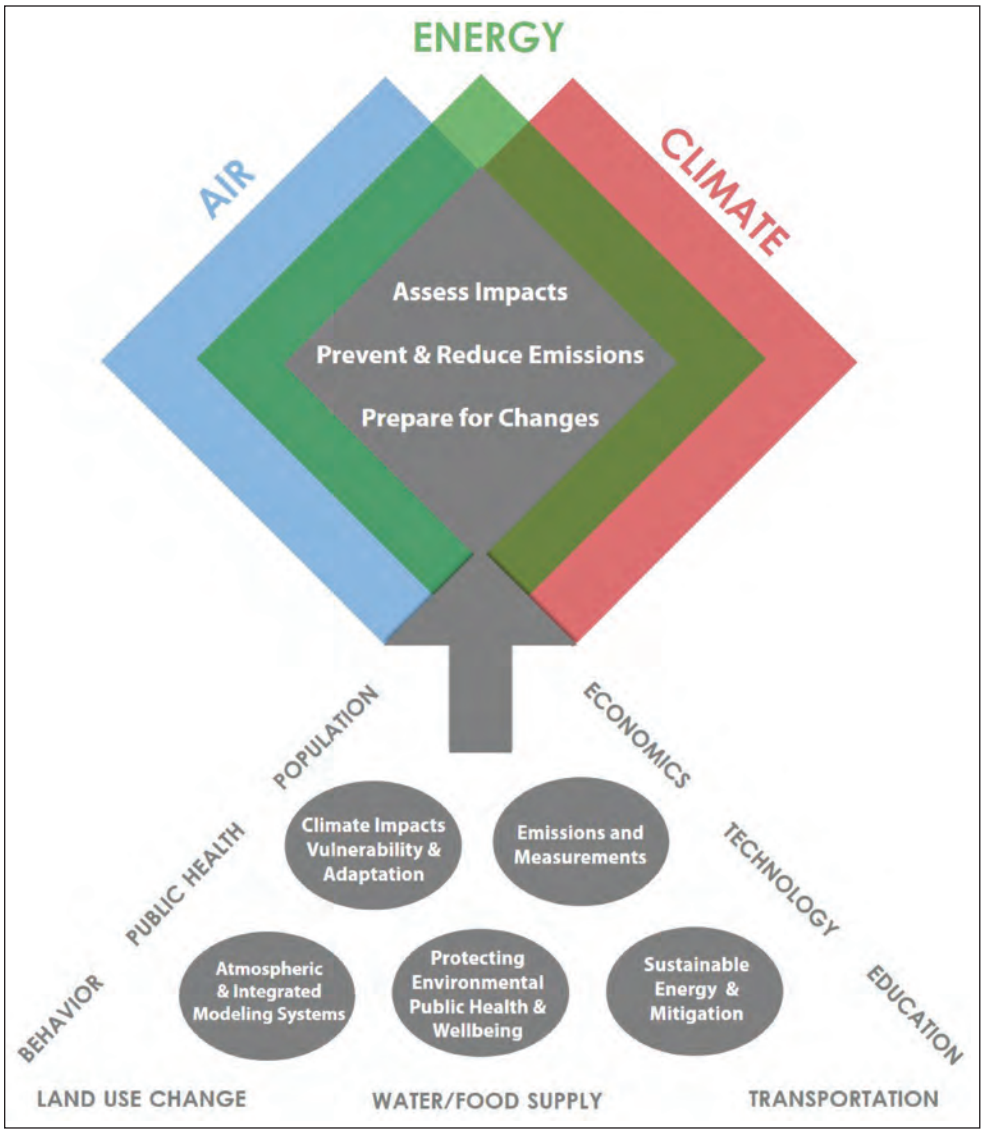

Figure 2. Integration of Air, Climate, and Energy Research.

Objective 1: Assess Impacts

Research Objective

Assess human and ecosystem exposures and effects associated with air pollutants and climate change at individual, community, regional, and global scales.

The human and ecosystem effects of air pollution occur at multiple scales and result from exposures to a mixture of pollutants in the atmosphere. Exposures and effects also are impacted by complex interactions between climate change and air quality. The effects of climate change on human health and the environment cut across media and are characterized by complex synergies between human and natural systems. Social and economic factors also impact the nature and degree of human exposures and the resulting health effects that may occur. Economics and energy choices significantly influence the amount and composition of emissions and the sources of air pollutants. The identification of factors that put people or ecosystems at risk (i.e., individual- and population-level characteristics including lifestage, pre-existing disease, genetics/ epigenetics, socioeconomics and other factors that confer vulnerability) must be considered to inform the decision making process.

New and existing methods and models need to be deployed in systems-based studies to assess these interactions and the factors that ultimately impact public health and welfare. Quantitative assessments describing exposures and potential human and ecosystem effects associated with air pollutants and climate change, including direct and indirect climate impacts to human health, air quality, and water quality, are needed to inform partner and stakeholder decision making. The resulting science must be translated to inform regulations and policy and to be used to make improved and informed decisions at the commercial as well as public and environmental health level.

Challenges:

What are the multipollutant exposures, effects, and integrated impacts of climate change on air and water quality and on public health and ecosystems?

What innovative approaches are needed to enhance the assessment of human and environmental exposures and effects of mixtures of pollutants in the atmosphere?

What are the characteristics that put populations and ecosystems at increased risk to effects from exposure to air pollutants and the impacts of climate change?

What are the key uncertainties and data gaps that need to be addressed to inform future reviews of the NAAQS?

How can the science of health and environmental outcomes best be communicated to decision making bodies and communities for implementation of best practices for improved public health and environmental well-being outcomes?

Objective 2: Prevent and Reduce Emissions

Research Objective

Provide data and tools to develop and evaluate approaches to prevent and reduce emissions of pollutants to the atmosphere and advance sustainable, cost-effective, and innovative multipollutant and sector-based approaches.

When making environmental decisions, policy-makers are challenged by the complex environmental, economic, and social interactions of various options. Innovative measures that maximize public health benefits are needed to prevent and reduce emissions to meet the standards and regulations that lead to improvements in air quality and human and environmental health.

As a result, there is a growing recognition of the need for sustainable, multipollutant strategies that prevent air pollution of all types without unintended environmental consequences to public health, land, water, or climate. Policy-makers are exploring technical and policy approaches that simultaneously address multiple pollutants as an alternative to the one-pollutant-at-a-time approach. Consistent with this thinking is an appreciation for co-benefits and the potential need for trade-offs in addressing multipollutant issues that consider environmental, social, and economic factors.

EPA policy-makers also need to understand how international emissions of air pollutants impact the effectiveness of domestic environmental policies and how domestic emissions impact other countries. Research is also needed to evaluate and assess alternative approaches to reduce or eliminate air pollutants that contribute to climate change. With the development of national policies such as the Clean Power Plan that promote innovation and adoption of clean energy technologies and emission controls, there is a need to understand the full life cycle health and environmental impacts of technology options and decisions to ensure that the clean energy choices of the future are indeed better for the environment.

Finally, environmental policies are only as effective as the emission reductions achieved. Innovative approaches to measure source and ambient pollutant concentrations provide opportunities to improve implementation and enforcement of environmental policies. With miniaturization of sensor technologies, less expensive yet more effective community-based monitoring and fenceline sensing approaches will become common. These approaches require not just technological advances, but strategic data processing capabilities as well.

Challenges:

What tools are needed to support the management of air pollution problems, at the different scales of time and space, associated with different pollutants and effects?

What methods need to be developed and data obtained to conduct life cycle analyses of alternative pollution reduction and energy options to inform EPA and other local, regional, national, and international decisions to ensure the most sustainable and cost-effective uses of resources?

What innovative monitoring technologies are needed to support the implementation of management strategies to prevent and reduce air pollution?

What are the most efficient integrated, sustainable pollution reduction and prevention solutions?

What advanced measurement methods and modeling tools are needed to support implementation of NAAQS?

Objective 3: Prepare for and Respond to Changes in Climate and Air Quality

Research Objective

Provide human exposure and environmental modeling, monitoring, metrics, and information needed by individuals, communities, and governmental agencies to take action to adapt

to and mitigate the impacts of climate change and make public health and welfare decisions regarding air quality.

The impacts of climate change have the potential to undermine environmental progress and policies, including successful efforts to improve air and water quality, reduce exposures, and improve public and ecosystem health. Although mitigating GHG emissions to minimize future climate changes is crucial, it also is necessary to develop the information to minimize and adapt to the adverse impacts caused by unavoidable changes in the climate.

Technical and user-friendly tools and information support the development of community- and individual-level strategies to reduce exposures to air pollution. This includes providing the necessary data to guide informed decision making to protect public health and welfare, as well as a thorough understanding of the public perceptions, behavioral responses, and social and economic factors that influence the decision making process. Therefore, it is critical to develop information and tools to enable communities and individuals to prepare for and adapt to the impacts of climate change and make informed decisions regarding air quality.

In addition, identifying populations and ecosystems that are the most vulnerable to (i.e., least able to cope with) the adverse effects of air pollution and climate change will allow for more targeted adaptation approaches. These at-risk populations and lifestages may have pre-existing social, health, and economic risk factors that may undermine well-being and health which can be ameliorated with appropriately translated practical information. EPA has an important role to play in providing understandable and useful information to help a wide range of stakeholders prepare and implement adaptation strategies.

Challenges:

What are effective preparedness and adaptation strategies to mitigate air pollutant and climate impacts, focusing on at-risk individuals, communities, and ecosystems?

What innovative preparedness methods are needed to effectively inform individual- and community-level adaptation to climate change and decision making regarding air quality?

What are the social, behavioral, and economic factors that may hinder the ability of communities and individuals to prepare and implement adaptation strategies for climate change and make informed decisions regarding air quality and carbon pollution?

Research Topics

The three research objectives described above serve as the framework for identifying research topics to focus the scope and nature of the ACE program. The current ACE research topics outlined in Figure 3 provide a framework for the ACE program to meet EPA's science challenges over the next four years. The vision described in the current ACE StRAP builds on the previous 2012 ACE StRAP and supports the Agency priorities; rapid developments in air sensor and computing technologies; and a growing public interest in environmental information for community self-empowerment. Structural changes to four of the five ACE research topic areas are intended to improve integration, infuse systems thinking and sustainability as founding principles, and enhance translation of science to inform Agency decisions and community discussions concerning air quality and climate change. Table 3 shows the research topic areas that were the focus of the 2012 ACE StRAP and the current research topic areas included in this plan for 2016-2019.

Table 3. Evolution of ACE Research Topics

ACE Research Topics	
ACE StRAP 2012-2016	**ACE StRAP 2016-2019**
Climate Impacts Mitigation and Adaptation (MA)	Climate Impacts, Vulnerability, and Adaptation (CIVA)
Emissions and Measurements (EM)	Emissions and Measurements (EM)
Modeling and Decision Support Tools (MDST)	Atmospheric and Integrated Modeling Systems (AIMS)
NAAQS and Multipollutant (NMP)	Protecting Environmental Public Health and Well-being (PEP)
Sustainable Energy Evaluation (SEE)	Sustainable Energy and Mitigation (SEM)

Air pollution research is presently the largest component of the ACE program. Climate change and energy research together make up roughly one-third of the ACE program, although both are envisioned to grow in emphasis. The closely coordinated intramural and extramural (EPA STAR – Science to Achieve Results program) components of the ACE research program provide an ideal balance of fundamental and applied science across ACE as needed to move the program forward.

The evolution of the ACE program includes a broader public health context focused on delivering effective, relevant, timely science to inform Agency regulatory drivers and strategic directions as well as supporting community needs. ACE has expanded its research focus on air pollution sources to include community-level considerations regarding public health and environmental well-being. Embedding public and environmental health outcomes and sustainable solutions into the ACE research portfolio prepares the Agency for complex 21st century challenges. In many cases, this expanded perspective can be gained by applying systems approaches and involving end-users in study design and interpretation. Some attributes of this design include emphasis on social, economic, demographic and biological (e.g., disease, genetic and epigenetic) factors that may better explain uncertainties in observed public and environmental health effects of air pollutants and may offer more effective support for responses to climate change. Specific examples include:

- Developing science-based solutions to achieve the greatest health and environmental benefits and to improve well-being by reducing exposures to harmful air pollutants;
- Supporting the development and use of low-cost, miniaturized air sensors for a variety of community and industrial applications;
- Developing approaches to improve estimates of emissions from agricultural sources and oil and gas operations;
- Understanding the impacts of climate change to better guide mitigation and adaptation related research;
- Expanding regional- and local-scale information on climate-related impacts to water quality, air quality, and ecosystems;
- Developing climate responses that improve community preparedness and resiliency; and
- Evaluating the broader environmental impacts of the energy system across the life cycle from resource supply to end use.

Table 4 briefly describes the ACE research topics along with examples of near- and long-term research. Additional information on each of these topic areas is discussed below.

Table 4. ACE Research Topics and the Near-Term and Long-Term Aims of the Program

ACE Research Topic	Near-Term Research		Long-Term Research	
	Aim	Examples	Aim	Examples
Climate Impacts, Vulnerability, and Adaptation (CIVA)	Address climate impacts on air and water quality and associated human and ecosystem health	Assess impacts of climate change on particulate matter and coastal ecosystems; Identify climate-related health impacts on at-risk populations and lifestages	Develop sustainable climate adaptation and mitigation approaches	Develop and apply tools to evaluate approaches to (1) simultaneously consider air pollutants and climate forcing; (2) improve resilience of communities to climate impacts on water quality and ecosystem degradation
Emissions and Measurements (EM)	Develop and evaluate regulatory methods for source and ambient air monitoring	Federal Reference Methods for NAAQS; Source compliance methods; Low-cost fenceline monitoring	Change the paradigm for air pollution monitoring	Support development and application of sensors; Use satellites to measure air quality; Integrate all monitoring methods and models into one national tool
Atmospheric and Integrated Modeling Systems (AIMS)	Develop and evaluate local, regional, and hemispheric air quality models	Community Multi-scale Air Quality model (CMAQ); Local-scale dispersion models; Hemispheric-CMAQ	Develop and evaluate multi-scale models that integrate multimedia processes and systems	Integrated multi-scale air quality and hydrologic modeling systems into a biosphere approach
Protecting Environmental Public Health and Well-being (PEP)	Inform NAAQS reviews	Assess impacts of criteria pollutants on human health and ecosystems	Develop approaches to inform and protect public health and the environment from air pollutant mixtures	Assess heterogeneity of pollutants, exposures, and health effects of regional air sheds; Identify modifiable factors to reduce adverse impacts of air pollutants; Effectively translate research to protect public health and welfare from air pollution
Sustainable Energy and Mitigation (SEM)	Evaluate environmental impacts of energy technology	Evaluate environmental performance of GHG mitigation technologies; Improve cookstove performance to protect health and reduce energy use	Protect human and ecosystem health in an evolving energy landscape	Apply systems modeling to evaluate emissions and impacts from present and future energy scenarios with a means of weighing benefits and risks

Topic 1: Climate Impacts, Vulnerability, and Adaptation (CIVA)

Policy makers want to know which populations and ecosystems face the greatest risks to the adverse effects of climate change and what measures can be taken to prepare for and adapt to the expected impacts. ACE research efforts in conjunction with those undertaken in the SSWR and SHC programs will develop information, methods, and tools to improve the understanding of the location, extent, and type of vulnerabilities of populations, ecosystems, and the built environment. The research is designed to help inform decisions relevant to climate adaptation that are flexible, account for underlying conditions, and avoid adverse impacts of adaptation actions. To maximize effectiveness of adaptation and preparedness approaches there is a need to develop approaches that integrate across complex systems and explicitly incorporate methods to describe complex systems behavior.

Signature Project:

Systems-based Approaches for Sustainable Solutions

Providing science, data, and tools for climate-smart EPA programs and practices to support sustainable solutions for global climate change challenges in multimedia systems

The change to Climate Impacts, Vulnerability, and Adaptation (CIVA) (formerly "Mitigation and Adaptation" in the 2012 ACE StRAP) reflects the restructuring of this topic area as it consolidates climate-related research on impacts into (1) air quality and health/ecosystems and (2) water quality and ecosystems. The topic emphasizes systems-based analyses seeking sustainable approaches to preparation, adaptation, and mitigation responses to climate change. Within this topic area, projects have been restructured to better align with EPA's mission (Health/Ecosystems and Air Quality; Watersheds/Ecosystems and Water Quality; Systems Thinking for Sustainability) and to enhance clarity for Agency partners and external stakeholders.

Health/Ecosystems and Air Quality

ACE research is focused on a more complete understanding of how climate change affects air quality and the related impacts on human health and the environment. Researchers will study how pollutant formation and transport may change as the climate and emissions change, develop methods to incorporate projected climate changes into air quality models, and examine how increased temperatures and other climate-driven effects may interact with air pollutants to alter health and environmental responses.

Watersheds/Ecosystems and Water Quality

ACE, coordinating and integrating with SSWR, is developing models and approaches that provide information about what watersheds may be at risk from a changing climate, and how and when they may be at risk. This effort involves incorporating continental-scale projections of temperature and precipitation into watershed-scale hydrological models, taking into account possible changes in land use, water effluents, and air emissions to study the possible effects on water temperature, nutrient content, and presence of pathogens.

Systems Thinking for Sustainability

ACE is incorporating "robust decision making" methods into tools to guide adaptation decisions. These approaches focus on analyses that enable adaptive management approaches in situations that face deep uncertainty about future conditions, such as climate change. This effort will use quantitative and qualitative information on uncertainty to evaluate tradeoffs between cost and risk for specific applications, including the Chesapeake Bay Program.

Integration and Collaboration

The research is designed to enable decision makers to identify priority adaptation actions and anticipate related co-benefits as well as unintended consequences that can occur in dynamic, complex systems. ACE researchers will develop and apply methods and models to understand these types of interactions and responses to develop sustainable adaptation strategies. This understanding can only be achieved through collaboration within and across ORD programs following the Climate Change and Nitrogen and Co-Pollutants Roadmaps, such as the efforts to understand how nutrient levels in water bodies may be affected by climate change. Research under the CIVA topic connects to the multimedia modeling within the AIMS topic, and both require interaction with watershed research being conducted in the SSWR program.

Translating Research for End-Users

ACE researchers recognize the need for research results to be effectively translated and delivered to those who are responsible for policy design and implementation. ACE is working with other ORD programs, particularly SHC, to incorporate climate impact data into tools that are accessible to a broad range of users in forms that are readily understood. As an example, tools such as those based on Geographic Information System (GIS) platforms can provide easily understood visualizations of complex, location-based sets of information and data, such as locations of waste disposal sites combined with projected changes in floodplains due to climate change. This information can enable better informed decision making aimed at limiting adverse impacts attributed to climate change. ACE will collaborate with SHC on further development of the *EnviroAtlas* to provide online, community-level information concerning the scope and type of health and ecosystem impacts associated with climate change. ACE will also work with other federal agencies, coordinated through USGCRP, to develop and provide integrated climate and land use scenarios to support the development of the National Climate Assessment, a major national product designed to inform decision makers and the public across the country.

Topic 2: Emissions and Measurements (EM)

The Emissions and Measurement (EM) topic area is not undergoing any restructuring, and will continue to provide foundational research and development to support critical Agency programs, including applications for implementation and compliance with relevant air pollution standards. The research conducted within the EM topic area within the ACE StRAP will be similar in scope to the work conducted under the 2012 ACE StRAP with necessary modifications considering scientific advancements that have been made over the past five years.

Ambient and Source Measurements

ACE is focusing on priority source and ambient monitoring methods, in particular, Federal Reference/Equivalency Methods and air quality modeling tools that may be improved and enhanced to meet the needs of EPA and state and local agencies in implementing NAAQS. Ease of use, accuracy and cost-drivers are major factors pushing these developments forward. ACE is pursuing research to support the development and refinement of emissions inventories or near-source emission profiles, especially for high-priority sources (for example, Portland cement, power plants); broad source categories (for example, mobile sources); and source sectors (for example, electric generating units, oil and gas facilities) to strengthen model development and standardize implementation plans for use by state and local air monitoring personnel.

Next Generation Air Monitoring

Technologies for real-time or near real-time measurement or monitoring of air pollutants are advancing rapidly. At the same time, many of these technologies are being miniaturized with expanded data handling capabilities. Researchers will evaluate these innovative technologies for monitoring multiple pollutants at sources and in the ambient air, and adapt them for a range of applications including compliance and enforcement, regional and national assessments, air quality planning, and community information. These advances will shape a new paradigm for air quality monitoring.

Developers and manufacturers will develop new and improved sensor technologies, while ACE researchers will provide a coordinating and motivating role to advance the field of air pollution sensors and their integration with the panoply of related measurement technologies and databases. ACE anticipates that portable sensors and integrated sensor networks will provide real-time, continuous data to evaluate emission profiles near and around specific emission sources (called fenceline monitoring), as well as to measure community ambient air constituents. Researchers are evaluating air sensors to assess their performance in measuring air quality. The technology is evolving sufficiently in terms of sophistication and accuracy to support assessment of air pollution emissions and may one day improve overall implementation of clean air regulations. The ACE program will pursue analytical and data management tools to enable local, regional, and national managers to evaluate the effectiveness of air pollution reduction strategies on an ongoing basis.

Signature Project:

Changing the Paradigm for Air Pollution Monitoring

Evaluating the efficacy of next generation monitoring technologies – from sensors to satellites – to complement and enhance air quality assessment and forecasting

ACE researchers will evaluate the performance and cost of measurement technologies to enable comprehensive management of sources that co-emit criteria and toxic air pollutants, GHGs, and other climate-forcing compounds and aerosols. They will do evaluations in ways that address not only air pollution problems, but also consider implications on water quality, and quantity and disposal of any waste generated by the air pollution controls. Additionally, methods, data, and models will be developed to shape atmospheric pollutant management strategies that can account for the responsive behaviors of institutions and individuals attempting to implement those strategies. This will require integration of social sciences, behavioral economics as well as traditional engineering, and atmospheric science approaches to provide a systems-based perspective on these issues.

Research examples include developing a prototype testing platform for sensor evaluation and the development of community-targeted tools for the use and interpretation of community-embedded sensors data. Researchers are evaluating mobile and stationary fenceline instruments and design-parameters for their use in a wide variety of dispersed emission scenarios to assess areal fugitive leakages as well as site-specific leakages such as at valve and other junction areas. For certain industries, like refining of oil and gas, where leaks are particularly difficult to isolate and enforcement can be arduous and costly, these new technologies are proving to be positive advances both economically (reducing lost product) and environmentally. These tools and methods are transferred to EPA regional offices and states as well as the Office of Enforcement and Compliance Assurance for compliance purposes.

Topic 3: Atmospheric and Integrated Modeling Systems (AIMS)

The Atmospheric and Integrated Modeling Systems (AIMS) topic area (formerly "Modeling and Decision Support Tools" in the 2012 ACE StRAP) is being restructured to provide enhanced integration among projects and to better reflect the multimedia/multipollutant/multiscale nature of the modeling research conducted by ACE scientists. The research under this topic is being consolidated into a smaller number of projects in order to better leverage research across projects while continuing in the same general scientific direction.

Multiscale/Multipollutant Models

ACE will develop and evaluate methods and models to support multiscale air quality management (e.g., from local communities to national and global management efforts). The Community Multi-scale Air Quality (CMAQ) model has historically been the workhorse of air quality models and continues to serve at the core of partner and stakeholder needs for air quality assessment and prediction to meet NAAQS implementation schedules. It also is at the core of other multiscale and multipollutant models used for air quality and climate interaction evaluations. An additional goal of the AIMS topic area is the development and evaluation of a next-generation air quality model that builds on the successes of CMAQ to integrate multiscale and multipollutant capabilities in an updated architecture to increase computational efficiency and applicability. ACE will use CMAQ and other focused air quality tools to understand synergies and tradeoffs associated with various mitigation and prevention options for the spectrum of primary air emissions (from traditional combustion components to GHGs) and across the air-water-climate nexus.

Research activities also will provide support for the evaluation of near- and long-term benefits and impacts of strategic management alternatives. EPA needs modeling and decision support tools to relate changes in air pollution and regional climate to impacts on human health and ecosystems across the United States. ACE research spans spatial scales ranging from local to regional to national to global, including characterization of ambient air quality for inclusion in multipollutant and near-source impact assessments. There are several examples of joint development and applications of air quality modeling tools derived and planned in conjunction with the SHC research program. Researchers are developing and refining models for dispersion from varied sources including roadways (R-LINE) as mobile source emissions have significant impacts on local atmospheric chemistry and the potential for exposure to those living nearby. The results of this research will provide robust and comprehensive modeling tools that can be applied across disparate spatial scales to characterize the role of background air pollution on NAAQS attainment and implementation, to support the development of major energy and transportation sector rules, to assess risks posed by criteria and hazardous air pollutants (HAPs), and to develop local and regional-scale air quality and climate data products.

Multimedia/Multi-stressor Models

ACE is developing a multimedia and multi-stressor modeling system to inform protection of human health and welfare. This systems model will serve both the current state of affairs and future climate and land-use scenarios.

Signature Project:

Integrated Multimedia, Multi-stressor Systems Model Development

Advancing the "one-environment" modeling paradigm to address both land use and climate changes, and to move toward a more inclusive "one-biosphere" treatment

ACE, SHC, and SSWR researchers are using a coordinated and integrated research approach to advance current tools that involve improving the air-surface exchange processes in air quality models to couple agricultural land management, meteorology and hydrology models for internally consistent drivers of ecosystem models. This multimedia biosphere modeling approach will result in improved assessment methods to support better understanding of the multitude of linkages across air, water, and land boundaries and provide a means to estimate potential impacts – supporting communication and policy development – that would not otherwise be understood under single media models.

Topic 4: Protecting Environmental Public Health and Well-being (PEP)

The Protecting Environmental Public Health and Well-being (PEP) topic area [formerly NAAQS and Multi-pollutant (NMP) topic area under the 2012 ACE StRAP] has been restructured to better integrate and translate both the science that supports regulatory standards and to broaden the usefulness of this information for a wider range of stakeholders. The projects planned for inclusion in this topic area will fully engage research across a range of scientific disciplines to produce integrated and comprehensive products and outputs that remain responsive, timely, and useful.

The PEP Topic area emphasizes research to address issues related to air pollution in the context of public and environmental health outcomes. This topic area reflects the evolution of research on air pollution and the growing emphasis on implementation-related research, translating research to better inform the public about measures that may be taken to reduce the impacts of air pollution on public health and welfare, and continued research to support development of standards. Research on human and ecosystem exposure and effects formerly at the core of the NMP topic area will now be conducted in the PEP topic area to continue to inform future NAAQS reviews and to advance assessments of multipollutant exposures. The PEP topic area will be expanded to include the translation of results to inform public health and well-being practices. This broadened focus will address ways to lower exposure or mitigate the biological responses at individual, community, or ecosystem levels, and, ultimately, to evaluate whether such interventions have benefits as measured by indicators of health, well-being, or economics. By integrating science that supports regulatory standards with additional public health and well-being interventions, the projects included in this topic will fully engage research across a range of scientific disciplines to produce integrated and comprehensive results.

The PEP topic constitutes the largest single topic area (approximately 40% of the ACE budget) serving a primary regulatory mandate of the Agency. However, the fabric of this topic is evolving with greater contextual consideration of the multipollutant reality of air pollution, its impacts on public health and welfare, and its reciprocal interactions with climate. As such, leveraging of this topic with CIVA is growing. Researchers will examine and expand currently available information and indicators to include additional components (e.g., multipollutant/ multi-stressor indices to incorporate climate change impacts). Specific goals of research conducted within this topic area include: (1) informing the development of new policies aimed at protecting public health and welfare by EPA and its Agency partners and external stakeholders, (2) measuring progress toward environmental health goals, and (3) providing information for communities and individuals to improve protection of public health and welfare.

Health and Ecological Impacts

ACE will continue to conduct transdisciplinary, source-to-outcome research to assess multipollutant exposures and health effects in field and laboratory settings, which include simple and complex mixtures of particles, criteria gases, and organic compounds. Researchers will develop, evaluate, modify, and apply models and methods to assess human and environmental exposures and impacts of air pollution and climate change at individual, community, regional, national, and international scales. This work is the core of that which supports NAAQS development and assessments. This work is essential and will be continued within both intramural and EPA STAR extramural research activities.

Researchers will develop integrated approaches to assess the physical, biological, and other relevant factors (e.g., socioeconomic, demographic, lifestyle, diet) that have an influence on air pollutant-related effects. This will include the identification of biological mechanisms that impact susceptibility and key exposure factors. Epidemiology and controlled human clinical research lie at the core of the PEP topic area and drive the reassessment of the NAAQS in accordance with the CAA mandate.[6] These assessments, however, are predicated and underscored on the strength of studies of mechanism and plausibility in animal and cell system studies that by design, involve realistic exposure scenarios (e.g., artificially generated photochemical exposure scenarios that mimic geographic regions within the United States). Studies will increasingly examine the interaction between behavior and social and economic factors to more thoroughly understand how these factors may influence health and well-being outcomes to better inform a variety of strategies to protect public health and the environment. Research in this area is integrated with the SHC program to better understand impacts to community public health and well-being. Translating the science for use in public health communication and community empowerment is an area that will see attention from EPA and other agencies, such as the Centers for Disease Control (CDC).

Signature Project:

Local and Regional Characteristics Influencing Public Health Impacts in Healthy and At-Risk Populations

Improving our understanding of factors influencing observed heterogeneity in air quality impacts, population exposures, and health responses - now and in the future

In keeping with the principles of sustainability, integrated research approaches will include analyses of expected and potential unintended impacts of novel systems scenarios as might occur indoors as individuals embrace tighter, more energy-efficient homes and buildings thereby adding to their cumulative multipollutant exposures. Such scenario designs require more complex thinking at the systems level to appreciate interactions and yield better informed assessments of the positive and negative impacts of human activities.

Factors Influencing Risk

Additional work is needed to better inform our understanding of at-risk populations and lifestages. Recent scientific findings suggest the possibility that greater numbers of people than previously thought are at increased risk of experiencing air pollution-related health effects, such as individuals with diabetes or certain genetic polymorphisms (genetic variations among individuals) and epigenetic changes. Research is also needed to identify the factors that may result in ecosystems being highly susceptible to changes in climate or to climate-driven changes

[6]The CAA requires review every five years of the science upon which the NAAQS are based and the standards themselves. The NAAQS review process identifies key uncertainties and knowledge gaps that will help guide ACE priorities on human and ecosystem effects research to inform future NAAQS reviews.

(e.g., changes in seasonal temperature and precipitation patterns). In addition, climate change can exacerbate the adverse impacts of other stressors already present, such as water and air pollution and changes in surrounding land use, leading to increased susceptibility to climate-related damage.

Integration and Collaboration

The PEP research on human and ecosystem exposure and effects is designed with the primary goal of informing future NAAQS reviews. The results of research will contribute directly to the Integrated Science Assessments developed in the HHRA program. Research is targeting better understanding of nitrogen and sulfur deposition to characterize the resulting changes and cross-media ecosystem functions and services. This research will be coordinated with that in the SHC Program and the SSWR program as reflected in the Nitrogen and Co-Pollutants Roadmap.

Topic 5: Sustainable Energy and Mitigation (SEM)

The SEM research topic focuses on understanding how changes in the resources, fuels, and technologies used to produce and use energy can pose risks or benefits to the environment and human health, with the understanding that efforts to mitigate climate change and air quality will be one of the most significant driving forces of change in the U.S. energy system. The SEM topic area (formerly "Sustainable Energy Evaluation" under the 2012 ACE StRAP) now better reflects changing Agency partner priorities and increasing emphasis on improving the data and tools to compare alternative energy options to inform decision making. The SEM topic is restructured into focused projects to address environmental impacts of energy at a national and regional systems level; to evaluate the performance and environmental consequences for specific production and conversion technologies; and to gain insights into the environmental impacts of energy end-use.

Signature Project:

Energy and the Environment: Improving Human and Ecosystem Health in an Evolving Energy Landscape

Evaluating and assessing the broader impacts of energy production and use from resource supply to end-use

Multiscale Evaluations

ACE research addresses the environmental impacts of energy production and use across significantly different scales, with the goal of integrating information across scale to provide a coherent understanding of the connections between energy and environment. One major focus is on national- and regional-scale energy system evolution over decadal time scales. A second area of importance is the evaluation of the environmental impacts associated with individual energy production and conversion systems, such as natural gas extraction and processing or fossil fuel-fired electricity generation. The third component will examine the health and environmental impacts related to energy end-use, such as point-of-use combustion (e.g., cookstoves) or energy efficiency measures (e.g., "tight" buildings and the potential for degraded indoor air quality).

At the national scale, researchers will use optimization models representing the U.S. energy system, life cycle impact models, and other methods and approaches to evaluate how changes in energy production and use technologies may impact air emissions and water demand, as well as other environmentally relevant parameters. For instance, researchers will use the Market Allocation (MARKAL) model

with the ACE-developed database of technologies to examine how different technology and policy development pathways might affect future emissions of air pollutants. This effort, in collaboration with EPA's Office of Air and Radiation, can provide insights into how technological change might affect the long-term costs and benefits of air quality management strategies.

At a technology-specific scale, SEM research will provide information on the costs, performance, and environmental impacts of energy production and conversion processes. This research will include pilot-scale studies of individual technologies and syntheses of the technical literature. Understanding how oxygen-fired coal combustion can change the characteristics of coal ash compared to air-fired combustion, for example, is important information for EPA and state regulators to understand as they begin to consider new technologies for climate mitigation. Research in this area will also evaluate the impacts related to renewable energy sources, including wind and solar energy. Information from this effort will feed into the national systems-level analyses.

Cookstoves

Research under SEM will also continue to evaluate the health and environmental consequences of cookstoves used in developing areas of the world to provide energy for cooking, heat, and light. This research is looking beyond the impacts to aid the development of new designs and alternatives, with a longer-term goal of providing insight into approaches for developing clean energy systems that reduce environmental damage, have little direct impact on health, and reduce GHG emissions.

Integration and Collaboration

The complexity and breadth of energy-environmental interactions requires extensive collaboration and integration of SEM research with that of other organizations. For instance, one approach includes integrating an atmospheric chemical transport model (CMAQ) developed under the AIMS topic, the MARKAL energy model, and an economics benefits model (BenMAP) developed by EPA's Office of Air and Radiation to evaluate the public health benefits, costs, and tradeoffs associated with various alternative energy scenarios. SEM researchers will work with colleagues in the Departments of Energy and Agriculture (individually and through the USGCRP interagency working groups) and the academic community to understand how energy production and use can affect EPA's ability to achieve its strategic goal to address climate change and air quality.

Anticipated Research Accomplishments

By its nature, the air, climate, and energy arena requires a strategic plan that comprises a breadth of research activities across a wide array of science and program issues. As science and technology evolve rapidly, opportunities arise for new technical approaches to environmental problems and science questions and whole new ways of thinking about problems. In addition, there are major changes involving social media, access to information, and public attitudes and activism toward personal environment and health. With air quality, climate and energy costs featured prominently in public interest polls, ACE continues to evolve to meet its mandated obligations supporting regulation and policy while it looks to the future, embracing sustainability, innovation, community engagement and anticipation of the air, climate, and energy issues ahead.

In that spirit, ACE reviews its five topic areas and associated projects each year. Evolution of research in the topic is guided by the "signature"

projects which reflect the vision or long term aim of each topic area (see Table 4). The accrual of knowledge through the shorter-term achievements is shaped by the vision of the "signature" project, which satisfies a critical goal of the Agency. Anticipated accomplishments for each research topic are described below.

ACE research will have the greatest impact when products are developed and delivered in ways most useful to ACE partners and stakeholders. ORD products specifically designed to be useful in the hands of partners are termed "outputs." The proposed ACE outputs for FY16 to FY19 are listed in the Appendix.

Climate Impacts, Vulnerability, and Adaptation (CIVA)

The research under this topic focuses on assessments of climate impacts and data-driven decisions, supporting preparative and adaptive measures in the face of climate change. For air quality, models integrating air pollution and climate interactions at multiple geographic scales provide information for informed decisions, including appreciation for the wide uncertainties in projected climate change impacts. Socioeconomic factors, land use and energy choices feed into these decision models sought by government agencies and communities alike. Projects supporting the development of tools and models and the translation of the complexities of scaling climate, weather, emission profiles, and atmospheric science outcomes serving community-scale decisions involve new innovative computational approaches that themselves evolve with advancing science.

Example Accomplishments:

- Evaluate regional impacts of climate change on air and water quality, aquatic ecosystems and public health
- Develop a synthesis and assessment of potential climate change effects on water quality and aquatic ecosystems
- Develop methods to evaluate sustainable climate change preparation and adaptation approaches
- Evaluate impacts and potential mitigation approaches to improve air quality and reduce exposures and effects associated with near-source environs

Emission and Measurements (EM)

The core of the ACE program is clearly focused on the regulatory drivers of the Agency. In the emissions and measurements area, this work includes the development of NAAQS Federal Reference Methods and Federal Equivalent Methods, development and evaluation of control technologies, and a variety of testing scenarios encompassing everything from alternative fuels to the optimization of combustion properties and the determination of combustion profiles and inventories. Further, technology options that necessitate the development of standardized testing guidelines for emissions and profiling emissions among mixed sources remain drivers of the research supporting program and regional partners. Advances in measurement technology could eventually usher in a new paradigm of air pollution monitoring.

Example Accomplishments:

- Develop and validate continuous measurement techniques for multipollutants in ambient air and along the fenceline of significant stationary sources
- Demonstrate utility of emerging air quality sensor technologies, remote sensing capabilities and data fusion techniques to characterize multipollutant air quality and exposure surfaces
- Characterize biogenic and anthropogenic emissions sources to support regulatory compliance and emissions inventories

Atmospheric and Integrated Modeling Systems (AIMS)

Research in this area addresses the long-term aim of developing a multimedia and multi-stressor modeling system to inform protection of human health and welfare. The advances in measurement technology under the EM Topic (above) will lead to a virtual collage of data tying community and personal sensors to a validated regulatory network, integrating satellite information, atmospheric chemistry and models into a synthesized location-specific tool. The regulatory application of such a tool is a long-range effort, but community and regional use is underway. Moreover, forecasting models can be built from this interconnected system to predict air pollution to which personal or community behavior or land-use decision making can be adjusted. The utility of such a network for ecosystem protection and assessment would follow on quite readily.

Example Accomplishments:

- Develop and apply empirical and computational approaches to characterize inputs of atmospheric pollutants to ecosystems and the attendant impacts, including through nitrogen deposition to terrestrial and aquatic ecosystems
- Develop modeling tools to estimate air quality and community and individual exposures at relevant local, regional, and hemispheric scales, including the impacts of climate change at regional and hemispheric scales

Protecting Environmental Public Health and Well-being (PEP)

Research under this topic primarily focuses on providing the information to support development of the NAAQS. In addition, regulatory agencies and individuals need to make sound and informed decisions to achieve environmental goals and sustain quality of life. Research serving the medical community provides some guidance in that the science serves both clinical and public health agendas. For example, infectious disease has long been studied in this fashion providing a path forward to meet the dual objectives to which ACE is striving: providing specific science evidence to take remedial or regulatory action and communicating public health information to inform community and individual actions.

One ACE example of early success is the teaming of EPA's Healthy Heart Program with CDC's Million Hearts Program. Working with public health and CDC investigators, EPA's data on the impacts of air pollution on cardiac health was contextualized with that of other risk factors in heart disease, and is now part of the physical evaluation protocols used by cardiologists and public health clinics. With health as a driver, the ability to capture attention and drive energy and community planning options becomes clearer to those who may be the most impacted by these decisions. As EPA research served to reveal the cardiac impacts of air pollution and refine the fundamental understanding of how this phenomenon could arise and lead to regulatory action, that research has also served as the driver and evidence to motivate public health education at both clinical and community levels. The coalition of regulatory and public health communities provides essential synergy to achieve solutions.

Example Accomplishments:

- A broad set of relevant research results and insights in exposure and health as well as atmospheric science to support five-year review cycle of the NAAQS
- Develop novel approaches to describe exposures and health effects associated with multipollutant mixtures as well as individual components.

- Provide fundamental information to improve our understanding of at-risk populations and lifestages and the influence of susceptibility factors including preexisting disease and other biological/genetic features
- Determine influence of social, economic, and environmental factors influencing exposures and effects of multipollutant air pollution
- Determine effective combinations of measurements, models and metrics to assess human exposures and health risks of multipollutant exposure in space and time

Sustainable Energy and Mitigation (SEM)

An overarching goal is to link across measurement technologies and advances in combustion science aimed at lower emissions, including the use of novel fuels, to maximize shared benefits while minimizing costs to the energy sector. Associated health studies of composition-directed emissions of alternative fuels and combustions conditions provide a systematic approach to aid the selection of the least impactful options.

Researchers are developing less conventional yet critical testing standards for cookstoves to be adopted worldwide as part of an international commitment of the Agency to the Global Alliance for Clean Cookstoves. EPA, the Department of State and other federal partners have key roles in mitigating health concerns from emissions while providing co-benefits by reducing climate impacts of black carbon. ACE has committed substantial effort in testing cookstoves and hypothesis-driven science to reduce exposures and health impacts through 2020.

Example Accomplishments:

- Develop approaches to understand potential future energy system configurations and subsequent environmental and climate impacts
- Assess potential health benefits of using modern, more efficient cookstove designs

Conclusions

The ACE Strategic Research Action Plan 2016-2019 is meant to serve as a guide to how ORD will address the many Agency priorities to address climate change and improve air quality. There is a structure for essential research to be done in this period and an obligation to ensure it is the best science and that it is effectively translated and communicated. The science must be flexible to change as new information is received and able to look at problems from varied perspectives. If systems approaches are to be adopted to achieve solutions, the approaches that appear most obvious may not be the most effective means to problem resolution. As the ACE program research evolves, it must remain resolute in its obligation to support program and regional office needs, but it must be aware of and open to new approaches or science arenas, such as the social sciences. Science is informed by failures and serendipity, which often lead to greater successes. The ACE program will continue to partner with its program and regional colleagues, communicating and translating its science and exchanging constructive critique to ensure that the health and well-being of the public and environment can be improved and sustained.

Appendix

Table of Proposed Outputs, Air, Climate, and Energy FY16-19

The following table lists the expected outputs from the Air, Climate, and Energy Research Program, organized by topic. It should be noted that outputs may change as new scientific findings emerge. Outputs are also contingent on budget appropriations.

Emissions and Measurements (EM)
FY16 - Ambient air monitoring methods for ozone to support review and implementation of NAAQS that will include all supporting documentation used in the final rulemaking for ozone
FY16 - Updates to key emission sources including: meteorologically-dependent, process-based emission estimates; species profiles; effects of vehicle technology and operating conditions on performance and pollutant emissions
FY16 - Village Green II Deployment: Deployment of up to 7 new VG stations (national and international)
FY16 - CAIRSENSE Project Data Collection Completion: Region 4 Sensor Evaluation at NCOR sites (Atlanta and Denver)
FY17 - Review of fenceline measurement technologies
FY17 - Develop a community of practice for remote sensing techniques and data collection
FY17 - Use of surface and satellite based observations to better quantify regional and global NH3 emissions
FY18 - Synthesis of new methods developed for measurement of particulate matter, air toxics, and volatile organic compounds
FY18 - Summary of test methods and measurement technologies for stationary combustion sources
FY18 - Improvements to mobile source emissions factors to inform MOVES model and evaluate and assess data gaps
FY18 - Deliver new and improved analytical methods to better analyze toxic organic particulates
FY19 - Synthesis of new technologies used for source emissions and ambient measurement
FY19 - Produce source emissions profiles for key non-point source categories
FY19 - Evaluating the value of data from small sensors, developing the technology necessary to combine data
Climate Impacts, Vulnerability, and Adaptation (CIVA)
FY17 - Near-term needs for climate-resilient communities: Online compilation of communities' key vulnerabilities to climate change and potential responses that maintain economic and environmental resilience
FY19 - Global Change Explorer: Set of population, socio-economic, and land use scenarios consistent with global storylines and EPA-specific scenarios (e.g., air quality scenarios), climate change visualization tools, Community Resilience ID tool, and other global change modeling tools and data
FY19 – Decision support tool for assessing AQ and climate impacts
FY19 - Climate impacts on air quality, air pollution exposure, and deposition to sensitive ecosystems
FY19 - The vulnerability of watersheds and near-shore environments to climate change

Atmospheric and Integrated Modeling Systems (AIMS)
FY16 - A modeling framework to examine the role of inter-continental transport on U.S. air quality and to study air quality-climate interactions
FY17 - Improved atmospheric system for nitrogen and a fully linked multimedia model set for aquatic acidification and coastal estuary air-water management analysis with a demonstration of ability to address climate change
FY18 – Demonstration and evaluation of prototype Next Generation Air Quality Modeling System for potential application in regulatory development and assessments
FY19 - Advanced atmospheric system with full terrestrial hydrosphere and linked or coupled multimedia modeling set for air-terrestrial and air-water management analysis with climate change and ecosystem service analysis capability fully incorporated
Protecting Environmental Public Health and Well-being (PEP)
FY16 – HEI report - Multicenter Ozone Study in Elderly Subjects (MOSES)
FY18 - Identify and characterize intervention strategies (e.g., nutritional, pharmaceutical, behavior to minimize exposure) that can provide additional protection for healthy and at-risk individuals and communities from the adverse effects of air pollution
FY18 – HEI report summarizing response from Enhanced Traffic Exposure and Accountability Studies
FY19 - Synthesize ORD research with respect to the public health impacts of exposure to air pollution in healthy and at-risk populations and across lifestages and the development of models, tools, and analyses to improve exposure estimates for determining health risk estimates.
FY19 - Synthesize ORD research with respect to characterization of modifiable factors relating to exposure and human health that can be altered to improve the public health of individuals, communities, and regions
FY19 - Synthesize ORD research with respect to development of deposition budgets for North America and identify remaining critical knowledge gaps related to nitrogen deposition and options for future research directions
FY19 - Advance tools and communication strategies for translating research results into recommendations that can be used by individuals, communities, and public health officials to increase communication of these results and environmental health literacy overall
Sustainable Energy and Mitigation (SEM)
FY16 - Synthesis of the environmental implications of a transformed energy infrastructure from resource supply/extraction through conversion and end use
FY16 - An assessment of the variability of emissions from bituminous coal as compared to bituminous coal blended with biomass/biofuel products at varying levels with a focus on organic HAPs and PM emissions
FY16 - Synthesis report on integrated cookstove research program summarizing standardized stove testing methods, guidance documents for regional stove testing centers, and environmental and health impacts of stove and fuel choices for home energy use
FY17 - Synthesis of findings from assessments and laboratory studies of the co-combustion of various biomass materials and coal
FY19 – Identification and analysis of long-range energy pathways for addressing climate mitigation, air quality and other environmental and health goals

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