



## Air, Climate, and Energy

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# Strategic Research Action Plan, 2016-2019 (Preliminary Draft)

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Washington, DC 20460

**PRELIMINARY DRAFT NOTICE:** This Strategic Research Action Plan, 2016–2019 is a preliminary draft. It has not been formally released by the U.S. Environmental Protection Agency (EPA) and should not at this stage be construed to represent Agency policy, nor the final research program.

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## I. Executive Summary

[To be completed in final Strategic Research Action Plan]

## II. Introduction

EPA's Air, Climate, and Energy (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 these research efforts support policies that have far-reaching positive impact across the nation, including reducing health risks from air pollution, preparing for the impacts of climate change, and advancing more resilient and sustainable communities.

This *Strategic Research Action Plan, 2016-2019*, provides a vision for the ACE research program guided by the considerable input and support of partnerships from within EPA program offices and regions, as well as from outside stakeholders including sister federal agencies, nonprofit organizations, private industry, and colleagues across the scientific community. The plan builds upon and continues to advance the research outlined in the action plan released in June 2012: *Air, Climate, and Energy Strategic Research Action Plan, 2012-2016*.

EPA's strategic research action plans provide a founding and structured vision for EPA's research staff and their partners in research efforts to support the Agency's legislative mandates, as well as to address the goals outlined in the Agency's *Fiscal Year 2014–2018 EPA Strategic Plan*. These plans are designed to guide an ambitious research portfolio that at once delivers the science and engineering solutions the Agency needs to meet its priorities, while also cultivating a new paradigm for efficient, innovative, and responsive government and government-sponsored environmental and human health research.

The ACE *Strategic Research Action Plan* outlines research approaches designed to achieve EPA's objectives for air, climate, and energy outcomes. It also highlights how the Air, Climate, and Energy research program integrates its efforts with those of other research programs across EPA's Office of Research and Development (ORD) to provide a seamless and efficient overall research portfolio aligned with the central and unifying concept of sustainability.

EPA's Office of Research and Development, as the science arm of the Agency, provides a world-class collective of scientific and engineering capabilities that, along with its grantees and other partners, endeavor to address the most pressing environmental and related human health challenges facing the nation and the world.

### III. Program Purpose

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 lead to a range of health and environmental welfare effects including, but not limited to, respiratory and cardiovascular effects and mortality in the human population and deposition-driven eutrophication and acidification in the environment. Great advances in understanding the human and environmental health impacts of air pollution along with the development of technologies, tools and models to prevent and reduce air pollution have led to greatly improved air quality over the last 40 years. Even so, impacts are still felt at these lower levels while at the same time, millions of people in the United States still live in counties that do not meet current air quality standards for one or more pollutants.

Global climate change is now impacting public health and the environment, and will increasingly have a range of major and potentially adverse effects on water resources, agriculture, wildlife ecosystems, contaminated sites and waste management practices, as well as the built environment (i.e., energy, infrastructure, and communities). Additionally, changes in climate are expected to increase health-related stressors such as heat and vector-borne disease and can lead to higher concentrations of harmful air pollutants, while the presence of some air pollutants in the atmosphere also can accelerate climate change. Even as initial steps are taken to reduce greenhouse gases (GHG) emissions, the rate of responses of the atmosphere and oceans mean that climate-driven impacts will continue to worsen for some time. In the absence of continued emission reductions, there is compelling and growing evidence that the public health and welfare of current and future generations are at risk. Air quality and climate are inextricably and nonlinearly linked, complicating assessments and interventions.

Energy to produce and transport goods, move people, and support the productive and growing economy of the United States is central to the issues of air quality and climate change. Energy production and use has major impacts on both air quality and climate with conventional energy options generally representing a major source of air pollution emissions including GHGs. As demand for goods and services grows in concert with an expanding population, current energy technologies will place further pressure on climate and air quality. Moreover, energy and water are also closely connected, through the need for water to produce energy and the use of energy to ensure adequate supplies of clean water.

In light of these facts, President Obama has put into place a *Climate Action Plan* to reduce GHG emissions from electricity generation facilities in the United States by 30 percent by 2030, to strengthen the capacity of communities to prepare for the impacts of climate change, and to take other measures to increase resilience to climate impacts and reduce GHG emissions. EPA's actions to reduce emissions include the Clean Power Plan proposal and development of GHG emission standards for heavy-duty vehicles. These and other actions, such as previous implementation of GHG standards for passenger cars and commercial trucks, are drivers of a changing energy landscape in the United States, which themselves will impact, hopefully for the better, human health and the environment.

### III.A. Problem Statement

The problems that span the nexus of air, climate, and energy, as well as the major research needs identified by EPA partners and stakeholders, form the basis of the overarching problem statement that guides the ACE research agenda:

*Protecting health and the environment from the impacts of climate change and air quality 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.*

Integrating the research issues inherent in this problem statement into a seamless research program that addresses air quality, climate change, and energy 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.

### III.B. Program Vision

To date, ACE and its predecessor programs have supported and conducted research that has improved the human and environmental health of the United States. This research has directly supported: the review, promulgation and implementation of the National Ambient Air Quality Standards (NAAQS), the development of the Endangerment and Cause or Contribute Findings for GHGs, implementation of the Renewable Fuel Standard, and the most recent National Climate Assessment.

This research has produced cutting-edge science leading to significant advances, including a more thorough understanding of the source to health effect continuum of particulate matter (PM), the development of complex multipollutant atmospheric models such as Community Multiscale Air Quality (CMAQ), and detailed evaluation of the impacts of climate change through a series of Synthesis and Assessment reports.

Research conducted under the Clean Air component of ACE—the longest-running component of the ACE portfolio—has been a fundamental part of EPA’s success in improving the Nation’s air quality. Although the broad scope of the benefits realized from EPA air research programs is in part unquantifiable, the White House Office of Management and Budget has estimated that the NAAQS has accounted for approximately 94 to 97 percent of estimated benefits from all EPA regulations and approximately 60 to 87 percent of estimated benefits across all federal agencies. These benefits include reductions in the number of hospital admissions and emergency department visits, fewer lost work and school days, and lower numbers of premature deaths. Additional research has indicated that improvements in air quality have led to an increase in life expectancy.

The full benefits of EPA's achievements in clean air, however, have not been shared by all, nor have they been guaranteed for the future. Even with the economic and public and environmental health improvements that have occurred concurrently during the last 40 years:

- Approximately 127 million Americans lived in counties that did not meet the air quality standard for at least one pollutant in 2008;
- Several aquatic and terrestrial systems remain acidified or exhibit disruption in species richness and eutrophication contributed to by air pollutant deposition;
- GHG emissions continue to increase in parallel with population growth and energy consumption, threatening public and environmental health; and
- The landscape of energy sources and technologies is changing, leading to uncertainty as to the impacts of future energy choices on human and environmental health.

With past accomplishments forming the foundation for meeting future challenges, the vision of the ACE research program is to provide the cutting-edge scientific information and tools to support EPA's strategic goal of protecting and improving air quality and addressing climate change.

The ACE research program builds on its record of highly relevant and exceptionally valuable science rooted in the sustainability paradigm, to continue to inform the Agency's development of policies that create enormous benefits for public health, the environment, and the national economy.

## IV. Research Supports EPA Priorities and Mandates

### IV.A. Statutory and Policy Context

*The ACE research program will conduct research to support EPA's programs mandated by the Clean Air Act (CAA). In doing so, ACE will foster innovative approaches 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 air quality standards to protect the public health and environmental welfare of the Nation. For six common air pollutants (particulate matter, ozone, sulfur dioxide, nitrogen dioxide, carbon monoxide, and lead) that cause serious health and environmental effects and are widely distributed across the country, EPA establishes National Ambient Air Quality Standards (NAAQS). Although regulated individually, collectively particulate matter and ozone 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 other pollutants that are known or suspected to cause cancer or other serious health or environmental effects. These pollutants, known as hazardous air pollutants or air toxics, are regulated on a source category by source category basis, rather than through an ambient standard.

In 2007, the U.S. Supreme Court determined that GHGs are air pollutants as defined by the CAA. The Court held that the EPA Administrator must therefore determine whether or not emissions of GHGs from new motor vehicles cause or contribute to air pollution that may reasonably be anticipated to endanger public health or welfare or whether the science is too uncertain to make a reasoned decision.

In 2009, after extensively reviewing the full weight of scientific evidence and the thousands of public comments received, the EPA Administrator issued the Endangerment and Cause or Contribute Findings for GHGs under Section 202(a) of the CAA. The finding concludes that GHGs endanger public health and welfare, including but not limited to impacts on air quality, heat events, water resources, ecosystems, sea level rise and coastal areas, energy, infrastructure, and settlements. Such climate change impacts are also expected to have important implications for programs developed under other statutes such as the Clean Water Act and Safe Drinking Water Act.

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 environments.

#### IV.B. EPA Priorities

EPA’s record of success in protecting public and environmental health from air pollution over the Agency’s 40 year history has relied on building a strong scientific foundation to support policies that reduce the adverse effects of the Agency’s designated criteria air pollutants. The hazardous air pollutants (also known as air toxics) have also been reduced both via specific emission

controls and as a co-benefit of other air pollution control efforts. Today, improving the air quality of the Nation remains a major priority especially for those who reside in communities as yet unable to fully meet air pollution standards or who may be at risk for health or socio-demographic reasons. Even more pressing is the need to address climate change which has significant negative global implications, including the potential for reversing past health and environmental gains from air pollution abatement. Even the indoor environment is stressed by climate change where pollutant penetration, indoor

#### **EPA’s Priorities\***

*Addressing climate change and improving air quality*

*Reinvigorating water-quality efforts, including support for green infrastructure*

*Taking action on toxics and strengthening chemical safety*

*Enhancing the livability and economic vitality of neighborhoods in and around brownfield sites*

*Aligning and incentivizing partnerships that spur technological innovations, reducing costs and pollution*

*Advancing research efforts to provide relevant, robust and transparent scientific data to support the agencies policy and decision-making needs.*

\*Administrator’s Message, EPA Strategic Plan 2014-2018

generated biological or other containments, and ventilation/heat issues pose evolving challenges to human health in the built environment.

These priorities are reflected in Goal 1 of EPA’s FY 2014-2018 Strategic Plan, (EPA, 2014): “Addressing Climate Change and Improving Air Quality.”

The Goal recognizes that there are inherent relationships between air quality and the changing climate. Further, the human and environmental health impacts of both air quality and climate change are heavily influenced by the energy choices of the United States and the world. The energy landscape is changing rapidly with changes in fuel sources, technologies for generation and emission control, and in terms of pressures on fundamental resource extraction and across the full life cycle of energy production and use. As a result, achieving the goal of protecting human health and the environment by addressing climate change and improving air quality is not possible without also understanding the Nation’s evolving energy landscape. This evolving energy landscape further complicates the dimensions of the multi-air pollutant approach. The reality of air pollution is one of multiple air pollutant constituents which change in time and space augmented by atmospheric chemistry. The evolution of the energy system is altering these conditions further and when coupled with climate change provides novel scenarios and geographic dimensions for human and environmental exposures. Understanding these ramifications underlies informed and appropriate decision making across communities and governmental entities.

Clearly, the scope and complexity of the climate–air quality interface is beyond that of previous air quality-only endeavors. The essential elements of previous air quality management efforts are in dynamic flux with needs at the health and environmental level across a variety of scenarios, with complementary tools needed for local to regional scale evaluations and predictions. Climate change also carries implications for water quality and ecosystem health which together with air comprise the complex “globalness” of the issue.

As the ACE research program embraces research that addresses global climate change in ways that can be translated to practice at the regional and local level, research is also conducted to help communities and ecosystems become more sustainable and resilient to the effects of climate change. To achieve these goals, ACE coordinates with other ORD research programs, respectively, the Safe and Sustainable Communities (SHC) and the Safe and Sustainable Water research programs. Communities challenged socio-economically or co-located with heavy industry or designated brownfields are by their nature of particular concern, as are tribal communities. Partnerships, notably with the EPA Regional Offices where these communities reside, provide real-world test-beds for research that is immediately useful to the public. Hence, the diversity of approaches to the air quality-climate challenges build from fundamental laboratory science to the community and national level in an effort to achieve and maintain air pollution standards that protect public health and ensure the resilience of the built and natural environments.

## V. Research Objectives

The ACE research program is designed to provide research results that meet EPA needs, fill gaps within the broader efforts across the federal government, and complement the research being conducted by the larger scientific community.

Three ACE research objectives flow from the Agency priorities noted above and provide a platform that encompasses the breadth and diversity of the science research issues and questions arising within the Agency's the air-climate-energy domain:

**Assess Impacts**—*Assess human and ecosystem exposures and effects associated with air pollutants and climate change at individual, community, regional, and global scales (Research Objective 1);*

**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 (Research Objective 2); and*

**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 adapt to and mitigate the impacts of climate change, and make public health decisions regarding air quality (Research Objective 3).*

These research objectives are intentionally designed to guide integrated research that considers issues in the context of the interactions among the domains of air, climate, and energy, as opposed to focusing specifically on air, climate, or energy individually. In addition, research within the ACE program may cut across multiple objectives. Research conducted at the intersections of the objectives will present the greatest opportunities for transdisciplinary research.

Consistent with the principles and characteristics of ORD's overall research program, the ACE research objectives and challenges outlined below are unified through a call for sustainable and innovative solutions to environmental problems. Research results to address the sustainability and innovation objectives will draw from activities that cut across the ACE research objectives and science, and will require integration at the program level. The following narratives for each research objective provide a brief overview of the key research drivers for the objective. Each research objective contains broad science questions that are intended to enable staff to apply their expertise and innovation in shaping specific research projects.

### 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 and climate change 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. Social and economic factors also impact the nature and degree of human exposures and the resulting health effects that may occur. Furthermore, economics and energy choices significantly influence the amount and composition of emissions and the sources of air pollutants. In addition, the identification of potentially susceptible populations (i.e., individual- and population-level characteristics, as well as exposure differences, that lead to increased risk of air pollutant-related effects, both for human health and ecosystems) must also be factored into these complex interactions to inform the decision-making process.

New and existing methods and models need to be deployed in transdisciplinary studies to assess these complex interactions and factors that ultimately impact public health and the environment. Quantitative assessments describing the human and ecosystem exposures and effects associated with air pollutants and climate change, including climate impacts to human health, air quality, and water quality, are needed to inform partner and stakeholder decision making.

*Challenges:*

*What are the multipollutant exposures and effects, and integrated impacts, of climate change on air and water quality, and on human and ecosystem health?*

*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 of populations and ecosystems that are more susceptible to effects from exposure to air pollutants and climate change impacts?*

*What are the key uncertainties and data gaps that need to be addressed to inform review of National Ambient Air Quality Standards (NAAQS)?*

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; 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 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. In keeping with this thinking is an appreciation for co-benefits and the potential need for trade-offs in addressing multipollutant issues.

In addition, 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 the gases and other compounds that contribute to climate change. With the development of national policies, such as the proposed Clean Power Plan promoting innovation and adoption of clean energy technologies and emission controls, EPA research plays an important role in analyzing the full life-cycle impacts of technology options and decisions to ensure that the clean energy choices of the future are indeed better for the environment as a whole.

Finally, environmental policies are only as effective as the actual 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 fence-line sensing approaches will become common requiring not just the technological advance but also strategic data processing capabilities.

*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: 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 decisions regarding air quality.*

Humans respond to adverse conditions by seeking means to prevent or rectify a given condition and/or by changing their behaviors. Often these changes occur at the community or societal level. As the impacts of climate change appear to have the potential to undermine environmental progress and policies, including apparently

successful efforts to improve air and water quality, reduce exposures, and improve public and ecosystem health, humans at multiple societal and governing levels are seeking ways to avoid deterioration of their health, lifestyles and environment. As such, while mitigating GHG emissions to minimize future climate changes is crucial, it also is necessary to develop fundamental information to minimize, prepare for, and adapt to the adverse impacts caused by unavoidable changes in the climate.

Tools and information of both technical and user-friendly form are needed to allow for the development of community- and individual-level strategies to reduce exposures to air pollution. This includes providing the necessary data to guide informed personal decision-making, as well as a thorough understanding of the public perceptions, behavioral responses, and social and economic factors that influence the decision-making process. Therefore, developing information and tools to allow communities and individuals to prepare for and adapt to the impacts of climate change and make informed decisions regarding air quality is critical.

In addition, the identification of populations and ecosystems that are the most vulnerable to (i.e., least able to cope with) the adverse effects of climate change will allow for more targeted adaptation approaches. These vulnerable populations 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 information that will help a wide range of stakeholders to prepare and implement adaptation strategies both structurally and through policy decisions.

*Challenges:*

*What are the most effective alternative preparedness and adaptation strategies, focusing on the most vulnerable individuals, communities, and ecosystems?*

*What innovative preparedness methods are needed to 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?*

## VI. Anticipated Research Accomplishments

The ACE research program comprises a breadth of research across a wide array of science and program issues. A sizeable portion of the work supports multiple partners and as such is interdisciplinary with short term and longer term products. Products are delivered and the projects from which they emanate evolve or end to allow for the growth of new research needs. Yet some research is highly focused by design, e.g., the development of Federal Reference Methods, and likely will continue through time as technology advances. Below are examples of

expected accomplishments in the period of this Strategic Plan, selected to represent the scope of the ACE program. This listing is not intended to be a complete list of all that is expected to be accomplished. [Additional accomplishments will be identified as the Strategic Research Action Plan is further developed...]

- 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 identifying at-risk populations 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
- Evaluate impacts and potential mitigation approaches to improve air quality and reduce exposures and effects associated with near-source environs
- Develop and apply empirical and computational approaches to characterize inputs and impacts of atmospheric pollutants on ecosystems, including through nitrogen deposition to terrestrial and aquatic ecosystems
- Develop modeling tools to estimate air quality and community and individual exposures at local, regional and hemispheric scales
- Develop and validate continuous measurement techniques for multipollutants in ambient air and along the fence line 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
- 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
- Develop approaches to understand potential future energy system configurations and subsequent environmental and climate impacts

## VII. Program Design

### VII.A. Existing Research Program Connection

The objectives of the ACE Program are largely consistent with the previous StRAP (2012-2016). The ACE Partners have expressed a need to continue much of the research originally envisioned in the previous StRAP. As a result, notable changes in research direction build on the existing research portfolio. As initiated in the previous StRAP, there is continued programmatic shift in emphasis within ACE on the sciences supporting implementation and evaluation of existing policies and regulations. The focus is on problem solutions and the essential information at the health and physical sciences level and less so on the problem identification level. The multidisciplinary approaches previously used are being applied with a reframing of the problem questions and challenges. Specific examples of the evolving research under each research topic are described in the next section (VIII. Research Topics).

### VII.B. Developing an Integrated Program

The impacts of air quality and climate change are heavily influenced by the energy choices of the United States and the world. The issues of air pollution, climate change, and energy are closely connected and those connections have been recognized by a variety of scientific organizations, including the National Academy of Sciences (NAS) and the U.S. Global Change Research Program. As demand for energy increases, along with the changes expected to accompany shifts toward clean energy alternatives, it is necessary to understand the interactions between air quality and climate change, and the associated potential impacts on human and environmental health. Like, climate is expected to have dramatic effects on the nation's water infrastructure. These effects will be felt in a variety of ways including acidification of aquatic systems, eutrophication of water bodies, and imbalance in the energy demand–water quality systems. The complexity of these issues demands the use of systems-based approaches to address the many simultaneously acting and interacting components if one is to better define the primary drivers and controlling conditions.

The broad reach of climate change will also likely impact all ORD National Research Programs (NRPs) and for this reason a Climate Roadmap has been developed to describe these interrelationships. This Roadmap (accessed separately) provides the context for climate impacts across media (air, water and land) and ORD research endeavors. Furthermore, to fully engage sustainability as a harmonizing principle both the ACE research program and the Climate Roadmap must account for interactions across social, economic, and environmental domains.

The ACE Program also formally integrates with the NRPs through other critical research areas identified in the ORD cross-cutting research roadmaps (Nitrogen and Co-Pollutants, Children's Environmental Health, and Environmental Justice). The ACE Program also integrates with other research areas where leveraging resources and expertise provides mutual benefits to the NRPs and EPA Partners, and more narrowly defined integration and

collaboration also exist (e.g., asthma research, high throughput air toxics pathway identification, community studies and citizen science). Currently, specific ACE research has been aligned to varying degrees with each of the roadmaps to provide an inventory of on-going research across ORD and how research in ACE and the other NRPs contributes to the broader context described in each roadmap. Through StRAP planning over the course of the next year additional opportunities to integrate with the other NRPs will be explored.

Additional opportunities for integration are being identified based on feedback from program partners and ORD scientists. These opportunities for integration will be further explored over the coming months as the NRPs complete development of the StRAPs. Potential opportunities for integration and leveraging with ACE research across the NRPs include:

1. Chemical Safety for Sustainability (CSS) and Safe and Sustainable Water Resources( SSWR) – Lifecycle assessment
2. CSS –High-throughput approaches to evaluate the toxicity of individual and mixtures of air pollutants
3. SSWR – Climate change impacts on watersheds
4. Homeland Security Research Program (HSRP) – Promoting community resiliency to the impacts of extreme events caused by climate change
5. Sustainable and Healthy Communities (SHC) – Ecological impacts of atmospheric deposition of nitrogen and co-pollutants; public health impacts of air pollutants and susceptible populations, especially asthmatics; development/application of air quality modeling tools; Influence of climate change on public health
6. Human Health Risk Assessment (HHRA) – Research contributing to the Integrated Science Assessments (ISAs); advancing cumulative risk assessment (CRA) methods to address ecological endpoints and multipathway/multipollutant exposures

#### VII.C. Partner and Stakeholder Involvement

The design of the research program will leverage expertise and capabilities across EPA and from external stakeholders to support the development of effective, sustainable policies. The ACE research program builds on the strong foundation that has been established in predecessor programs in EPA's Office of Research and Development (ORD), including the Clean Air, Global Change, and Biofuels research programs.

Communication from program and regional partners comes in a variety of formal and informal avenues. Monthly and quarterly updates and with these partners has established a solid basis for the communication of new or evolving needs as well as a research project progress and updating. Nevertheless, early in the year formal, coordinated research needs information is provided by program and regional partners for use in the ACE research portfolio review and planning update which covers up to two years upcoming. Once completed the portfolio is communicated through a formal webinar and followed up in more detail as needed. Once completed a formal two-day project level progress / plans event is held with all interested partners where more discourse on both short and long term goals occurs with feedback on the

full breadth of the Ace program and its expected outputs. Assistant Administrator briefings follow with the program and regional partners to finalize the portfolio for the coming year including expected products.

Stakeholders outside the Agency provide guidance less formally and indirectly through interagency meetings such as the Committee on Natural Resources and the Environment and Sustainability (CENRS), U.S. Global Change Research Program (USGCRP), and the Intergovernmental Panel on Climate Change (IPCC). National and international science meetings across diverse interdisciplinary also provide insights into pressing science and emerging environmental issues.

Through these interactions, ACE has developed a defined vision for its future with aligned research to support the pursuit of that vision. The ACE program draws upon its own expertise and capabilities related to science questions that span the source to health and ecosystem outcome paradigm, including source emissions characterization and control, atmospheric chemistry, air quality modeling, ambient measurements, human exposure assessment, epidemiology, toxicology, and human clinical research. The ACE program also attempts to leverage its activities not only across ORD but across its program partners and notably with regional partners who often provide the critical context to link the laboratory to reality.

## VIII. Research Topics

The ACE research program is designed to provide insights into the complex interactions between air, climate and energy issues to inform Agency decisions. The results of ACE research are translated in a coordinated manner with EPA Program Office and Regional partners and external stakeholders to better inform those policy decisions.

The Research Objectives described in Section V. were used to frame ACE research topics into specific areas that focus the scope and nature of the research to achieve the Objectives. Air pollution related research is the largest component of the ACE Program. Research efforts related to climate change and energy are together roughly one third of the clean air component although both are envisioned to grow during the timeframe of the current StRAP. Table 1 briefly describes the ACE research topics along with examples of near-term and long-term research which have been designed to deliberately form a continuum along topic lines. Each research topic is further described in the succeeding sections.

The Program objectives and research topics are similar to those in the previous action plan released in June 2012. The specific research under each objective builds on the research conducted to date. Originally, the ACE program comprised eight topics which have in this Strategic Plan have been refined and integrated in to five Research Topic Areas. Perhaps the most substantive change resides in the Sustainable Energy Evaluation (SEE) topic area. Research in the SEE topic is evolving from a focus on biofuels to a more comprehensive treatment of the U.S. energy system. Research on air pollution has been evolving from a single to multipollutant approach with a growing emphasis on implementation related research and continued research

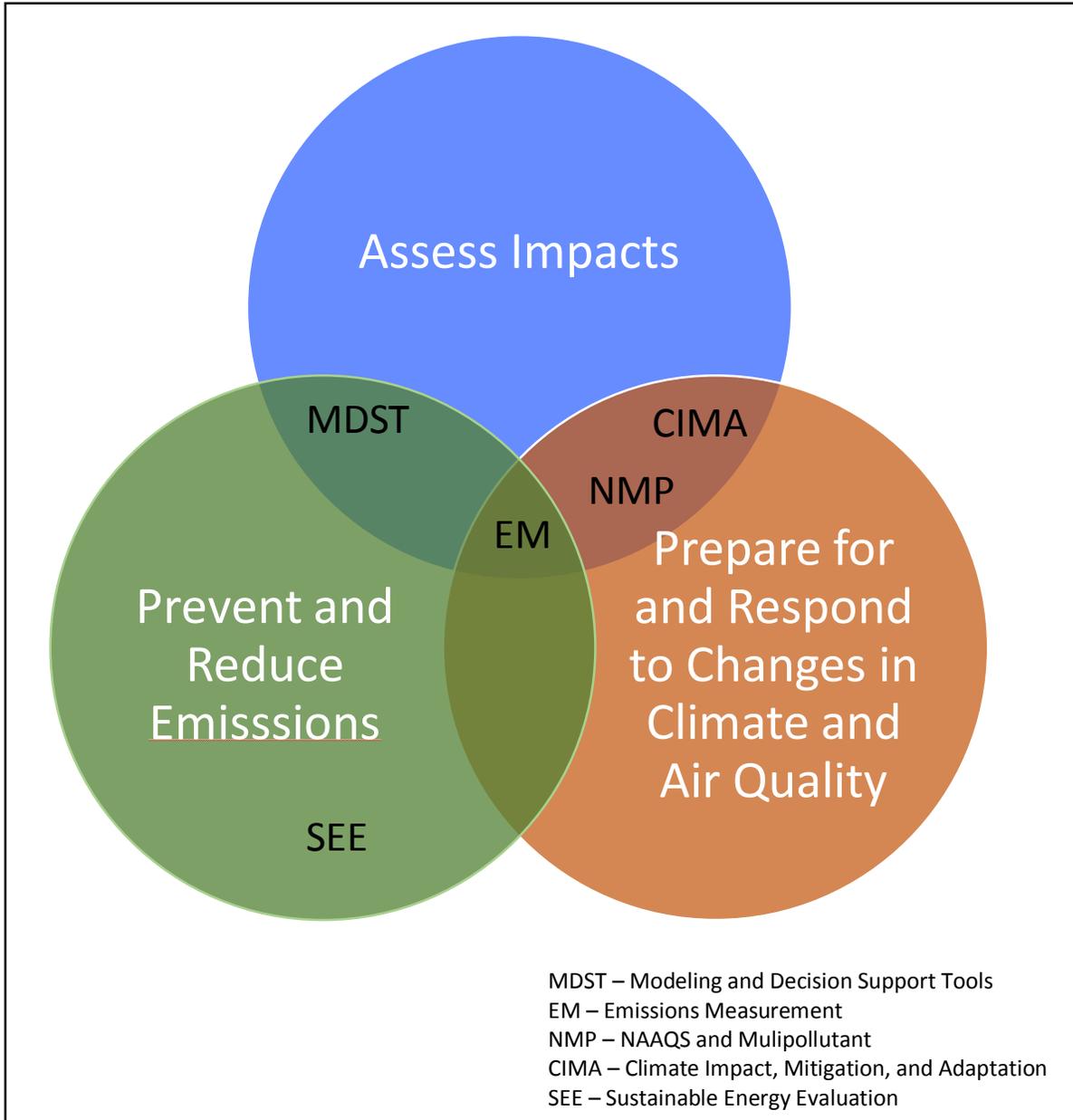
to support development of standards. Climate change research is envisioned to be a growing area in support of the Climate Action Plan and related programs, coordinated across ORD's research programs. Since the 2012 action plan the ACE Program is placing additional emphasis on:

- Exposures and effects of multipollutant mixtures
- Social, economic, demographic and biological (e.g. disease, genetic and epigenetic) factors that may better explain observed public health effects of air pollutants
- Developing science-based solutions to achieve the greatest health and environmental benefits and 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 methane emissions, particularly from oil and gas operations
- Research of the impacts of climate change to better guide mitigation and adaptation related research
- Preparedness and resiliency to a changing climate – ensuring water quality and informed communities
- Regional- and local-scale information on climate-related impacts to water quality, air quality, and ecosystems
- Evaluating the broader environmental impacts of the energy system – from resource supply to end-use
- Fully integrating short-term into long-term research aims

**Table 1.** 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
<b>Climate Impacts, Mitigation and Adaptation (CIMA)</b>	Address climate impacts on air and water quality and associated human and ecosystem health	Assess impacts of climate change on criteria pollutants and ecosystems; Identify subpopulations vulnerable to climate change	Develop sustainable climate adaptation and mitigation approaches	Develop and apply tools to evaluate policies that simultaneously achieve air and water quality, ecosystem and climate change mitigation goals; Integrated climate and land-use scenarios
<b>Emissions and Measurements (EM)</b>	Develop and evaluate regulatory methods for source and ambient air monitoring	Federal Reference Methods for NAAQS; source compliance methods	Change the paradigm for air pollution monitoring	Support development and application of sensors; Use satellites to measure air quality; Low-cost fence line monitoring
<b>Modeling and Decision Support Tools (MDST)</b>	Develop and evaluate local, regional and hemispheric air quality models	CMAQ; Local-scale dispersion models; Hemispheric-CMAQ	Develop and evaluate models to integrate multimedia processes and systems	Integrated air quality and hydrologic models
<b>NAAQS and Multipollutant (NMP)</b>	Inform NAAQS reviews	Assess impacts of criteria pollutants on human health and ecosystems	Develop approaches to interpret multipollutant exposures and human and ecological effects	Assess health effects of mixtures; Develop multipollutant exposure metrics; Perform near-source multipollutant studies; Apply genetic/epigenetic approaches
<b>Sustainable Energy Evaluation (SEE)</b>	Evaluate environmental impacts of energy technology	Assess environmental impacts of oil and gas extraction; Assess human health impacts of biofuels	Protect human and ecosystem health in an evolving energy landscape	Apply systems modeling to generate emissions from future energy scenarios and evaluate potential environmental impacts

Figure 1 shows how the five Topics relate to the three Objectives. Most of the projects support more than one objective, and one of them, Emissions and Measurement, supports all three.



**Figure 1.** ACE Research Objectives and Research Topics

## Topic 1: NAAQS and Multipollutant (NMP)

Transdisciplinary, source-to-outcome research will continue to be conducted to assess multipollutant exposures and health effects in field and laboratory settings, which include both simple and complex mixtures of particles, criteria gases and organic compounds. Models and methods will be iteratively developed, evaluated, modified and applied to assess human and environmental exposures and impacts of air pollution and climate change at individual, community, regional, national, and international scales. The NMP topic remains at the core of the ACE program and constitute the largest single topic area (~40%) 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 and its interactions with climate. As such leveraging of this topic with Climate Impacts, Mitigation and Adaptation (CIMA) is growing. Currently available information and indicators will be examined and expanded to include additional components (e.g., multipollutant/multistressor indices to incorporate climate change impacts) to (1) inform the development of new policies by EPA and its partners and external stakeholders, (2) measure progress toward environmental goals, and (3) provide information for communities and individuals.

Integrated approaches will be developed to assess the physical, biological, and other relevant factors (e.g., socioeconomic, demographic) that result in increased susceptibility or vulnerability to air pollutant-related effects. This will include the identification of biological mechanisms that impact susceptibility and key exposure factors. It will also include the examination of the interaction between behavior, and social and economic factors to more thoroughly understand how they may inform research outcomes and impact strategies to protect public health. Research in this area is integrated with the SHC program to better understand community public health impacts.

Recent scientific findings suggest the possibility that greater numbers of people than previously thought have augmented susceptibility to air pollution-related health effects, such as individuals with diabetes or certain genetic polymorphisms (genetic variations among individuals). Research is also needed to identify the factors that result in ecosystems being highly susceptible to changes in climate or to climate-driven changes (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. Additional research is also needed to improve understanding of nitrogen and sulfur deposition to characterize the resulting changes in ecosystem functions and services. This research will be coordinated with that in the Sustainable and Healthy Communities Program (which specifically houses the issue of susceptibility) and the Safe and Sustainable Water Resources program as reflected in the Nitrogen and Co-Pollutants Roadmap.

The NAAQS and Multipollutant research on human and ecosystem exposure and effects will be conducted to inform future NAAQS reviews. The results of research under the NMP topic area contribute directly to the Integrated Science Assessments developed in the HHRA program. Moreover, the NMP research on atmospheric deposition of nitrogen, sulfur and other co-pollutants are integrated with the SHC and SSWR research programs. The Clean Air Act requires a review of

the NAAQS for each criteria pollutant every five years. 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 decisions.

In keeping with the principles of sustainability, integrated research approaches will include analyses of both expected and potential unintended impacts of novel systems scenarios as might occur with 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.

## **Topic 2: Emissions and Measurements (EM)**

Innovative technologies for monitoring multiple pollutants at sources and in the ambient air will be developed, evaluated, and adapted for a range of applications including compliance and enforcement, regional and national assessments, air quality planning, and community information. These new sensor technologies, such as portable sensors and integrated sensor networks, will provide real-time, continuous data to evaluate emission profiles near and around specific emission sources (so-called fence-line), as well as for measurements of community ambient air constituents. These sensors are also being miniaturized sufficiently for use in characterization of personal exposures. This rapidly evolving technology is evolving sufficiently in terms of their sophistication and accuracy to enable compliance assessments of air pollution emissions and may one day improve overall implementation of clean air regulations. Analytical and data management tools will be pursued under the ACE program to enable local, regional, and national managers to evaluate the effectiveness of air pollution reduction strategies on an ongoing basis.

The performance and cost of measurement technologies will be evaluated to enable comprehensive management of sources that co-emit: criteria and toxic air pollutants, GHGs, and other climate-forcing compounds and aerosols. Evaluations will be done in ways that address not only air pollution problems, but also consider implications on water quality, and quantity and disposal of any wastes 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 the traditional engineering, and atmospheric science approaches to provide a systems-based perspective on these issues.

Not to be overlooked are priority source and ambient monitoring methods, in particular, Federal Reference/Equivalency Methods and air quality modeling tools that need to be improved and evaluated to meet the needs of EPA and state/local agencies in implementing NAAQS. Ease of use, accuracy and cost-drivers are major factors pushing these developments forward. In a related context, research to support the development and refinement of emissions inventories especially for high-priority sources, source categories and source sectors will be pursued to strengthen model development and implementation plans by state and local air monitoring personnel.

This focus of the ACE program towards implementation science is a major segment of the shift as noted earlier.

### **Topic 3: Modeling and Decision Support Tools (MDST)**

Methods and models will be developed and evaluated to support multiscale air quality management (e.g., from local communities to national and global management efforts). These tools will be used 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), 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. The Agency requires modeling and decision support tools to relate changes in air pollution and regional climate to impacts on human health and ecosystems across the U.S. This research spans spatial scales ranging from local to regional to global, including characterization of ambient air quality for inclusion in multipollutant and near-source impact estimates. There are several examples of joint development and applications of air quality modeling tools derived and planned in conjunction with the SHC research program. 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, development of major energy and transportation sector rules, and assessment of risks posed by hazardous air pollutants (HAPs; and develop local and regional-scale air quality and climate data products.

Research under this Topic area is aimed at developing a “one environment” modeling approach to inform protection of ecosystems and human health. This ultimate systems model will serve both the current state of affairs and future climate scenarios. A coordinated and integrated research approach between ACE, SHC and SSWR is being used 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. The multimedia modeling approach will result in improved assessment methods to support better communication and policy development.

### **Topic 4: Climate Impacts, Mitigation and Adaptation (CIMA)**

To effectively target available resources, policy-makers need to understand which populations and ecosystems face the greatest risks to the adverse effects of climate change. ACE research efforts in conjunction with those undertaken in the SSWR and SHC programs will develop methods and tools to improve the understanding of the location, extent, and type of vulnerabilities faced by populations, ecosystems, and the built environment. This information, in combination with an understanding of the potential impacts of adaptation actions, can help inform decisions that are flexible and appropriate for underlying conditions. 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. The integrated research approach involving the SSWR and SHC research programs aims to achieve improved understanding of these complex systems.

Research also will develop approaches to support adaptation risk management to enable decision-makers to identify priority adaptation actions and anticipate related, perhaps less

obvious co-benefits or, alternatively, unintended consequences. It is recognized that approaches taken to adapt to climate change can have environmental and public health consequences that may not be specifically addressed within this science question. For example, the construction of protective barriers against flooding and sea level rise may damage shoreline ecosystems. Also, in a warming climate individuals may spend more time indoors in air conditioned, energy consuming environments. This, in turn, will spark an increased demand for electricity, leading to greater air pollution emissions and water demands on the same days that tend to have the most potential for high ground-level ozone concentrations and when water availability for power generation may be at its lowest. Methods and models will be developed and applied to understanding these types of interactions and responses to develop sustainable adaptation strategies.

Information and communication technologies are rapidly evolving, with new and enhanced tools being continually introduced to the market place. These tools have great potential to support climate change adaptation strategies. EPA already utilizes communication technologies (e.g., Enviroflash, UV Index App) to provide individuals with information that allows them to adapt or make informed public health decisions in response to current environmental conditions. The effectiveness of these types of tools on behavioral responses will be assessed for human health impacts of air pollution and climate change. Geographic information systems (GIS) can provide easily understood visualizations of complex, location-based sets of information and data, allowing for informed decision-making aimed at limiting adverse impacts attributed to climate change, and reducing exposures to air pollution, respectively. ACE research, in collaboration with SHC and their development of the *Environmental Atlas*, will advance the use of GIS to provide information concerning the scope and type of impacts associated with climate change, and the development and delivery of accessible, user-friendly of data, such as information on the climate and air related to different urban planning scenarios.

Community- and individual-level responses to prevent and reduce climate change impacts are influenced by social, behavioral, economic, and other systems that exhibit nondeterministic behaviors that are not easily modeled or predicted. These consequences can have impacts that cascade well beyond the immediate actions of policies and approaches, often in unexpected ways. For instance, climate change can impact energy systems by affecting crop yields, which subsequently could impact the production of the same alternative fuels intended to address climate change in the first place.

### **Topic 5: Sustainable Energy Evaluation (SEE)**

The emphasis of the research under this topic area will be on emerging fuels, resources and technologies that pose the greatest risks or benefits to the environment and human health, with the understanding that efforts to mitigate climate change and air quality will be the driving force of changes in the U.S. energy system.

The research in the SEE topic area relies on an integrative approach to bring together data and analyses to evaluate and assess the environmental impacts of energy from the systems and lifecycle viewpoint, including dynamics between the energy sectors, and crossing the energy continuum from extraction to end-use. In support of this, ACE researchers will develop methods, models, and data of traditional and alternative energy systems and their impact on air pollution

and climate change. Impacts considered will include costs, performance, and the effects on human health, water quality, and ecosystems. Additional analyses will assess the impacts of anticipated and alternative strategies for achieving national energy and environmental goals. An example is an analysis of potential alternative strategies that may improve the sustainable use of limited resources.

In addition, models from various disciplines and media will be linked to conduct integrated analyses of the impacts of atmospheric pollutants. For instance, one approach includes integrating an atmospheric chemical transport model (CMAQ), an energy allocation model (MARKAL), and an economics benefits model (BenMAP) to evaluate the public health benefits, costs and tradeoffs associated with various alternative energy scenarios.

## IX. Conclusion

[To be completed in final Strategic Research Action Plan]

## Appendix A. Table of Proposed Outputs

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

[To be completed in final Strategic Research Action Plan]

*The following table lists an example of the expected outputs from each of the Air, Climate, and Energy Research Program topics. Outyear (FY16-19) outputs are still under development. A more comprehensive list will be included in the final StRAP.*

<b>Topic</b>	<b>Output</b>	<b>Due Date</b>
Emissions and Measurements	Develop a community of practice for remote sensing techniques and data collection	FY2017
Climate Impacts, Mitigation and Adaptation	Better understanding of methods to assess urban resilience to climate change	FY2017
Modeling and Decision Support Tools	A modeling framework to examine the role of inter-continental transport on U.S. air quality and to study air quality-climate interactions	FY2016
NAAQS and Multipollutant	A synthesis report assessing the best approaches and methods to determine toxicity of multipollutant mixtures	FY2016
Sustainable Energy Evaluation	Summary of water use implications from the full energy system resulting from changes in energy resource supplies, technologies, and patterns of end use	FY2016