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United States
Environmental Protection
Agency

Science to Protect Public Health and the Environment

EPA RESEARCH PROGRAM OVERVIEW 2016-2019

Office of Research and Development
Overview: Science for a Sustainable Future

EPA 601/K-15/007

Science to Protect Public Health and the Environment

EPA Research Program Overview 2016-2019

U.S. Environmental Protection Agency
October 2015

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Introduction

The United States has made tremendous progress in environmental protection, and we now have cleaner air and water, waste sites restored to useful purposes, and safer consumer products. For more than four decades, EPA research has informed policies and led to impacts that define environmental progress. EPA research provided the evidence and assessments that led the Agency to ban the use of lead in gasoline, protecting an entire generation of children from hazardous lead exposure. EPA research illuminated the critical link between secondhand tobacco smoke and serious health impacts, findings that turned the tide so that smoking is no longer permitted in many public spaces, reducing the risks for all.

EPA researchers continue to build on this progress by delivering new scientific understanding and technologies to help solve the complex environmental challenges affecting our health, environment and economy.

This document provides an overview of EPA's research programs within the Office of Research and Development. This critically important work is providing the science needed to address the biggest problems facing environmental science, the Agency, and the world. This cutting-edge and innovative research portfolio is connecting the dots in an unprecedented and integrated way by characterizing problems up front, recognizing the inherent connections between a healthy and sustainable environment and healthy people, and working across historical media-specific lines with an understanding that problems aren't isolated to just air or water or land, but in fact, cut across those domains. Environmental challenges include:

- Rising global average temperature (see text box, Our Changing Climate) is associated with widespread changes in weather patterns which can impact people's lives. Many areas have seen changes in rainfall, resulting in more frequent and intense flooding and drought events, as well as more frequent and severe heat waves. These events can cause loss of life, injury, and property damage, and can disrupt basic services such as transportation, electrical power and water supply.

- Much of the western U.S. is facing record-setting drought with mountain snowpack levels at or near their lowest levels on record. In addition to greatly reducing water supplies, drought contributes to increased incidence of wildfires and forest disease, leading to loss of life and property damage, air pollution health effects, habitat destruction, and potential impacts to water quality.

- Nutrients, such as nitrogen and phosphorus, are polluting our waterways, creating another difficult environmental and human health issue affecting local and regional economies. We face a serious challenge—to achieve the beneficial level of nutrients in the environment to enhance food production and other services, while protecting human and ecosystem health.

- Tens of thousands of chemicals are currently used, but only a small fraction have been thoroughly evaluated for potential risks to human health, wildlife and the environment. We know very little about people's real life exposures to most of these chemicals; in particular we lack data about exposures during critical stages of life and development.

- Many communities are disproportionately overburdened by pollution. We need to better understand the impacts of chemical and non-chemical stressors in causing disparities in health effects and how to help communities improve resilience to disasters.

Advances in science and technology, including social sciences, can help us address these and other complex challenges. EPA's portfolio of research for 2016-2019 builds on the research program from 2012-2016 and is designed to advance our understanding of the complex relationships between human activities and their impacts on public health and the environment. This overview of EPA research summarizes:

- Research Organization and Support for EPA Strategic Plan
- Guiding Principles for EPA Research
- Highlights of EPA Strategic Research Action Plans

Our Changing Climate

Over the past century, the large amounts of carbon dioxide and other greenhouse gases released into the atmosphere have been the most important cause of recent climate change. The earth's average temperature has risen by 1.4° F, and if no action is taken to reduce emissions, the average temperature will rise another 2- 11.5° F over the next hundred years*. EPA's 2015 Report on the Environment says that, among other impacts, future global warming is projected to produce more severe droughts in the southwestern U.S.

*Melillo, Jerry M., Terese (T.C.) Richmond, and Gary W. Yohe, Eds., 2014: Climate Change Impacts in the United States: The Third National Climate Assessment. U.S. Global Change Research Program, 841 pp. doi:10.7930/J0Z31WJ2.

Research Organization and Support for EPA Strategic Plan

EPA science is anchored in the priorities of the Agency. EPA's *FY 2014-2018 EPA Strategic Plan*[1] states, "Sustainable, innovative approaches grounded in science—the underpinning of the EPA's decision making—are instrumental to solving today's environmental challenges. Now more than ever EPA's leadership as a pre-eminent science and research institution is essential."

To embrace the critical need for science leadership, EPA's Office of Research and Development (ORD), the science arm of the Agency, has established six highly integrated and transdisciplinary national research programs that closely align with the Agency's strategic goals (2014-2018) and cross-agency strategies (see Figure 1). The six 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)

Each research program engages EPA program and regional offices and outside partners and stakeholders to identify the research priorities that are important for achieving EPA's strategic goals and objectives.

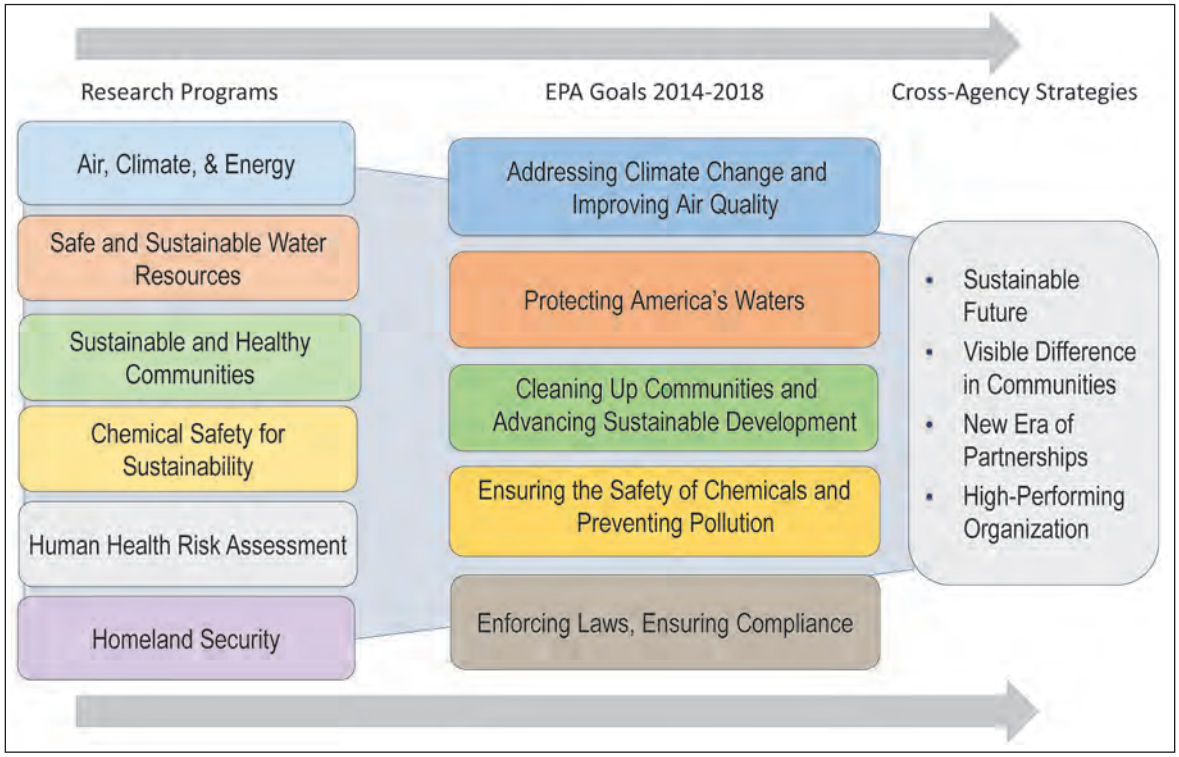
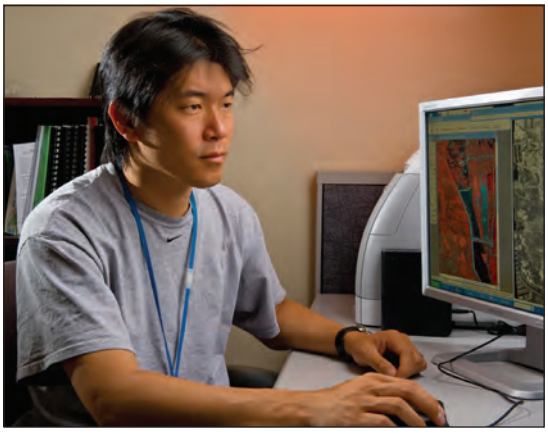


Figure 1. The EPA Office of Research and Development's six national research programs are closely aligned with EPA Strategic Goals and Cross-Agency Strategies. Research in any one program also helps the Agency achieve multiple goals.

ORD's Six Research Programs Aligned with EPA Strategic Goals

EPA staff scientists and engineers conduct research in laboratories and research facilities at 14 locations across the country. Overall resources for ORD in fiscal year 2015 included $521 million and 1755 employees. EPA staff are joined by a network of collaborators, partners, fellows, and grantees. For example, scientists in the research laboratories collaborate with scientists in EPA regional offices on projects addressing specific regional concerns. Grantees and fellows compete from across the nation to receive funding from EPA's Science to Achieve Results (STAR) extramural research program. EPA is one of 11 federal agencies that participate in the Small Business Innovative Research (SBIR) program, enacted in 1982 to strengthen the role of small businesses in federal research and development, create jobs, and promote technological innovation.[1]

EPA continues to experiment with initiatives to foster innovation and creativity in research. Staff are exploring scientific competitions and challenges, citizen science and crowd-sourcing, public-private partnerships, and other activities that promote innovative thinking and sustainable solutions. For example, the "Pathfinder Innovation Projects" internal agency competition offers EPA scientists an opportunity to win seed funding for out-of-the-box ideas that could be "game-changers" for environmental protection.



[1]See http://epa.gov/ncer/

Guiding Principles for EPA Research

Several principles guide the design and implementation of EPA research programs. They are: Protect Public Health and Advance Sustainability; Ensure Science Quality and Transparency; Achieve Broad Impact; Innovate; Inform Decisions and Actions; Seek Collaboration; and Support High-Performing Workforce. Completed and ongoing research activities that illustrate these principles are highlighted below.

Protect Public Health and Advance Sustainability

Protecting public health is one of EPA's fundamental goals. EPA research uses a systems approach to understand what causes environmental problems, and to design solutions that benefit health, the environment, and the economy—all of which are interconnected. Systems approaches help advance understanding of the complex relationships between human health and the environment, and this knowledge leads to progress in achieving sustainability—meeting today's needs without compromising the ability of future generations to meet their needs. One example of current research:

- **Clean energy future:** natural gas is playing a key role in reducing carbon emissions, creating jobs, and providing a domestic source of energy. EPA's research on the potential drinking water impacts of the development of America's shale gas resources is helping ensure that responsible development will benefit the economy, energy security, and environment.

Ensure Science Quality and Transparency

Given the stakes of environmental decisions, it is imperative that EPA produce and rely on high quality science. Whether it's a community determining the safety of reusing precious water for a variety of purposes, a national policy under scrutiny by the Supreme Court, or an enforcement action requiring an industry to revamp its processes to prevent toxic emissions, the science and technology underlying these important decisions must be of the highest quality and accessible to the public. EPA's commitment to quality science includes a rigorous peer review policy, publishing results in peer-reviewed journals, and review by external scientific committees such as the National Academy of Sciences and EPA's Science Advisory Board and Board of Scientific Counselors. Our commitment to transparency includes public access to EPA's publications and supporting scientific data.

- **Scientific advice:** Each research program benefits from the advice of a dedicated subcommittee of EPA's Board of Scientific Counselors with ongoing engagement throughout the duration of the 2016-2019 research program. EPA recognizes that its sound, high quality research will be used not only by the Agency, but also by other federal, state and local agencies, private companies and organizations around the world.

Achieve Broad Impact

EPA's research addresses environmental problems of national and international significance and strives to produce scientific results that are timely and solution-oriented. For example:

- **Climate change:** EPA research contributed evidence that provided the scientific foundation for EPA to move forward

with regulations to reduce greenhouse gas emissions from stationary sources. Groundbreaking research on the role of black carbon in climate change is helping decision makers assess benefits of reducing these emissions on a global to local scale. This work, together with other air quality research, such as studies on cookstoves, has global impact affecting billions of people.

The World Health Organization estimates that exposure to smoke from traditional cookstoves and open fires leads to 4.3 million deaths each year. EPA research helps to improve air quality, protect public health and slow climate change.

- **Streams and wetlands impact water quality:** Smaller water bodies play an important role in the health of larger downstream waterways such as rivers and lakes, as described in an extensive EPA state-of-the-science report[2]. The report provided the science behind the 2015 Clean Water Rule that clarified the jurisdiction of the Clean Water Act, protecting the streams and wetlands that form the foundation of the nation's water resources.
- **Clean air:** Over the last 45 years, air quality in the U.S. has improved dramatically. EPA's National Ambient Air Quality Standards are the highest impact regulations, ensuring U.S. air quality that prevents thousands of heart attacks and premature deaths, and millions of cases of respiratory illness, such as bronchitis and asthma. Every five years, EPA reviews the standards for air pollutants such as particulate matter, ozone, and nitrogen oxides. The standards often face legal challenges, including cases that are decided by the U.S. Supreme Court. EPA depends on the sound, peer-reviewed scientific research and assessments that characterize the health, ecological and welfare effects from exposure to these pollutants.

EPA's CMAQ Model is a powerful computational tool used by EPA and states for air quality management. The National Weather Service uses the model to produce daily U.S. forecasts for ozone air quality. CMAQ is also used by states to assess implementation actions needed to attain National Ambient Air Quality Standards.

Innovate

Fostering creativity and stimulating transformational change can solve complex problems in new and innovative ways. Sometimes, it's the advent of technological advances in other fields that can be applied to an environmental problem. Examples include:

[2]See http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=296414

- **Rapid, automated chemical testing:** Agency researchers and their partners are revolutionizing the assessment of potential risks to humans and the environment from exposures to chemicals and forging a new generation of predictive capabilities, technologies and solutions. New tools enable rapid screening of chemicals for adverse effects, using very small amounts of chemicals in laboratory test samples, high-throughput robotics, and automated analysis.

- **Satellite data for water monitoring:** A team of scientists from EPA, NASA and the U.S. Geological Survey used satellites to monitor and assess water quality and harmful algal blooms in lakes, reservoirs and estuaries. This new approach can provide early warning to environmental and public health agencies to prepare for action.

Inform Decisions and Actions

EPA relies on sound science to inform decisions that affect communities across the nation. To ensure research is relevant, ORD works very closely with EPA partners to define the most pressing environmental problems, research needs, and data gaps. EPA research is intended to be accessible and meet both near- and long-term science needs. Significant research efforts focus on developing the science that serves as the foundation for environmental regulations. Providing technical support to help with more immediate local issues continues to be of great value to EPA regions. ORD is also poised in times of crisis, such as chemical spills, explosions or other potentially hazardous releases into the environment, to make its laboratories and technical experts available to provide immediate assistance to the on-site decision makers. Research plans and products are peer-reviewed to ensure transparency of methods and results. For EPA research to be relevant and accessible, it also has to be translated and delivered such that it can be of real value to the end users. The clients for EPA research range from scientists to policymakers, lawyers, and the general public. Examples include:

- **Asbestos assessment in Region 8:** EPA and federal partners assessed the risk to public health from asbestos-contaminated vermiculite in Libby, MT. This assessment informs risk management decisions, including the ongoing clean-up and remediation activities in the Libby community. These activities have reduced the asbestos outdoor air concentrations in Libby, making the air quality in Libby similar to other Montana cities and reducing risks of cancer and respiratory disease from asbestos.

- **Reducing stormwater runoff:** Stormwater flowing from paved streets, parking lots, and building rooftops can accumulate chemicals and other pollutants that can adversely affect water quality. Green infrastructure, which includes approaches such as rain gardens, porous pavement, and green roofs, can alleviate flooding and protect water quality. EPA's National Stormwater Calculator is a desktop application that estimates reductions in stormwater runoff for various green infrastructure options, and it is a practical and easy-to-use tool for local decision makers such as urban planners, landscape architects, site developers and homeowners.

EPA green infrastructure researchers provide key tools, such as the National Stormwater Calculator, to address stormwater management.

Seek Collaboration

EPA science has even greater impact through strong collaboration with public health and environmental partners. ORD works collaboratively across its research programs and also develops partnerships within EPA and with external organizations to accomplish its work. Partners include scientists, engineers, decision makers, risk managers, and other experts in EPA program and regional offices, other federal agencies, state and local governments, and other research organizations. Developing scientific tools and information jointly with partners, and soliciting feedback from EPA partners and outside stakeholders, helps ensure that research results are meaningful and that research products are tailored to meet the needs of decision makers at the federal, state and local levels.

- **Children's environmental health:** Children's environmental health research involves many disciplines, such as reproductive and developmental health, genetics, exposure science, sociology, and pediatrics, and requires coordination and collaboration across EPA research programs, laboratories and centers. In a long-running partnership with the National Institute of Environmental Health Sciences, EPA supports university-based, multi-disciplinary research centers dedicated to children's health[3]. These centers have provided the foundational science for understanding environmental health impacts on children and have contributed evidence supporting policy decisions related to air pollution, pesticides and endocrine-disrupting chemicals.

- **Homeland security:** Multiple agencies are involved in responding to environmental disasters, including terrorist incidents. EPA regularly collaborates with other federal agencies to conduct joint research and operational activities. For example, a recent full-scale test operation focused on sampling, decontamination and waste management for a facility contaminated with simulated anthrax spores. EPA's partners in the effort included the U.S. Departments of Homeland Security, Health and Human Services, Justice, Defense, and Energy.

EPA partnered with the U.S. Department of Health and Human Services on a campaign to promote heart health.

Support High-Performing Workforce

EPA's research organization is unique in its breadth of expertise and science leadership to address multifaceted environmental issues. Engineering, environmental health, ecology, computer science, and meteorology are just a few examples of the many scientific and technical fields represented. Multidisciplinary research is encouraged so that scientists can work together across many different areas of expertise. As science evolves, so do the areas of expertise needed to maintain highly relevant and outstanding research. EPA's Office of Research and Development developed a workforce strategy to address the critical expertise gaps in the next three to five years and to serve as a guide for future hiring decisions. Social science is just one area of expertise needed for research planned in the next several years.

[3]See http://epa.gov/ncer/childrenscenters/

Strategic Research Action Plans 2016-2019

EPA has developed six Strategic Research Action Plans, one for each of the national research programs. The plans describe the research vision, objectives, topics, and expected accomplishments. Each explains the programs' efforts to collaborate with EPA partners and stakeholders. Involving those who rely on EPA research, from staff to senior managers, in setting priorities and following research progress through to translation, is vital to program success and ultimate impact.

Integrating across the six programs is a particular focus for the 2016-2019 plans. Many environmental issues cut across the six programs. ORD puts special emphasis on ensuring that research on cross-cutting issues is coordinated and collaborative. Embracing such integration ensures that the work is designed to tackle the increasingly complex nature of environmental challenges and threats.

In addition, because of their Agency-wide prominence, four key topic areas have been selected for focused and active integration across the six national programs: climate change, children's environmental health, nitrogen and co-pollutants, and environmental justice (see Figure 2). Each of these efforts is described in a cross-cutting research roadmap led by one of the research programs. The roadmaps describe ongoing research and also help inform the national research programs' strategic planning activities. EPA program and regional office partners provide instrumental input that helps shape ORD's investment in these cross-cutting topics. The research programs work together to address additional important cross-cutting issues, such as community resilience and integrating new data streams into risk assessment.

Highlights from the six Strategic Research Action plans, including examples of research planned for the years 2016-2019, and examples of research collaboration on cross cutting issues are summarized in the following pages.

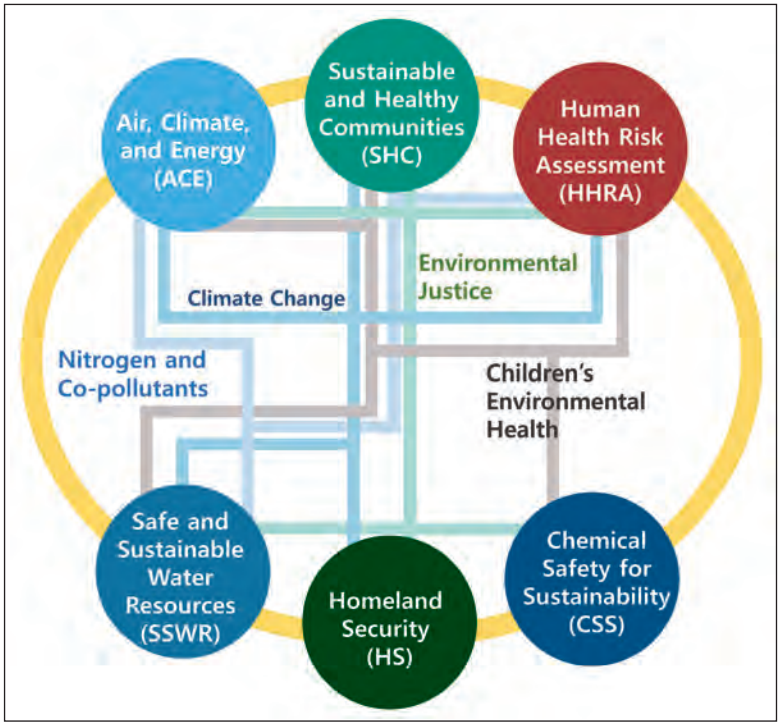


Figure 2. Integration across the six national research programs and four roadmap topics.

Air, Climate, and Energy

The Air, Climate, and Energy (ACE) research program builds upon 40 years of achievement in air pollution research that has led to landmark outcomes—including visibly cleaner air, healthier communities, and longer life expectancies. Looking forward, we understand that air quality and climate are inextricably linked, and global climate change is adversely affecting public health and the environment in many areas of the country. Energy production and use have major impacts on both air quality and climate with conventional energy options generally representing the major source of air pollution emissions, including greenhouse gases.

ACE research will directly advance EPA's strategic goal to address climate change and improve air quality. The ACE program continues to fulfill Clean Air Act requirements by providing scientific support to decision makers on individual air pollutants of concern. However, we all breathe mixtures of air and are not often exposed to air pollutants one at a time. As a result, ACE research is also focused on assessing impacts of exposures to a combination of many pollutants in the air, analyzing approaches for preventing and reducing emissions of pollutants including greenhouse gases, and helping communities, states, and regions respond to the impacts of changes in climate and air quality.

By addressing air, climate, and energy issues in an integrated way, the ACE research program provides the scientific results and innovative technologies that are needed to take action on climate change and improve air quality.

The ACE program has brought together scientists from a broad range of disciplines including atmospheric and climate science, air and water quality, environmental health, exposure, ecology, economics, and more. These scientists and engineers work collaboratively with those who use and depend upon our research—EPA policy makers, state, local and regional officials and external stakeholders—to ensure the ACE program is responsive and relevant to the greatest needs. By working together to articulate highest priority problems and research, the ACE program is focused on three main objectives:

1) **Assess Impacts**
   Develop and apply methods to assess the impacts and effects of air pollution exposure and climate change at individual, community, regional, and global scales.

2) **Prevent and Reduce Emissions**
   Provide the science needed to develop and evaluate approaches to prevent and reduce harmful air emissions. The data and methods resulting from this research can be used to analyze the full life cycle impacts of new and existing technologies and assess the sustainability of various energy choices.

Research Challenges

We breathe a mixture of air pollutants. Current scientific understanding of environmental and health risks of air pollution is based on single pollutants.

The effects of climate change on air, water and ecosystems will vary by region and locality. Helping communities prepare for climate change requires scientific data across a range of geographic scales, not currently available.

Energy choices have trade-offs, but the health and environmental risks and benefits of new technologies and approaches are not well understood.

Social, behavioral, and economic factors influence the effectiveness of air quality and climate policies, and methods are lacking to address all factors together.

3) **Respond to Changes in Climate and Air Quality**
   Provide modeling and monitoring tools and information to help government agencies and communities prepare for impacts to air, water, and land from climate change. While reducing greenhouse gas emissions is a critical part of minimizing future climate change, it is also necessary to adapt to the environmental impacts caused by unavoidable changes in climate.

The ACE program will continue to provide direct technical assistance to its EPA partners in the program offices and regions; provide research needed for immediate policy or regulatory action; and anticipate and develop the science needed for decisions in the coming decade. As the lead for the cross-cutting issue of climate change research, the ACE program works closely with scientists from other federal programs and across EPA, including the other five research programs (see text box). EPA is one of 13 departments and agencies that contribute to the U.S. Global Change Research Program (USGCRP), which coordinates federal climate change research. ACE research is of interest to scientists and environmental managers all over the world.

2016-2019 ACE Strategic Research Action Plan Research Examples

The ACE program encompasses research related to air quality monitoring, modeling, public health, climate change and energy sustainability. Examples of this research for 2016-2019 are described below.

Next Generation Air Pollution Monitoring

Historically, approaches for monitoring air pollution generally use expensive, complex, stationary equipment, which limits who collects data, what data are collected and how data are accessed. This landscape is changing rapidly with the emergence of lower-cost, easy-to-use, portable air pollution monitors (e.g., sensors) that provide high-resolution data in near real time and may be used by state and local agencies, research scientists, regulated facilities, communities and individuals for a range of different purposes. ORD collaborates with EPA programs and regions, states and federal partners on this research.

Agency scientists will continue to evaluate and utilize versatile, next-generation air monitoring technologies in novel ways, such as mounted to vehicles or applied along fence lines.

Global Climate Change Research Roadmap

EPA's mission to safeguard the environment and protect human health puts the Agency at the forefront of federal efforts to mitigate and prepare for climate change impacts to air, water, land, ecosystems, and human health. Highlighting the unique role that EPA plays, the Climate Change Research Roadmap illustrates how EPA's research will: improve the understanding of the interactions between climate change and the environment; evaluate the resulting impacts on human health and welfare; develop strategies to prepare for and respond to these impacts; and ensure that such responses promote sustainability and avoid further, unintended adverse impacts. The Roadmap illustrates the coordination and integration of research related to climate change across the six national research programs (ACE, CSS, HHRA, HSRP, SHC and SSWR), responding to the needs of EPA's Office of Air and Radiation, Office of Water, Office of Solid Waste and Emergency Response, Office of Policy, Office of Children's Health Protection and the EPA regional offices.

Working with the industrial community and other partners, they are providing spatial and temporal data useful for assessing both air pollution source emissions and ambient air quality around facilities and areas of high interest, such as energy production and processing plants, industrial facilities, agricultural operations, landfills, brown fields and waste water treatment operations.

EPA researchers are advancing next generation mobile air quality monitors.

EPA researchers designed and installed solar-powered, community-based air monitoring systems ("Village Green Benches") to explore real-world applications of next-generation air monitors, and develop new approaches for harnessing the proliferation of new data they are generating.

EPA-supported Air, Climate, and Energy Research Centers

Through the highly-competitive Science to Achieve Results (STAR) grants program, EPA will fund the fourth-generation of air research centers, now the Air, Climate, and Energy Research Centers, a network of university-based, multidisciplinary consortia. Center researchers are focusing on the challenges faced by different regions of the country in achieving and sustaining air quality as climate change continues. Local conditions can be highly variable, including differences in emission sources, topography, climate, meteorology, demographics, and socioeconomic and cultural patterns. Researchers are improving understanding of how these social, economic, environmental and other factors affect regional differences in the mix and magnitude of air pollution. Results will inform policy makers on the development of innovative approaches that enhance the effectiveness of air pollution control strategies and achieve the greatest public health benefits.

Helping to Protect Local Air Quality in a Changing Climate

As part of their efforts to protect public health, states across the nation rely on EPA's Community Multi-scale Air Quality Model (CMAQ) to help predict changes to air quality as a result of proposed actions to meet clean air standards. But while that system has proved invaluable for more than a decade, a new challenge has emerged: climate change. EPA modelers are developing new frameworks for incorporating critical data across multiple scales, down-scaling global climate meteorological projections to expand CMAQ's powerful capabilities for calculating local and regional air quality projections. The work will support air quality managers who must consider how changes in climate would affect their state efforts to achieve clean air.

Public-Private Research Partnership: Health Effects of Air Pollution

Through a long-term partnership, EPA and the motor vehicle industry jointly fund the Health Effects Institute, which sponsors independent, peer-reviewed research on the health impacts of motor vehicle emissions. For 2015-2020, the Institute is focusing on research to inform decisions on air quality and on climate-driven technology. The program has four core program elements: (1) addressing the continuing challenges of multipollutant science; (2) accountability and transparency; (3) assessing emerging fuels and technologies; and (4) global health.

EPA and the Health Effects Institute are developing the next generation of tools and scientific information to examine the combined effects of air pollution on human health and the relationship between air quality and climate change.

Safe and Sustainable Water Resources

Water is one of our Nation's most precious resources. The United States uses about 400 billion gallons of water each day. We depend upon it for our lives and our livelihoods, for healthy ecosystems and a robust economy. Yet a host of challenges threaten the safety and sustainability of our water resources, including biological and chemical contaminants, aging water-system infrastructure, demands of the energy, agriculture and manufacturing sectors, population change, climate change, extreme weather events and homeland security threats.

To address these challenges, EPA's Safe and Sustainable Water Resources (SSWR) research program is using an integrated, systems approach to develop scientific and technological solutions to protect human health and to protect and restore watersheds and aquatic ecosystems.

The research directly advances EPA's strategic goal "Protecting America's Waters" and provides scientific and technical support to meet

Research Challenges

Excess levels of nutrients and sediment remain the Nation's largest contributor to water-quality deterioration. The rate at which water bodies are newly listed for water-quality impairment exceeds the pace that restored waters are removed from the list. Surplus nutrients cause widespread damage to aquatic ecosystems and impact public health.

Sustainability of groundwater, with regard to drawdown, recharge, and increasing potential of contamination, is a growing concern.

Current drinking water and water treatment systems are inadequate to meet future needs.

Many water systems are outdated and inefficient, losing trillions of gallons of treated water each year because of pipe leaks and breaks.

Stormwater overflows in combined sewer systems send billions of gallons of untreated sewage into lakes and rivers.

Changes in population, land use, climate and extreme events will affect water resources and aquatic ecosystems.

Agency obligations enforcing key legislative mandates, including the Clean Water Act and the Safe Drinking Water Act.

SSWR scientists have worked closely with partners from EPA programs and regional offices, as well as federal and state agencies, public and private stakeholders and the scientific community to identify research priorities. Four main objectives guide the SSWR research program:

1) **Address Complex Chemical and Microbial Pollutants**
   Develop new methods for detecting, quantifying, monitoring, and treating complex chemical and microbial pollutants. This research focuses on new and emerging contaminants that threaten human health and aquatic ecosystems, providing scientific and engineering guidance to strengthen drinking water and water quality standards.

2) **Transform the Concept of 'Waste' to 'Resource'**
   Develop innovative water treatment technologies and green infrastructure techniques to tap current streams of wastewater for resources. Through this research, stormwater runoff as well as wastewater from homes and industries has the potential to become a source for certain, closely defined ("fit-for-purpose") water use, and as a source for recovering energy, nutrients, metals and other valuable substances.

3) **Quantify the Benefits of Water Quality**
   Clean water and healthy ecosystems provide many services that are currently undervalued. By developing models and tools to estimate the economic benefits of water-quality improvements, this research will aid in the protection or restoration of water quality.

4) **Translate Research into Real-world Solutions**
   Move results out of the lab and into the hands of end users who can use those applications to sustainably manage water resources and infrastructure.

As the lead for the cross-cutting issue of nitrogen and co-pollutants research, the SSWR program works closely with scientists from other research programs, EPA program and regional offices and other federal agencies (see text box).

Nitrogen and Co-pollutants Research Roadmap

Excess nutrients in water are causing widespread damage to aquatic systems and impacting public health. Significant, sustainable reductions in nutrients must be economically efficient, socially acceptable, environmentally sound, adaptable to climate change, land-use and demographic changes, and permanent. These requirements can be met only through integrated research that informs the systematic collective, adaptive management of nutrients across air, land, and water. To achieve that, SSWR is leading a collaboration on nitrogen and co-pollutants research across multiple media and spatial scales. The Nitrogen and Co-pollutant Roadmap is a collaboration among ORD's research programs (ACE, HHRA, SHC, and SSWR), EPA's Office of Water, EPA's Office of Air and Radiation, and EPA's Regional Offices. The roadmap provides a cross-media, integrated, multi-disciplinary approach to sustainably manage reactive nitrogen and co-pollutant (in particular phosphorus, but also sulfur, sediments) loadings to air, surface and ground water to reduce adverse impacts on the environment and human health.

2016-2019 SSWR Strategic Research Action Plan Research Examples

SSWR research focuses on high-priority, current and long-term water resource challenges identified in partnership with EPA program and regional office partners and other partners and stakeholders. Examples of research for 2016-19 are described below.

Addressing Harmful Algal Blooms

Human activities appear to be increasing the frequency of harmful algal blooms — the rapid overgrowth of certain types of toxin-containing algae and cyanobacteria. The proliferation of such organisms can pose risks to human health by contaminating recreational waters and drinking water supplies. EPA researchers are developing predictive capabilities, analytical methods, and remote sensing techniques to detect blooms. EPA works with partners at NASA, NOAA and USGS to use data collected by satellites. That and other innovative work will provide stakeholders and decision makers with improved scientific information and tools to effectively assess and manage harmful algal blooms and associated toxicity events.

NASA satellite image of harmful algal bloom striking Lake Erie in the summer of 2014, resulting in a "do not drink" water advisory for the entire City of Toledo, OH.

Green Infrastructure in Communities

For many cities, stormwater management remains one of the greatest challenges to meeting water quality standards. Local communities can realize cost savings and many other benefits by using green infrastructure—natural and engineered techniques that increase the capacity of local watersheds to absorb stormwater runoff and seasonal snow and ice melt. EPA researchers are developing a green infrastructure classification framework, and advancing research to test and refine sophisticated tools, models, and screens that incorporate multiple community-based parameters, including the evaluation of financial strategies and economic costs. Results will help communities effectively use innovative green infrastructure techniques to meet their goals for minimizing stormwater discharge and mitigating combined sewer overflow events. Green infrastructure can potentially improve water quality, while providing other benefits such as additional green space in urban settings and recharging ground water supplies.

Green roofs can be used effectively to reduce stormwater runoff from commercial, industrial, and residential buildings.

Reducing Risks from Water Treatment Disinfection By-products

The presence and potential health effects of by-products from chemical water treatment, known as disinfection by-products, are a concern for water treatment facilities and public health officials. EPA researchers are tapping

recent technical advances in integrated toxicological and chemical characterization studies (see more in the Chemical Safety for Sustainability section of this document) to advance the understanding of the joint impacts of initial source water quality and the choice of disinfection techniques and technologies. Results will advance water treatment techniques and better protect public health.

EPA researchers are helping water quality treatment facilities reduce risks from disinfection by-products.

Quantifying National Water Quality Benefits

The long-term sustainability of water quantity and quality depends on better assessing the value of clean, abundant water that contributes to human health, recreation, food production and other environmental services. Without that understanding, the degradation of water quality due to chemical and microbial contaminants, including nutrients, will continue to outpace water quality improvements. ORD and EPA policy partners are advancing national water quality benefit-cost analyses and modeling tools that will build the capacity for estimating the economic benefits of water quality improvements. These resources include a new generation of studies that will identify market and non-market values associated with water quality, and will identify useful metrics for linking water quality models to economic valuation.

Sustainable and Healthy Communities

How do communities meet their day-to-day needs without compromising the ability of their children and future generations to one day meet their own? And more specifically, how can we take action to protect our shared environment—air, water, land, and ecosystems—in ways that are economically viable, beneficial to human health and well-being, and socially just?

The Sustainable and Healthy Communities (SHC) research program is developing the knowledge, data, and tools to answer those questions. The program is focused on providing

Research Challenges

Communities need information to make decisions on infrastructure, land use, transportation, and waste management that meet short-term priorities while minimizing impacts to, and maximizing benefits for long-term public health and community prosperity.

The complex and dynamic interactions of social, economic, and environmental trade-offs are not well understood, nor incorporated into usable, accessible tools and models.

Information is limited on linkages between human health and well-being, ecosystems, local economies, and disproportionate environmental burden.

scientifically sound information to EPA program and regional offices and U.S. communities to inform decisions that produce more sustainable outcomes for our environment, society, and economy.

The SHC program is strongly aligned with advancing EPA's strategic goal, "Cleaning Up Communities and Advancing Sustainable Development," and the cross-agency strategies of "Working Toward a Sustainable Future" and "Working to Make a Visible Difference in Communities." The program is also helping the Agency implement key recommendations made by the National Research Council (NRC) in its reports *Sustainability and the US EPA and Sustainability for the Nation*. The NRC explicitly recommends adopting a sustainability framework that requires a comprehensive approach for incorporating sustainability into decisions and actions.

Traditional methods for evaluating environmental impacts typically focus on one pollutant or one type of activity. To better evaluate effects of policies or programs, SHC focuses on incorporating environmental science into more holistic approaches (such as health impact assessment) that consider the interaction of environmental, social and economic factors on the health of a population. SHC is partnering with EPA regional offices and communities to apply these methods to help solve complex community issues.

SHC research is focused on many of our nation's most pressing problems, including: contaminated sites and revitalizing communities, oil spill response and clean up, and shifting the paradigm from disposal of waste to reuse of materials and resource management.

Collectively, the SHC research program delivers information and tools needed to support and inform decisions that advance outcomes that sustain a healthy environment, society, and economy. Four broad research objectives guide that work:

1) **Support Community Decisions**
   Assist decision makers through the development of information, methods and tools incorporating decision science, citizen science, spatial analysis, cause-and-effect modeling, and sustainability assessments. These resources help decision makers frame different options, increase community-engagement, and identify potential solutions that promote a more sustainable future.

2) **Develop Tools and Metrics to Identify, Monitor, and Track the Links between Human Well-being and the Environment**
   Explore ecosystems services, natural and built environments, and the interactions of chemical and nonchemical environmental factors to better understand how environmental conditions provide a foundation for human well-being. SHC researchers and their partners are developing metrics, including indicators and indices (combinations of indicators), that communities can use to better assess and predict the environmental, public health, and economic implications of decision alternatives. A particular emphasis is on identifying the links between the environment and disproportionate impacts on vulnerable groups and lifestages.

3) **Research and Technical Support for Environmental Clean Up, Mitigation, and Restoration, and for Advancing Sustainable Development**
   Help community stakeholders improve the efficiency and effectiveness of addressing contaminated sediments,

land, and ground water, and resultant vapor intrusion. The program also provides and evaluates standards, products, data, and approaches to prevent, characterize, and clean up environmental releases of petroleum and other fuel products. SHC methods, models, tools, and data are designed to enhance sustainable materials management.

4) **Develop and Apply a Sustainability Assessment and Management Toolbox** Provide community stakeholders with a suite of tools that, when used together, produce a full accounting that links environmental decisions with human well-being. The "Sustainability Toolbox" can be used to identify and characterize the costs, benefits, and potential tradeoffs of different decisions as they relate to social (including public health), economic, and environmental outcomes.

As the lead for developing the cross-cutting roadmap for environmental justice research, the SHC program works closely with EPA's Office of Environmental Justice and the five other national research programs (see text box).

Environmental Justice Research Roadmap

EPA has long recognized that environmental risks are often greater for low income and minority communities. The impacts on communities at higher risk are influenced not only by differential exposures due to close proximity to sources of harmful chemicals, but also by interactions with non-chemical stressors that may impact effects posed by exposures to environmental contaminants. Disproportionate impacts can also arise from enhanced susceptibilities, as well as from the lack of sufficient health services or benefits. Communities may suffer from inadequate physical and economic infrastructures, such as poor housing, lack of transportation, and inadequate water systems. SHC is the lead on the Environmental Justice Research roadmap to promote sustainable, healthy communities by providing state-of-the-science tools and information that can be used to characterize and mitigate environmental and health inequities. The program will collaborate with the other programs in ORD (ACE, HHRA, SSWR, HSRP and CSS) and EPA partners, including the Office of Solid Waste and Emergency Response, the Office of Environmental Justice, and the Office of Children's Health Protection, on research to advance EPA's EJ 2020 Action Agenda.

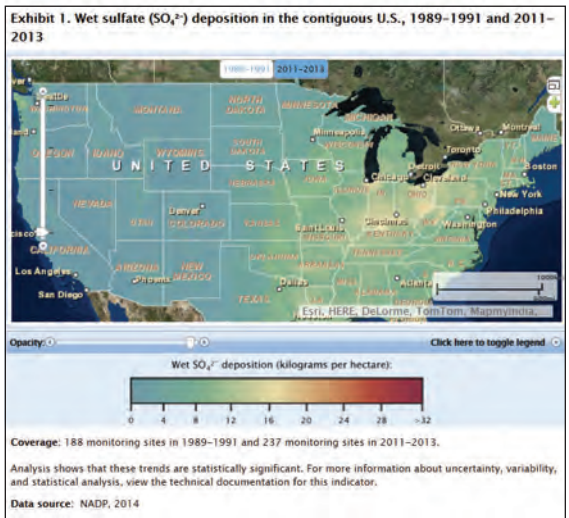
2016-2019 SHC Strategic Research Action Plan Research Examples

SHC is developing information and tools to offer solutions to community-based decision makers within and outside the Agency. Examples of research planned for the 2016-19 timeframe are described below.

Making the Connection: Developing Environmental Indicators and Indices to Inform Decision Making and Track Progress

Local communities face multiple and sometimes conflicting priorities when it comes to balancing immediate goals with long-term needs and stability. To help them meet those challenges, EPA researchers are developing a suite of environmental indicators and indices that provide researchers and others with a way to characterize current conditions across a host of environmental media, particularly as they connect to human well-being. For example, the indices and indexes inform EPA's Report on the Environment, an easily accessible, on-line resource that presents the best available indicators of national trends in environmental and human health conditions. Other searchable databases

allow users to find the appropriate metrics for different decision contexts, such as land use, materials management, community revitalization, or commercial, residential, or transportation planning.



Indicators of national environmental and human health trends are readily accessible from EPA's Report on the Environment at: http://cfpub.epa.gov/roe/.

Helping Communities Identify the Benefits of Ecosystems

An important goal of the SHC research program is to help community stakeholders and national decision makers assess, and predict effects due to, the interactions between people and the natural environment. EPA is conducting research to identify the benefits that local communities derive from the natural environment, "community-based ecosystem goods and services." For example, natural wetlands help purify water and provide flood control, but these benefits are hard to quantify. There are a whole host of resources like wetlands that provide important goods and services that are often undervalued. The research includes the identification and inventory of ecosystem goods and services at multiple geographic scales, approaches communities can use to measure those benefits, and the development of a library of ecological production models. Researchers are also advancing the understanding of how climate change and other major drivers and stressors affect the production, delivery, and benefits of ecosystem goods and services.

Helping Address Contaminated Sites

SHC plays a major role in advancing techniques and technologies to help communities and others remediate and rehabilitate Superfund and other contaminated sites, including addressing challenges sparked by hazardous materials reaching groundwater, which can lead to contamination of drinking water and vapor intrusion—when volatile organic compounds and other gases migrate from underlying water and soil into the air of homes and other buildings. Examples of this work include improving the application and interpretation of high-resolution groundwater characterization technologies, advancing the long-term evaluation of the use of permeable reactive barriers for the treatment of groundwater contamination, novel vapor intrusion studies using real-time observations and modeling scenarios, and the continued operation of three technical support centers focused on site characterization and monitoring, engineering and groundwater issues at contaminated sites.

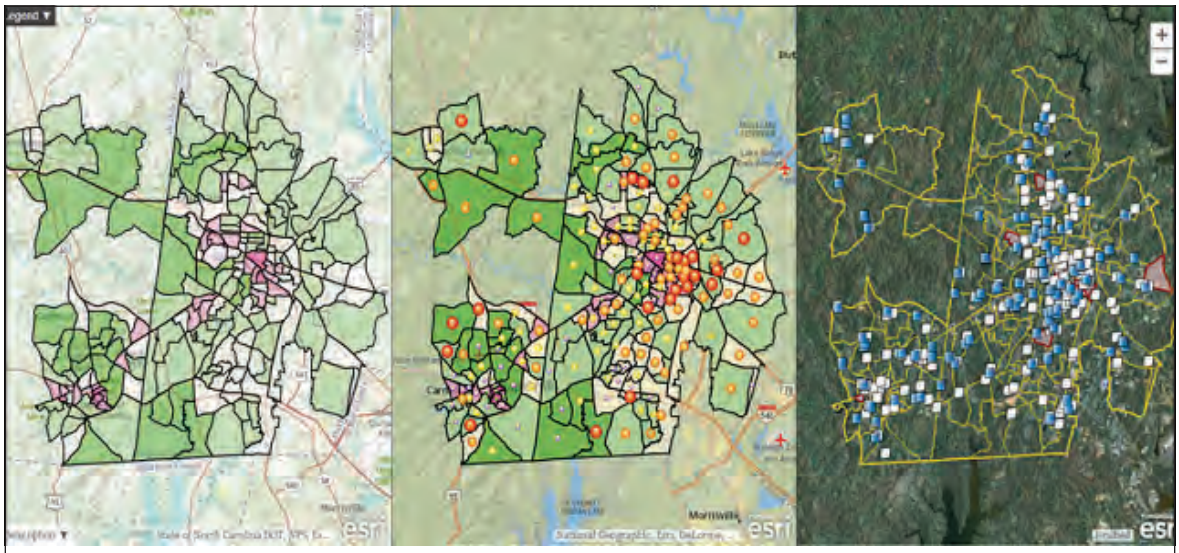
Supporting EPA Regional Science Needs

SHC sponsors collaborative projects in communities across the country, taking advantage of unique opportunities to apply new research tools, gaining immediate feedback, and improving the design and delivery of research results as they are used more widely to make a difference in communities. SHC's Regional Sustainable Environmental Sciences Research program unites problem-solvers from the Office of Research and Development directly with experts from each of the Agency's ten regional offices located across the country.

Examples of regional projects include: *Engaging Communities and Citizen Science to Assess and Address Children's Environmental Health from Transit and Air Pollution; Improving Public Health through Urban and Roadside Vegetation; and Using Ecosystem Services Assessment and Health Impact Assessments as Part of a Stakeholder-driven Approach to Storm Recovery: Long Island Case Study*.

EPA's EnviroAtlas: A Mapping Tool to Assess the Benefits of Nature

EPA researchers are expanding EnviroAtlas, a collection of interactive tools and resources that allow users to explore and visualize the many benefits people receive from nature in ways that are immediately applicable to decision-making and planning. The dynamic resource combines multiple ecosystem-based data sets, sophisticated geographic information systems, and visualization tools to present fine-scaled, multilayered maps and other resources that people can download and use to inform decisions to keep their communities healthy and resilient. Development plans for EnviroAtlas extend out to 2017, incorporating updates, additional data, analysis tools, and increased functionality as they become available.



Using EnviroAtlas, many types of users can access, view, and analyze diverse information to better understand how various decisions can affect an array of ecological and human health outcomes.

Chemical Safety for Sustainability

Chemicals are a lynchpin of the American economy. Moving toward sustainability requires innovation to design, produce, and use chemicals in safer ways.

The challenges faced in today's chemical environment are formidable. Tens of thousands of chemicals are currently in use and hundreds more are introduced into the market every year. Many of these chemicals have not been thoroughly evaluated for potential hazard to human health, wildlife and the environment, particularly when considering the consequences of use over a chemical's life cycle (from production to disposal). Current toxicity testing methods focus on evaluating hazard from exposures to individual chemicals and are expensive and time consuming. Characterizing exposures to multiple chemicals, and understanding their impacts across the life cycle of products, further amplifies the challenge. Innovative methods to assess hazard and exposure, and to integrate this information to assess risk, are needed to make better-informed, more-timely decisions about chemicals.

To address these challenges, the Chemical Safety for Sustainability research program (CSS) is leading development of innovative science to support safe and sustainable selection, design, and use of chemicals and materials required to promote human and ecological wellbeing, as well as to protect vulnerable species, lifestages, and populations. The ultimate goal is to enable the Agency to address impacts of existing chemicals, anticipate impacts of new chemicals and materials, and evaluate complex interactions of chemical and biological systems.

The research strategy guiding the work was developed in partnership with EPA program and regional offices, and with input from other federal agencies, states, public and private stakeholders, and the global scientific community. The research program recognizes that transformative approaches are needed to improve the information used in chemical evaluations. CSS science is strategically scoped with four integrated research topics to support Agency priorities.

Research Challenges

Thousands of chemicals have not been evaluated and new chemicals are continually being developed and introduced into commerce.

Chemical substitutions and other alternatives designed to solve one environmental health problem may have unintended consequences.

The real-world is inherently more complicated than current experimental models of toxicology can depict.

Decision-makers need demonstrated solutions to translate new information into action.

1) **Chemical Evaluation**
   Advancing cutting-edge methods to provide data for risk-based evaluation of both existing chemicals and emerging materials.

2) **Life Cycle Analytics**
   Exploring new ways to evaluate risks to human and ecological health across the lifecycle of manufactured chemicals, materials and products. CSS methods will efficiently evaluate alternatives and support more sustainable chemical design and use.

3) **Complex System Science**
   Adopting a systems-based approach to examine complex chemical-biological

interactions and predict potential for adverse outcomes resulting from exposures to chemicals.

4) **Translation and Delivery**
Promoting web-based tools, data, and applications to support chemical safety evaluations and related decisions. CSS engages Agency partners and stakeholders to ground truth the transparency, access, relevance, and applicability of our research.

As the lead for the cross-cutting issue of children's environmental health, the CSS program works with scientists from the other research programs and from EPA program and regional offices, to identify research priorities and coordinate research (see text box).

Children's Environmental Health Research Roadmap

Public concern about the potential role of environmental factors on children's health including asthma, autism spectrum disorder, and childhood obesity is increasing. To date, research in this area has been limited and recent studies are difficult to evaluate and interpret. The Children's Environmental Health Research roadmap presents ORD's vision for providing integrated, cutting-edge science required for EPA actions to promote children's environmental health and wellbeing. It recognizes that EPA has a unique mandate to focus on understanding the role of exposure to environmental stressors on health impacts during early life and across the course of development. The Children's Environmental Health Research Roadmap is a collaboration among ORD's research programs (ACE, CSS, HSRP, HHRA, SHC, and SSWR), EPA's Office of Children's Health Protection, Office of Air and Radiation, and Office of Solid Waste and Emergency Response.

2016-2019 CSS Strategic Research Action Plan Research Examples

The CSS program maps out innovative research that will transform how scientists and policy makers assess the safety of chemicals and exposure to them. Working closely with EPA partners to conduct case studies of new approaches improves the quality of the science and confidence in the methods. Examples of CSS research for 2016-2019 are described below.

Accelerating the Pace of Data-driven Chemical Evaluations

Driven by limitations of current chemical testing methods, EPA needs very rapid and efficient methods to prioritize, screen, and evaluate chemical safety for thousands of compounds. The ToxCast research program generates data and predictive models on a large number of chemicals using high-throughput screening methods and computational toxicology approaches that are increasing the pace and decreasing the cost of chemical screening.

ToxCast uses robotics technology to screen chemicals for potential toxicity, developing a cost-effective approach for prioritizing the thousands of chemicals that need toxicity testing.

While ToxCast measures changes in biological activity, ExpoCast uses related high-throughput estimates to assess exposure, another key aspect of assessing risk. ExpoCast and new approaches known as *non-targeted measurement methods* are being developed and deployed to more rapidly generate much-needed exposure information on several thousand chemicals, including data on chemicals not expected to be found in environmental samples. Together, this multi-year effort is generating an unprecedented volume of exposure and toxicology data and making it publicly available. Moving forward, researchers will assess how to apply these data from the very start to a range of applications including: chemical screening and priority setting for more in-depth studies of health hazard; human or ecological risk assessments; and the design of safe chemicals.

Shifting the Paradigm of Toxicity Characterization

Traditionally, toxicological testing for chemical exposure has focused on observing health outcomes such as disease and death. Using systems science, CSS research will identify early indicators, or "tipping points" of adversity or biological harm associated with chemical exposures, and build predictive models that are public health protective. To facilitate this research, ORD is funding four university-based centers. The centers will develop cell models for high-priority biological systems such as the brain, liver, kidney, testis, breast tissue, heart and neurovascular, and evaluate them for use in research into the interactions of chemicals with key biological processes. This innovative work will provide new biological insight into how tissues and organs function during chemical exposures and illuminate when and how those "tipping points" occur. Scientists will use the data to develop advanced computational models of how organs and tissues respond to chemicals, and use the models to evaluate predictive models of human disease or response.

EPA is advancing and supporting innovative science to model the brain and other high-priority biological systems.

Transforming Ecological Risk Assessments

EPA's uses a tiered ecological risk assessment process for registering and regulating chemical compounds. Chemicals determined to present an appreciable risk based on first tier screening with minimal data are subject to higher-level assessments that provide quantitative estimates. For the vast majority of chemicals and species, little or no data exist and refined assessments must rely on modeled estimates of exposure and effects. The Ecological Modeling project area will advance efficient methods to improve risk assessments with limited data availability, as well as more complex approaches where data are more abundant. Research will also focus on developing and evaluating ecological models for endangered species and wildlife populations exposed to pesticides. The ability to apply models with varying complexities and data requirements will enhance EPA capacity to protect sensitive ecosystems and species.

This work will provide demonstrated ecological risk assessment tools that reduce uncertainty for high priority and methodologically challenging chemicals. The resulting decision framework for using models of various complexities and data requirements appropriate for the assessment will enhance Agency capacity to protect sensitive ecosystems and species.

Integrating Life Cycle Thinking

To make sustainable decisions it is important to understand the broad range of impacts to human health and the environment associated with a chemical or product throughout the life cycle. CSS is developing efficient tools that will help consider, among the broad range of impacts, the potential for exposures to human and ecological species across the chemical life cycle where limited data are available. Scientists are developing approaches to efficiently evaluate environmental and human health impacts and identifying metrics to quantify tradeoffs between risks and other sustainability factors. By bringing together two of ORD's leading disciplines, exposure science and life cycle assessment, this project is transforming how scientists in the broader community are attacking these same challenges. Research in this area will be focused on how to operationalize sustainability analysis for chemical safety evaluation by leveraging and extending methods in life cycle assessment and exposure modeling to incorporate metrics of human and ecological risk.

Human Health Risk Assessment

Every day, EPA and diverse stakeholders must make decisions to protect human health and the environment from the known or potential adverse effects of exposure to environmental pollutants. Such decisions span a large regulatory landscape and require different types of environmental pollutant risk information: evaluating data on new chemicals entering the market; characterizing potential public and environmental health impacts during emergency situations; screening and prioritizing chemicals for monitoring at Superfund sites and in the air and water; evaluating health and ecological effects data to derive benchmark estimates; and interpreting and integrating different lines of evidence to support decisions to establish, retain or revise national standards.

Research Challenges

Decision makers need timely and robust scientific risk evaluations that include an ever-expanding number of exposure scenarios and environmental contaminants.

Current risk assessment methods must continually modernize and accelerate the application of scientific advances in molecular biology and computational sciences.

Communities need technical support to assess urgent environmental contamination issues, assess exposures to multiple pollutants and address cumulative risk concerns.

EPA's Human Health Risk Assessment (HHRA) research program is designed to provide robust and responsive risk assessment support for a wide range of risk management decisions aimed at protecting human health and the

environment. The HHRA program provides an essential portfolio of risk assessment products and undertakes targeted and innovative development of new approaches to advance risk analysis.

The HHRA program addresses all of the Strategic Goals in the Fiscal Year 2014-2018 EPA Strategic Plan: "Addressing Climate Change and Improving Air Quality"; "Protecting America's Waters"; "Cleaning Up Communities and Advancing Sustainable Development"; and "Ensuring the Safety of Chemicals and Preventing Pollution." In addition, HHRA research supports the cross-agency strategies "Working Toward a Sustainable Future" and "Making a Visible Difference in Communities."

The HHRA research program adapts and evolves as needed. The program adjusts in response to Agency needs, new scientific opportunities, and new challenges and needs in the risk assessment and management arenas. To help partners and stakeholder gain confidence in the application of new approaches, projects in the program are targeted at characterizing the utility of emerging science and tools to improve risk assessments. Program researchers regularly engage Agency and external partners and stakeholders to solicit feedback and ensure that assessments are conducted in open, transparent ways.

The three main HHRA program objectives support the vision of protecting public health and the environment by providing state-of-the-science chemical assessments, refining risk assessment approaches, advancing innovative applications and providing stakeholder engagement.

1) **Characterize Risks**
   Efficiently support a range of decision making with an agile, fit-for-purpose portfolio of robust and responsive assessment products that characterize risks and potential impacts to human health and the environment.

2) **Advance and Refine Assessment Approaches**
   Refine risk assessments by identifying critical issues and advancing analytical approaches and applications to incorporate new science, methods and technologies.

3) **Enhance and Engage**
   Enhance data access and management systems to support transparency and efficiency; provide outreach and engage stakeholders to ensure support, training, and tailoring of assessment priorities and products.

Cross Program Collaboration: Incorporating New Data Streams into Health and Environmental Risk Assessments

The HHRA and CSS programs are working together to evaluate how the new data emerging from computational toxicology can be used effectively in risk assessment. Characterizing the utility of these new data and tools for improving risk assessment will build both stakeholder confidence in and capacity for their application, and thereby accelerate their acceptance in regulatory decision making. Projects in the HHRA program include case studies demonstrating several new approaches applied to different classes of chemicals, various endpoints and toxicities, and with varying degrees of supporting evidence.

2016-2019 HHRA Strategic Research Action Plan Research Examples

The HHRA program provides a course of action for delivering direct scientific and technical support on risk assessment. Examples from the 2016-2019 research program are described below.

Integrated Science Assessments (ISAs)

The HHRA program regularly develops ISAs as a major component of its research portfolio. The ISAs evaluate and synthesize the most policy-relevant science for reviewing the National Ambient Air Quality Standards (NAAQS), set by EPA for six principal pollutants: ozone, particulate matter, carbon monoxide, sulfur dioxide, nitrogen oxides and lead. Called *criteria pollutants*, these are derived from numerous sources and are considered harmful to public health and the environment. Because each ISA communicates critical science judgments, it forms the scientific foundation for the review of the NAAQS. The ISAs are developed on a five-year cycle, in response to regulatory requirements, and are vetted through a rigorous peer review process.

Integrated Risk Information System

Under the Integrated Risk Information System (IRIS) program, EPA evaluates scientific information on health effects that may result from exposure to environmental contaminants. The web-accessible IRIS database provides health effects information on more than 550 chemical substances, and these scientific evaluations support EPA decisions related to air and water pollution, Superfund cleanups, and other regulatory activities. For 2016-2019, the IRIS program is focused on implementing a series of recommendations from the National Research Council to improve the process for developing IRIS assessments, including enhancing stakeholder engagement. Additionally, the IRIS program is embarking on an effort to review and update older assessments in the database. Together, the ongoing improvements will continue to strengthen the IRIS program and increase transparency and productivity.

Cumulative Risk Assessment

To address the desire of communities to understand and conduct local or "place-based" risk assessments, EPA scientists are developing methods to integrate and evaluate impacts of chemical and non-chemical stressors on human health and the environment. Cumulative risk assessment requires understanding key biological, social, spatial, temporal and environmental factors and how they contribute to disproportionate risk. Research may include scenario-specific case studies in collaboration with regional partners. Advances in cumulative risk assessment will support communities in addressing environmental justice concerns.

Homeland Security

Recent major disasters in the United States (Hurricane Sandy, the Deepwater Horizon oil spill, the Oklahoma tornados, avian influenza, and the West Virginia water contamination incident) and abroad (Fukushima nuclear power plant accident) illustrate the critical need for rapid recovery after all types of disasters. The U.S. Government has recognized that preparing for and responding to most disasters, man-made or natural, have common elements.

The mission of EPA's Homeland Security Research Program (HSRP) is to conduct research and deliver scientific products that advance the Agency's homeland security responsibilities in ways that also help communities become resilient to disasters.

To guide that work, HSRP researchers work closely with Agency partners and stakeholders, including emergency response professionals and water utilities, to understand their most important gaps in the science and technology needed for decontamination and resiliency. This work directly supports EPA strategic goals to protect America's waters and clean up communities.

The homeland security research program uses a systems approach to develop methodologies, strategies, and tools to support water security and wide area contamination after disasters. The program has two primary objectives:

1) **Improve Water Utilities' Abilities to Prepare for and Respond to Incidents that Threaten Public Health**
   Disasters are likely to impact water utilities' ability to function. To build resilience, HSRP develops modeling tools that support the design and operation of water systems to decrease their vulnerability to disasters. HSRP also builds tools, technologies and data to support post-incident responses including decontamination of infrastructure and treatment of contaminated water.

2) **Advance EPA's Capabilities to Respond to Wide Area Contamination Incidents**
   Terrorist incidents or natural disasters can result in wide area contamination with chemical, biological, radiological and nuclear agents or materials. HSRP develops cost effective and efficacious cleanup strategies and methods to enable recovery of the contaminated area including cleanup approaches and waste management strategies and tools.

Research Challenges

Environmental disasters due to intentional or natural causes can result in the loss of human life and create long-term injury to social, economic, and environmental systems.

Devising and adapting methods and technologies to effectively respond to and recover from these incidents requires understanding the complex and evolving nature of the incident and subsequent response activities.

2016-2019 HSRP Strategic Research Action Plan Research Examples

From preparing for terrorist threats that could impair our air, water, land and infrastructure to responding to natural disasters and industrial accidents, the HSRP program addresses EPA's environmental priorities. Examples of research for 2016-2019 are described below.

The Water Security Test Bed: Advancing Water Security in Real-World Scenarios

EPA and research partners designed and constructed a replica of a municipal drinking water piping system at the Department of Energy's Idaho National Laboratory, part of efforts to advance decontamination techniques beyond laboratory and field-scale studies. Experiments at the newly constructed facility will allow researchers to conduct the first evaluations of technologies and techniques for monitoring and decontaminating drinking water systems under real-world conditions; tests will include in-line contaminant detectors, decontamination methodologies (including automatic flushing), and wash water treatment methodologies. EPA researchers will also be leading the development of water systems modeling tools.

Water security test bed at the Idaho National Laboratory.

Decontamination Technologies for Wide Area Contamination Events

Recent catastrophic events such as the Fukushima Daiichi incident following the earthquake and ensuing tsunami in Japan clearly demonstrate the need for decontamination and remediation techniques that can be effective across large areas (single building to entire neighborhoods), and a diversity of environments (from soil and vegetation to manmade structures). HSRP is developing and improving decontamination engineering processes to facilitate implementation of technologies in the field and provide information to assist in scaling up of such methodologies to improve resiliency. For example, Agency researchers are developing risk reduction and self-help remediation methods for use after a contamination incident involving a wide area anthrax or radiological contamination incident.

EPA supports its responders' ability to characterize site contamination by developing sampling protocols, sample preparation methods, and analytical methods for chemicals, biotoxins, microbial pathogens, and radiological agents.

Sampling Strategy for Anthrax

Any large-scale contamination event involving the bacteria responsible for anthrax (*B. anthracis*) will require extensive environmental sampling to inform remediation and decision support regarding the potential for re-inhabiting areas and buildings. HSRP scientists have reviewed and assessed traditional sampling strategies, and are developing innovative new strategy options to support responses, such as modeling tools to support air sampler placement after a wide area outdoor release of *B. anthracis*.

Cross Program Collaboration: Community Resilience

Increasing the resilience of communities to changing climate, declining ecosystem goods and services, and man-made or natural environmental disasters is an area of interest in all of the EPA national research programs. HSRP is facilitating research coordination in this area as it continues to grow over the 2016-2019.

As a part of these research efforts, HSRP is developing indicators of community environmental resilience. By highlighting strengths and weaknesses, these indicators will support communities' efforts to improve their resilience to disasters and help focus research on building tools and technologies needed to minimize the impact of disasters and to improve post-disaster adaptation. HSRP will collaborate with the other programs in ORD (ACE, SHC, HHRA, and SSWR) to develop these indicators and the tools that facilitate their use by communities.

Science to Protect Public Health and the Environment

EPA research is strategically designed to deliver the scientific and engineering solutions the nation—and the world—need to meet today's complex environmental and human health challenges, while advancing a more sustainable and resilient future. Together, its six national research programs—Air, Climate, and Energy; Safe and Sustainable Water Resources; Sustainable and Healthy Communities; Chemical Safety for Sustainability; Human Health Risk Assessment; and Homeland Security Research—are laying the foundation for new ways of looking at and solving environmental problems. The cross-cutting roadmaps are demonstrating the value of interdisciplinary research that spans media-specific lines in recognition that in the real world, environmental problems don't stop at the borders of land, air or water. EPA research is forging a path to the future while building on a forty-year legacy of scientific achievement and leadership. Beginning with framing problems up front with input from partners and stakeholders, EPA research is using innovative, interdisciplinary, and integrative solutions that transcend traditional boundaries. It's connecting the dots between a healthy ecosystem and healthy people, and working across media to solve problems in an unprecedented way. EPA research closes the loop by translating research findings to partners and stakeholders and assisting those who use our data, tools, and models. This model of science-based, problem-driven research designed to inform solutions will drive change in the scientific community and the way we address the nation's most challenging environmental problems today and tomorrow.

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EPA Strategic Research Action Plans and Roadmaps can be downloaded here:

http://www2.epa.gov/research/strategic-research-action-plans