EPA 601/R 12/002 | June 2012 | www.epa.gov/research

U ited States
En ironmental Protec ion
Agenc

Science for a Sustainable Future

EPA RESEARCH PROGRAM OVERVIEW 2012 - 2016

SCIENCE

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

EPA 601/R-12/002

Science for a Sustainable Future

EPA Research Program Overview 2012 - 2016

U.S. Environmental Protection Agency
June 2012

Table of Contents

Science for a Sustainable Future 4
Air, Climate, and Energy. 9
Safe and Sustainable Water Resources 11
Sustainable and Healthy Communities. 13
Chemical Safety for Sustainability 16
Human Health Risk Assessment 19
Homeland Security 21
The Path Forward to Sustainability. 23
References 24

Science for a Sustainable Future

EPA Research Program Overview 2012 to 2016

Not long ago, computers were clunky, room-sized machines reserved for research institutions and large corporations. People made calculations using slide rules. Data-sharing required face-to-face meetings or trips to the post office. These realities were accepted as part of modern life.

But where some saw the status quo, others saw opportunity. A special mixture of creativity, imagination, and ingenuity sparked a technological revolution that brought about game-changing innovations such as personal computers, the internet, cellphones, and other technologies that changed the way people live and work.

It was also not long ago when, city dwellers breathed air thick with smog, rivers were choked with pollution, fish were poisoned by acid rain, and second-hand tobacco smoke was nearly ubiquitous. Pollution was viewed as a necessary byproduct of modern society and economic prosperity.

But the same combination of intellect and imagination that put telecommunications devices into people's pockets and global positioning systems on their dashboards sparked a realization that societal progress and a healthy environment are not mutually exclusive.

Ground-breaking, innovative science and research made possible a new era with a host of environmental achievements such as lead-free gasoline, no-smoking policies, low-emission vehicles, cleaner lakes, rivers, and coastal waters, and restored hazardous waste sites that are now safe for playgrounds and homes. The cumulative benefits of this work are restored ecosystems, improved public health, and increased overall life expectancy in a time when our economy and population have continued to grow. For example, the value of goods and services produced in the U.S. increased dramatically over the same time period that many types of air pollution decreased (see Figure 1).

Every day, the U.S. Environmental Protection Agency (EPA) continues to turn the vision of a healthy economy and a healthy environment into a reality for all Americans. It's a vision that starts with science.

Aligning with Sustainability

EPA relies on its Office of Research and Development (ORD) to produce the science, research, methods, and tools needed to pursue the Agency's mission of protecting human health and the environment. In 2011, to ensure maximum effectiveness of these activities, the Agency embarked on a major effort to strategically realign ORD's research portfolio around the concept of sustainability. The realignment is designed to achieve not only a cleaner and less polluted environment, but one that is healthy, productive, and fully sustainable.

> *"to create and maintain conditions, under which humans and nature can exist in productive harmony, that permit fulfilling the social, economic, and other requirements of present and future generations."*
> -- National Environmental Policy Act, 1969

Back in 1969, the National Environmental Policy Act (NEPA) established "a national policy which [will] encourage productive and enjoyable harmony between man and his environment." EPA focused its initial efforts on tackling specific and obvious challenges—cleaning the air, water, and land and developing ways to prevent further contamination.

It is now time to focus efforts on tackling the complex, interconnected environmental challenges that require innovative thinking, new tools and sustainable approaches. In its 2011 report, *Sustainability and the US EPA*[1], the National Research Council of the National Academy of Sciences stated that "… current approaches aimed at decreasing existing risks, however successful, are not capable of avoiding the complex problems in the U.S. and globally that threaten the planet's critical natural resources and put

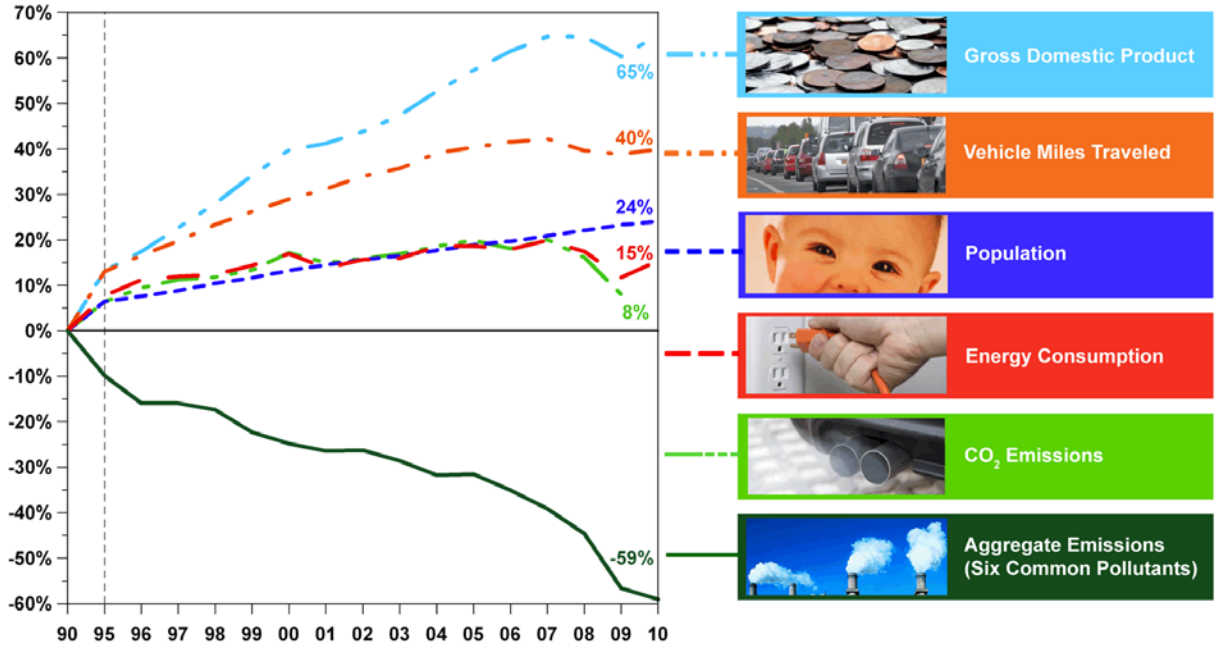

Figure 1. Comparison of Growth Areas and Air Emissions, 1990-2010
Over this time period, U.S. gross domestic product and the total miles traveled by U.S. vehicles increased significantly. At the same time, the U.S. population and total energy consumption increased, as did emissions of the greenhouse gas carbon dioxide. Even while these increases occurred, levels of 6 major categories of air pollutant emissions (e.g., particulate matter, sulfur dioxide, others) decreased substantially, in large part due to Clean Air Act regulations. (Reference: U.S. Environmental Protection Agency (2011). Office of Air & Radiation. *Our Nation's Air, status and trends through 2010*. Available: www.epa.gov/airtrends/2011/index.html.)

current and future human generations at risk."

While EPA's historic efforts have led to major improvements in our environment, we have reached a critical juncture. We have a new awareness of increasingly complex and global environmental challenges, and new science, tools and technologies to address them. With these insights and capabilities, we can build upon our traditional expertise in research for risk assessment and management by conducting innovative research for sustainable solutions. Focusing on development of solutions also means engaging decision makers and other users of research from the beginning of the process—to ensure that the end results will meet their needs. The overall goals are to minimize risk, while maximizing benefits to society, the economy, and the environment.

This new level of environmental protection calls for systems-based thinking and approaches that account for linkages between different environmental systems. Systems-approaches recognize that actions taken by industry and consumers affect the environment, efforts to protect the environment impact industry and consumers, and impacts on one system can affect others and the larger whole (see Figure 2). In the pursuit of sustainable policies and practices, EPA, states, tribes, and local communities, need the right scientific tools to weigh environmental decisions with a full evaluation of these cross-system impacts and consequences. The realignment of EPA research is geared toward producing scientific tools and solutions that will support decision-making within the context of environmental, economic and social goals.

With a sustainability focus and systems-based approaches, EPA researchers are working collaboratively, across many scientific disciplines and in close partnership with EPA partners and outside stakeholders, to conduct research that is truly transdisciplinary. This means that researchers actively engage experts not only from related scientific fields, but also from other sectors, including economics, law, policy, communications and information sciences. This integrated, transdiciplinary approach to research is designed to deliver results that meet the needs of decision-makers and establish a broad scientific foundation for a sustainable future.

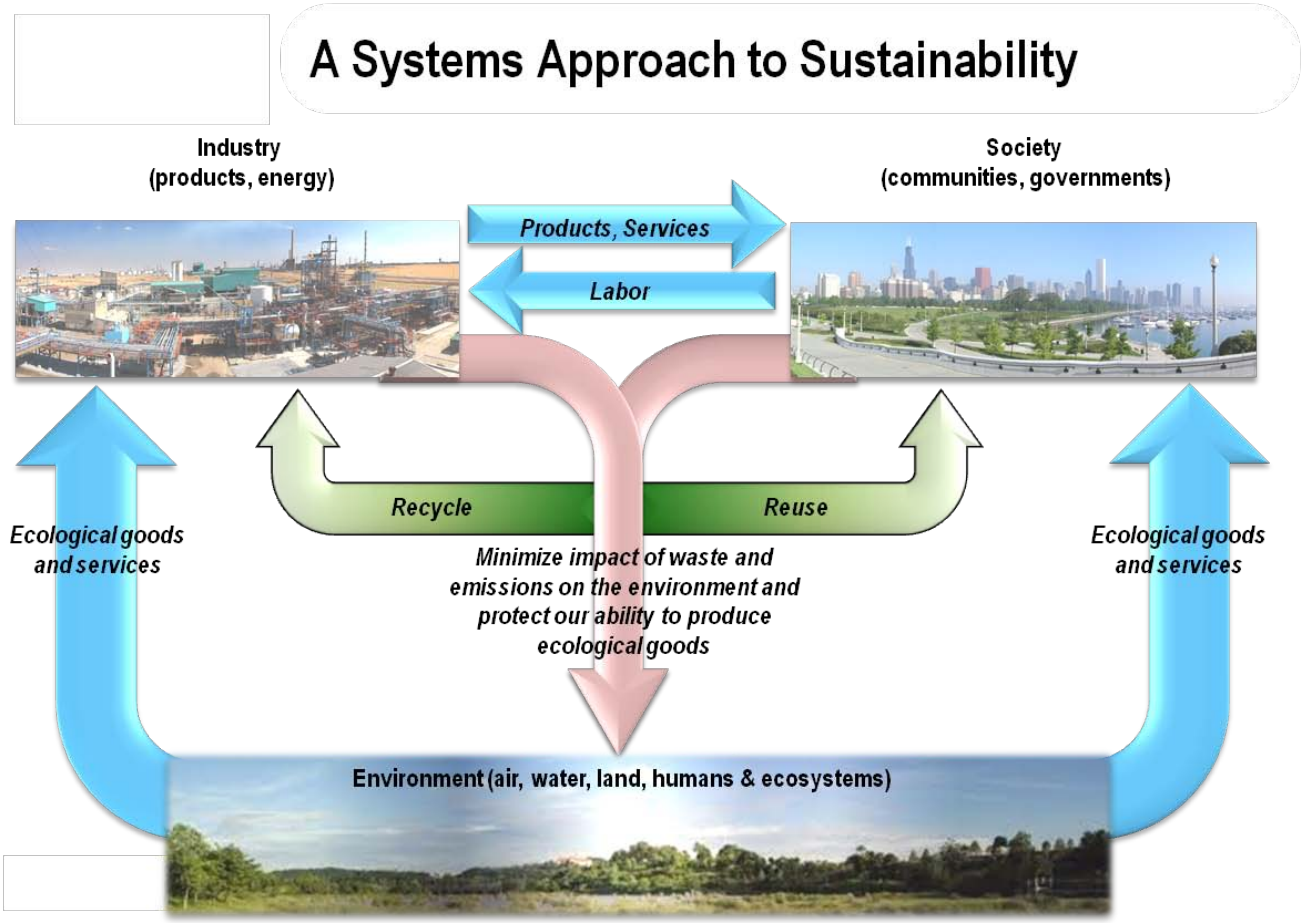

Figure 2. A Systems Approach to Sustainability illustrates the flow of materials and services between the three pillars of sustainability – economy, environment, and society. (Image adapted from: J. Fiksel, A Framework for Sustainable Materials Management, *Journal of Materials*, August, 2006.)

Designing Research to Meet Priorities

Beginning in 2011, EPA's research programs were re-designed to be as responsive as possible to the Agency's priority needs and to advance the science of sustainability. As a starting point, the research programs are now aligned with the goals outlined in the *EPA's FY 2011-2015 Strategic Plan*[2] (see Figure 3).

Four integrated research programs address EPA strategic goals, and two highly targeted research programs focus on EPA's special responsibilities related to homeland security and human health risk assessment. The research programs address a wide span of needs, from future-oriented anticipatory research, to problem-specific research, to technical support. The programs are designed to meet the needs of partner offices within EPA and to be useful to others who rely upon our research. Transforming EPA's research portfolio in this manner—by realigning thirteen research programs into six integrated areas—has created many opportunities to collaborate, leverage expertise and coordinate research among areas that were previously planned and managed independently.

For example, the Chemical Safety for Sustainability program integrates research on pesticides and toxics, endocrine disruptors, computational toxicology, nanotechnology, and more. The Safe and Sustainable Water Resources program brings together research on drinking water and water quality. Some topics, such as climate change and children's health, involve multiple areas of research and, therefore, are supported across multiple research programs. To advance environmental sustainability, the six research areas contribute to and reinforce one another, emphasizing the integration of environmental

EPA Strategic Goal	Current Research Program	Former Research Program
Taking Action on Climate Change and Ensuring Air Quality	Air, Climate and Energy	Global Change Clean Air Other Research
Protecting America's Waters	Safe and Sustainable Water Resources	Drinking Water Water Quality
Cleaning Up Our Communities	Sustainable and Healthy Communities	Human Health Ecosystems Other Research
Assuring the Safety of Chemicals	Chemical Safety for Sustainability	Endocrine Disruptors Computational Toxicology Other Research
	Homeland Security Human Health Risk Assessment	Homeland Security Human Health Risk Assessment

Figure 3: EPA's Research Programs Support Agency Strategic Goals

science research (see Figure 4).

Integration across the six programs also ensures that research is designed to tackle cross-cutting EPA priorities, including environmental justice, children's health, and science and technological innovation.

Research is conducted by hundreds of EPA staff scientists and engineers in laboratories and research facilities at 13 locations around the country. They are joined by a network of collaborators, partners, fellows, and grantees supported by EPA's Science to Achieve Results (STAR) extramural research program. EPA is also 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.

EPA has also taken several steps to foster creativity and innovation through its research. The Agency actively supports scientific competitions and challenges, public-private partnerships, and other activities that promote innovative thinking and sustainable solutions. To spark innovative research among EPA scientists, ORD sponsors an internal competition known as "Pathfinder Innovation Projects" that provides seed funding for the best, game-changing proposals.

The environmental challenges of the 21st century cannot be met by EPA alone. To engage a broader community, EPA works to ensure that its research is catalytic and high-impact. Collaborations with other federal agencies, state and local governments, and other entities help advance the environmental protection mission. Developing scientific tools and information that can then be used by the broader environmental protection community empowers others outside of EPA to develop innovative, sustainable solutions. The Agency has also recognized that excellent research, done invisibly, cannot have impact. To this end, researchers are committed to sharing results broadly through printed communications materials, social media, webinars, conferences and many other venues.

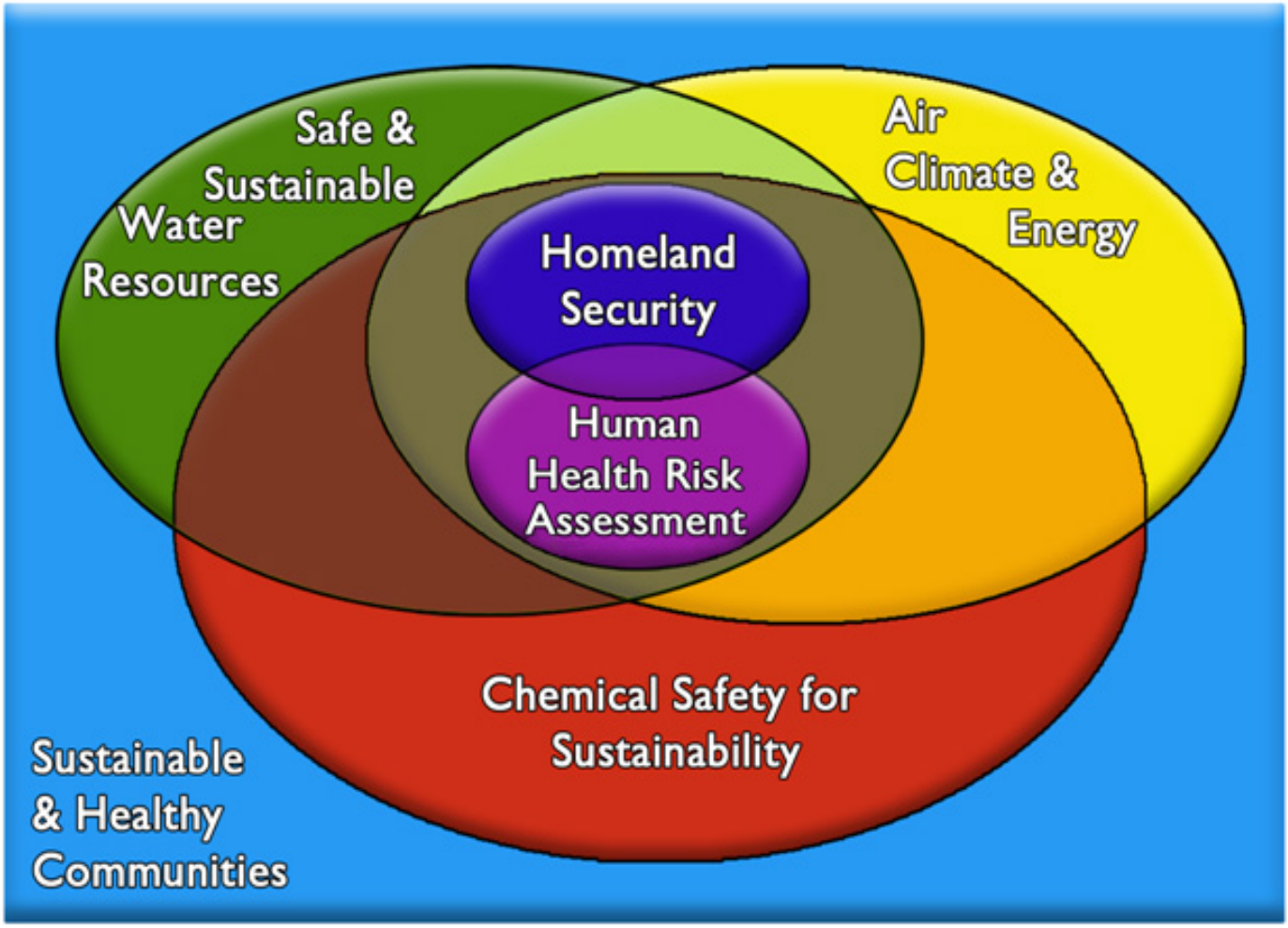

Figure 4: EPA's Six Integrated Research Programs. EPA's six research programs emphasize coordination and integration. The Sustainable and Healthy Communities program integrates research across the environmental spectrum. Air, climate, water and chemical research all inform the Agency's risk assessment and homeland security research efforts.

In designing the research programs, EPA scientists undertook an unprecedented effort to solicit ideas—engaging managers and staff throughout the Agency, conducting "listening sessions" with the public, and hosting other open platforms. Through these efforts, EPA researchers heard firsthand about needs for advanced scientific and engineering knowledge, data, methods, and analytical tools. The discussions sparked collaboration, innovation, and creativity from every corner of the EPA research community in designing the needed research. Continuing interactions will help ensure that Agency program and regional offices, states, tribes, and other stakeholders receive the scientific information they need to make decisions and implement the nation's environmental laws.

Brief descriptions of the six programs follow.

Air, Climate, and Energy

The Air, Climate, and Energy (ACE) research program builds upon 40 years of achievement in air pollution research that led to landmark outcomes—including healthier communities[3] and longer life expectancies[4]—by addressing air, climate, and energy issues in an integrated way. The program is designed to provide the science needed to adapt to changing climatic conditions and prevent harmful air pollution emissions, including greenhouse gases.

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. ACE research is focused on assessing cumulative impacts of exposures to a combination of many pollutants in the air, 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. The program also incorporates scientific and technological breakthroughs such as smart phones, sensors, multi-scale computer models and innovative chemical design to help solve air pollution and climate problems.

Integrating air, climate, and energy research into one 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 worked collaboratively with those who use and depend upon our research—EPA policy makers, regional officials and external stakeholders—to ensure the ACE program is responsive and relevant to priority needs. As a result, ACE research is focused on three central themes:

Assess Impacts

The effects of air pollution on human health and the environment result from exposures to mixtures of pollutants in the atmosphere and occur at multiple geographic and temporal scales. At the same time, complex interactions between climate change and air quality result in health and environmental impacts that are closely linked with socio-economic factors and energy choices.

ACE research is developing and applying methods to assess the impacts and effects of air pollution exposure and climate change at individual, community, regional, and global scales.

Challenges for Air, Climate, and Energy

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.

Prevent and Reduce Emissions

There is a growing need for systems-based, multi-pollutant strategies that prevent air pollution without unintended environmental consequences. ACE research helps provide the science needed to develop and evaluate approaches to preventing and reducing 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 determine whether certain energy choices are sustainable.

Respond to Changes in Climate and Air Quality

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. Because climate and air quality are closely linked, communities will need real time air pollution and health information about pollutant mixtures to make informed decisions about personal and public health under changing climatic conditions.

ACE research provides modeling and monitoring tools, metrics, and information on air pollution exposure that can be used by individuals, communities, and governmental agencies as they make public health decisions related to air quality and climate change. ACE is also looking over the horizon, towards the development of high-tech air pollution sensors that will provide real-time air quality information to communities, regulators, and the public.

Research Examples

- **Health impacts of multi-pollutant air exposures**
  Multi-city studies and multi-disciplinary Clean Air Research Centers are currently focused on explaining how meteorology, air pollution composition and exposure may impact air pollution health effects. New approaches are being used to evaluate the health impacts of multi-pollutant exposures across multiple life stages—from infancy through old age—taking into account social stressors, biological factors and susceptibility. For example, air pollution impacts on the brain and cardiovascular, respiratory, reproductive, immunological and endocrine systems are all being studied. This research will inform national air pollution regulations, analyses of the benefits of mitigating air pollution, and public health strategies for those most susceptible to air pollution exposure.

- **Next generation of air pollution monitoring**
  EPA research is underway to explore the use of new technologies for faster, cheaper, hand-held access to air pollution information. For example, sensor-based technologies connected to cellphones and ground-based remote sensing technologies are being studied. In addition, research is also investigating how satellite measurements and data from modeling can be used to increase the effectiveness of existing monitoring data and reduce costs. Advances in air monitoring technology can help individuals and communities make choices in near real-time to better manage air quality. This work is closely coordinated with the Sustainable and Healthy Communities research program.

- **Adapting to impacts of climate change**
  EPA's Climate Ready Estuaries program helps coastal communities such as those in the San Francisco and Massachusetts Bays develop plans to protect important coastal resources from the impacts of climate change. This research is providing models of coastal ecosystem processes and climate change sensitivity analyses to inform local adaptation plans. This transdisciplinary research is being coordinated with the Safe and Sustainable Water Resources program.

ACE provides scientific and technical support to EPA's Office of Air and Radiation, other EPA policy and regional offices, and state and local governments as they protect the air we breathe and help reduce greenhouse gases. This research will directly advance EPA's strategic goal to take action on climate change and improve air quality.

Cross Program Collaboration on "One Environment" Model

EPA is developing an approach to modeling "One Environment" that will collectively address the interactions of changes in global climate, land-use, air quality, water quantity and quality and economic development. This integrated approach will provide new information to support strategic policy decisions and national, regional and local environmental decisions. This work is closely coordinated among ACE, Safe and Sustainable Water Resources and Sustainable and Healthy Communities research programs.

Public Private Partnership on the Health Effects of Air Pollution from Motor Vehicles

The Health Effects Institute, jointly funded by EPA and the motor vehicle industry, sponsors independent research on the health impacts of motor vehicle emissions. This partnership includes research on emerging technologies and fuels and their potential health and environmental impacts.

Safe and Sustainable Water Resources

Sustainable drinking water and water resources are vital to supporting healthy people, ecosystems and economies.

EPA's Safe and Sustainable Water Resources (SSWR) research is designed to provide the innovative science and technologies that the Agency—and the Nation—need to maintain, deliver, and protect our water. SSWR work includes research for a sustainable water infrastructure, safe drinking water delivery, stormwater management, sustainable wastewater treatment and healthy aquatic systems. SSWR integrates previously independent Agency research programs on drinking water and water quality with the simple rationale that water is all one resource. Recognizing that the pursuit of sustainable use, delivery and quality of our water requires integrated approaches, the SSWR research program spans two integrated research themes:

Sustainable Water Resources

Water resources are threatened by a host of complex and far-reaching challenges—from naturally-occurring contaminants, to those resulting from human activity, to the demands of a rapidly increasing population and the impacts of climate variability. EPA research in the SSWR program focuses on delivering the science needed to provide safe and sustainable drinking water, recreational waters, and healthy aquatic ecosystems.

Sustainable Water Infrastructure Systems

SSWR also focuses on research to support better and cost-effective urban stormwater management through the integration of natural and "green" infrastructure with traditional "gray" water infrastructure.
Results from this systems approach to watershed management provide resource managers and decision makers with the information they need to ensure the sustainability of critical water resources; produce, store and deliver safe and high quality drinking water; and provide transport and use-specific treatment of wastewater and stormwater.

The SSWR Program was designed by EPA scientists in collaboration with water research foundations, water industry associations, states, tribal groups and partners from EPA's Office of Water and EPA's regional offices—who work closely with state and local governments to implement water protection programs. Our partners identified six critical areas for water-related EPA research and technical support:

- Nutrients – Implementation of cost-effective strategies to reduce nutrients
- Chemicals – More efficient and effective management and regulation of known and emerging chemicals of concern
- Pathogens – Implementation of regulatory strategies for new and emerging pathogens
- Infrastructure – Development of tools, technologies and approaches for sustainable water infrastructure
- Watersheds – Adoption of systems approaches to protect watersheds
- Climate change – Understand and address the impacts of climate change on the management of availability and quality of water resources.

Challenges for Safe and Sustainable Water Resources

Current drinking water and water treatment systems are inadequate to serve a growing population.

Many water systems are outdated and inefficient, losing trillions of gallons of water each year.

Stormwater overflows send billions of gallons of sewage into lakes and rivers.

Nitrogen- and phosphorous-contaminated run-off from suburbs and agricultural land pollutes groundwater, lakes, rivers, and coastal waters, causing widespread damage to aquatic ecosystems and impacting public health.

Climate change will affect water resources, impacting water supplies and aquatic ecosystems.

Research Examples

- **Meeting the challenge of nutrient pollution**
  Nutrient pollution of water is one of the critical challenges faced in this decade. The overabundance of the nutrients nitrogen and phosphorus in water diminishes the integrity of our nation's streams, lakes and reservoirs and poses risks to human health.

  To address this serious issue, SSWR research is developing data and computer models that quantify nitrogen and phosphorous inputs to watersheds, calculate instream nutrient losses, demonstrate approaches to establish stream nutrient criteria that protect downstream waters, and develop new approaches for reducing the amount of nutrients flowing into the nation's waters.

- **Addressing stormwater management challenges**
  Managing stormwater flow and its impact on wastewater treatment systems is an increasing environmental and economic challenge for communities across the nation. EPA scientists and engineers are working collaboratively with other agencies and municipalities to develop innovative and efficient solutions.

  Researchers are also investigating the use of green infrastructure—such as rain gardens and wetlands—to restore and maintain natural hydrology. Green infrastructure can help communities better manage excessive stormwater flow and minimize impacts on wastewater and drinking water treatment systems. Studies are addressing the design, size, location and integration of green infrastructure with engineered infrastructure so that water quality can be optimized with other benefits to the environment, economy, and society.

- **Advancing Technologies for Real-time, Accessible Water Quality Data**
  Researchers are exploring an experimental satellite remote sensing technology that would enable monitoring of coastal systems across a range of spatial and temporal scales not currently feasible. To test the accuracy of the satellite data, scientists are comparing satellite information to measurements of coastal pollution taken by small, robotic submarines. This approach has many additional applications, and has the potential to make water quality data as accessible as weather data.

Results from the SSWR research program provide scientific and technical support to EPA's Office of Water, EPA's other program and regional offices, and state, tribal, and local governments as they protect drinking water and water resources, through environmental laws such as the Clean Water Act and the Safe Drinking Water Act. This research will also advance EPA's strategic goal to protect America's waters.

Cross Program Collaboration on Hydraulic Fracturing Research

Hydraulic fracturing is a process used by oil and gas producers to recover oil and natural gas from unconventional underground sources such as coalbeds, shale gas formations and tight sands. SSWR is assessing the impacts of hydraulic fracturing activities on drinking water resources. SSWR has taken a transdisciplinary research approach that includes the hydraulic fracturing water use lifecycle in its scope. EPA is working in consultation with other federal agencies, state and interstate regulatory agencies, industry, non-governmental organizations and others in the private and public sectors who have provided input on study planning and are sharing existing data and technical expertise. Issues include identifying chemicals of potential health concern, examining data on the composition and variability of hydraulic fracturing fluids, assessing the amount of water used in the process, and evaluating the potential for contaminants to reach drinking water. This research is designed to better understand whether drinking water resources may be adversely impacted by hydraulic fracturing. Research on hydraulic fracturing is conducted in coordination with the ACE research program.

Collaboration with the US Army on "Net Zero"

The US Army is pursuing a goal of net zero water, waste and energy use at 20 Army installations by 2020. SSWR, ACE, and SHC scientists are partnering with the Army and contributing their expertise in water treatment to help select strategies and implement technologies for projects on Army bases. This includes developing and applying innovative technologies for water management, for example, large-scale water reuse and closed loop systems. Ultimately, the partnership will generate practices that can be applied in communities across the United States and around the world, helping to ensure a sustainable water future.

Sustainable and Healthy Communities

How can we meet today's needs without compromising the ability of future generations to meet their needs? More specifically, how can we protect our shared environment—air, water, land, and ecosystems—in ways that sustain human health and well-being, are economically viable, and socially just?

Providing the scientific foundation to answer these questions is the goal of EPA's Sustainable and Healthy Communities (SHC) research. Agency researchers and their partners are working together to better understand the balance between the three pillars of sustainability—environment, society, and economy. The transdisciplinary work conducted through SHC will provide decision tools and data that communities need to make strategic decisions for a prosperous and environmentally sustainable future. The SHC research program also conducts research to seek more cost-effective means of accomplishing EPA's mission to address existing sources of land and groundwater contamination. Approaches are needed that will maximize the benefits of multiple approaches to environmental protection, recognize synergies between protecting human and ecosystem health, and reduce the likelihood that policy decisions will have unintended negative consequences.

The design of this research program was truly collaborative, as is its implementation. EPA scientists held a series of meetings with internal EPA partners in the policy and regional offices and conducted listening sessions with community officials, Tribal representatives, academic experts, and non-profit organizations. These discussions highlighted community and local government approaches for managing their financial and natural resources and for providing services that directly affect their local economies, environment, and the health and well-being of their residents.

These community approaches require decisions about options for how to provide solid waste collection and disposal; maintain and diversify transportation options; develop building codes and zoning for land use planning, and implement shared public/private responsibilities for meeting infrastructure needs, including distribution of water and power. Not only are these decisions the focus of cutting-edge research on sustainability, they are also the same decisions that communities identified as their highest priorities for sustainable practices. Communities repeatedly asked EPA for new ways to better account for the full suite of impacts and outcomes associated with their decisions about how to provide these services.

Challenges for Sustainable and Healthy Communities

Communities face difficult decisions on infrastructure, land use, transportation, and waste management.

The social, economic, and environmental tradeoffs of these decisions are not well understood.

Information is limited on impacts to human health, ecosystems, local economies and disproportionate environmental burden.

To organize this breadth of research, SHC is structured into four interrelated themes having the following objectives:

Data and Tools to Support Community Decisions

SHC is using new technologies and other innovative means to engage communities and stakeholders as partners in the planning, design, and implementation of research to meet their sustainability goals. Research products will help communities diagnose environmental problems, analyze alternatives,

and track the performance of their approaches. In particular, the suite of tools is designed to be highly accessible through user-friendly interfaces based on decision science and to incorporate new and emerging social networking technologies and social networking platforms, such as smart phones, environmental apps, and crowd-sourcing.

Forecasting and Assessing Ecological and Community Health

SHC is conducting innovative research that will enable communities to assess the sustainable provision of ecosystem services and how the natural and built environment affect the health and well-being of their residents. Researchers are developing methods to quantify the production of ecosystem goods and services (i.e., benefits provided by functioning ecosystems, such as maintenance of safe and productive soils, protection from floods by coastal wetlands, and uptake of carbon dioxide by trees). A key product will be a searchable database of ecosystem services. Researchers are also working to improve understanding of how people—including sensitive populations such as children, the elderly, and low income minorities—are exposed to pollutants and environmental stressors (e.g., exposures due to diet, housing, or from contaminated land). This work will also identify factors that lead to disproportionate impacts on sensitive populations.

Implementing Near-Term Approaches to Sustainable Solutions

Research in this area builds on EPA program office experience to improve the efficiency and effectiveness of methods to address existing sources of land and groundwater contamination, while advancing innovative regulatory approaches that reduce new sources of contamination and enable recovery of energy, materials and nutrients from waste.

This research provides the scientific support to EPA program and regional offices and to states and tribes that implement federal requirements and guidelines related to land and groundwater contamination. Many of these issues are also relevant at the community level, such as contamination from waste sites, oil spills, and leaking tanks at gasoline stations. SHC science and analytical tools help programs evaluate management options for sites contaminated by past practices or current environmental releases. Waste and materials management research informs choices for reusing materials, deriving energy from wastes, producing less waste and better management of unavoidable waste streams. Student fellowships, environmental justice, and small business innovation research are all supported within this theme.

The research also provides scientific support to regional and program offices on nitrogen impacts on ecosystem services and sustainable nitrogen use. Further, SHC is the home for the periodic production of the *EPA's Report on the Environment*.[5]

Integrated Solutions for Sustainable Outcomes

SHC will assess the state of sustainable practices and design approaches for achieving better outcomes for four high-priority community decision areas: waste and materials management; infrastructure, including energy and water; transportation alternatives; and planning and zoning for buildings and land use. It will use whole-system modeling to integrate these four areas to better achieve outcomes with multiple benefits and to develop and test methods to estimate the Total Resource Impacts and Outcomes of alternate decisions (TRIO accounting). The work will begin in Durham, North Carolina, using real world data and conditions and will provide important feedback to all other SHC themes.

SHC Research Examples

- **Improving Materials Management Decisions and Operations**

  To better manage the nation's waste streams, environmental managers in both the public and private sectors are seeking opportunities for increased efficiency and more sustainable materials management. SHC research is focused on identifying opportunities for beneficial reuse, developing methods to derive energy from waste streams, and finding ways to minimize wastes produced from construction and demolition operations while improving their treatment and disposal. The research will be carried out in partnerships across the public and private sectors.

- **Quantifying Ecosystem Services**
  SHC scientists are developing production functions for ecosystem services and benefits for numerous areas in the United States. These will be used to build a searchable database that will allow researchers and developers of decision-support tools to have the best available information on the distribution of ecosystem services and how they might change under alternative future scenarios. In addition, a National Ecosystem Goods and Services Classification System will support standardization of metrics for goods and services to facilitate comparison across geographies, thus supporting ecosystem service markets and trading.

- **Sustainable Management of Nitrogen:**
  Excess amounts of reactive nitrogen in the environment create a cascade of harmful effects that include eutrophication of lakes, blooms of toxic algae, "dead zones" (hypoxia) in the Gulf of Mexico and other estuaries, acid rain, contributions to global warming and ozone depletion, and health effects due to pollution of air and drinking water. SHC research products will help EPA and others implement an integrated management approach that balances the benefits of nitrogen use while minimizing its negative health and environmental impacts. Key products include: source maps of nitrogen inputs to the United States; assessments of the certainty associated with estimates of nitrogen sources to U.S. surface waters; and a report to inform air quality regulations that provides estimates of critical nitrogen deposition loads, locations of sensitive ecosystems, and associated nitrogen effects on ecosystem services. Local-scale products include N-Sink, a simple geo-spatial tool designed to enable watershed managers to describe sources and sinks of nitrogen within a watershed, and a web tool that provides local estimates of nutrient inputs. This work is closely coordinated with ACE and SSWR nitrogen research.

- **National Atlas of Sustainability**
  The Atlas is an interactive web tool that will help communities identify and quantify the benefits of ecosystem services. Examples include the ability of natural land cover to protect drinking water quality and reduce water treatment costs; urban trees to reduce heat-island effects and absorb pollutants from vehicle traffic; vegetation to remove carbon dioxide from air and store carbon; and the physical and mental health benefits that people receive from convenient access to parks, greenways, and waterways. The Atlas will provide necessary information to help communities thoughtfully design and manage their built infrastructure in concert with their natural environment.

Research results provide scientific and technical support to EPA's Office of Solid Waste and Emergency Response, Office of Water, Office of Air and Radiation, Office of International and Tribal Affairs, Office of Community Sustainability, Office of Environmental Justice, other EPA program and regional offices, and state, local, and tribal governments. The SHC research program directly supports EPA's strategic goal to clean up communities and advance sustainable development through improved access to new tools and information, better accounting of ecosystem services, and innovative solutions that maximize co-benefits while minimizing unintended consequences.

Cross Program Collaboration on Children's Environmental Health

EPA's Children's Environmental Health and Disease Prevention Research Centers, jointly funded with the National Institute of Environmental Health Sciences, address a broad range of issues including the impacts of environmental chemicals on neurodevelopment, vulnerability of the fetus during gestation, and chemical and non-chemical stressors at all stages of early development (e.g., physical activity, psychosocial issues, and the condition of school and residential buildings). The factors that affect the vulnerability of children to disproportionate environmental risks range from local to national in scope. Research related to children's health and environmental justice is highly relevant to all of the other research programs.

Chemical Safety for Sustainability

Ensuring chemical safety is a top priority for EPA. Improving the safety of the chemical manufacturing process as well as the chemicals themselves is necessary for building a more sustainable environment. Providing the information and methods to make better-informed, timely decisions about chemicals is also a critical part of this endeavor.

The challenges faced in today's chemical environment are formidable. More than 80,000 chemicals are currently listed or registered for use under EPA authorities, and at least a thousand more are introduced every year[6]. Many of these chemicals have not been evaluated thoroughly for potential risks to human health and the environment or potential consequences across their lifecycles. EPA's research on chemical safety aims to meet these challenges.

Current processes and procedures for evaluating and assessing the impact of chemicals on human health, wildlife, and the environment were, for the most part, designed decades ago. Many of these approaches have not fully incorporated recent advances in exposure science, biology, and computational technologies. As a result, we do not have a full picture of how chemicals come into contact with organisms, how they interact with biological processes, and how those interactions may lead to adverse outcomes. In addition, current approaches are resource- and time-intensive—making it increasingly difficult to keep pace with the growing number of chemicals in commerce.

The Chemical Safety for Sustainability (CSS) research program recognizes that transformative approaches are needed to improve the information used in chemical risk assessments. CSS research focuses on new approaches to increase the pace at which relevant information can be obtained and integrated into assessment and decision making. Information from these new approaches can support sustainable approaches to chemical design, production, and use across chemical, material, and product life cycles. New methods can be developed and applied to evaluating chemicals currently in commerce and improving guidance for safer chemical design and use.

Challenges for Chemical Safety

Each year more than 1,000 new industrial chemicals and pesticides are introduced into commerce.

Most chemicals in use today have not been thoroughly assessed for health and environmental risks.

Methods for assessing health risks of chemicals are time-consuming and costly.

New types of chemicals, such as nanomaterials, may require new toxicity testing methods.

Chemicals are rarely designed from the start to fulfill the needed function while also minimizing toxicity.

The following research goals guide the CSS program:

Developing the Scientific Knowledge, Tools, and Models for Integrated Evaluation of Chemical Toxicity

EPA researchers and their partners are developing chemical testing methods to provide data for different types of assessment and management decisions. The research addresses: use of chemical properties to predict toxicity; high-throughput and other screening approaches to prioritize chemicals for further testing; development of more efficient approaches for exposure research and toxicity testing; and new methods to address particularly complex environmental risks.

Improving Methods for Assessment and Informing Management for Chemical Safety and Sustainability

Research addresses methods for improving the practice of risk assessment using data from new toxicity testing methods and strategies. Another important focus is to synthesize and evaluate toxicity and exposure data so that it is useful for decision-makers and appropriate to the nature of the problem being assessed.

This includes cutting-edge sustainable molecular design research that will lead to safer chemicals, able to accomplish their functions without causing toxicity or other environmental harm. This work on specific chemicals will result in general guidance useful for those who regularly design, produce and use chemicals.

Targeting High-Priority Research Needs for Immediate and Focused Attention

Work in this area focuses on the application of methods and models to address the high-priority, time-critical needs of EPA partner offices and stakeholders. Examples of current research include carbon- and metal-based nanomaterials that have commercial potential and data methods and models for characterizing PCB sources and exposures in school environments.

Research Examples

- **Understanding the inherent properties of chemicals and their relationship to health and environmental impacts**
  "Inherency" refers to the physicochemical properties that characterize a chemical. CSS researchers are compiling and sharing data on inherent chemical properties and information on the relationships between chemical characteristics and health outcomes. For example, because of their small size, nanoparticles may have unique properties compared to larger particles of the same chemical. Currently, there is not sufficient data on the potential fate and toxicity of nanoparticles to humans and the environment. CSS research on nanomaterials aims to assess the potential risks of these materials by estimating the transport, fate, exposure, and human and ecological effects of nanomaterials in environmental systems.

  This research can be used to inform risk assessment decisions, and ultimately, enable the development of nanomaterials with reduced potential toxicity and increased societal benefits to reach the marketplace in a timely fashion. Further, the research can inform the development of additional testing guidance for use by material manufacturers.

- **Models of complex biological or environmental systems**
  Systems models are multiple-level or multiple-scale models that predict or simulate exposure, effects, or sustainability of complex biological systems. Research in this area investigates how a chemical comes in contact and interacts with the biological processes of human and wildlife to cause adverse outcomes. For example, using advanced computational techniques, models of organs such as the liver enable researchers to predict how the liver will respond if exposed to different doses of chemicals. Another type of model predicts human exposure to chemicals under different dietary and residential scenarios. These models support regulatory decision-making on chemicals by EPA program offices and regions.

  Innovative chemical screening technologies, such as automated, rapid screening (i.e., high throughput screening) are used to generate chemical data on the adverse effects of large numbers of chemicals. Rapid screening methods will help EPA address the large backlog of chemicals in need of toxicity evaluation. Chemicals identified as less toxic can be channeled for expedited decision-making, and those identified as more toxic, can be prioritized for more thorough testing.

- **"Dashboards" for decision-makers**
  Providing regulatory decision-makers with user-friendly tools to access all available data about chemicals is critical to the success of the CSS research program. "Dashboards" are interactive web-sites that provide access to software and data that are needed to evaluate a chemical for a policy decision. The CSS program is producing dashboards that yield a graphical depiction of all the available chemical data that will help answer questions about chemicals. Using dashboards, decision-makers will access summary information derived from chemical exposure and hazard data, decision-rules, and predictive models, and seamlessly integrate this information to

arrive at more holistic risk assessment and risk management decisions.

The CSS research effort unites chemists, exposure scientists, biologists, engineers, and economists and other social scientists. The data, methods, and scientific tools developed in the CSS research program will help prevent pollution through the design of safer chemicals and processes and guide the development and use of chemical prioritization and testing processes. This research, in turn, informs different types of health and safety decisions, including those related to regulations, chemical development, production, use and management.

Research results provide scientific and technical support to EPA's program offices, particularly the Office of Chemical Safety and Pollution Prevention, regional offices and state, tribal, and local governments. The research will also help advance EPA's strategic goals to clean up communities, advance sustainable development, and ensure the safety of chemicals and prevent pollution.

Cross-Program Collaboration on Sustainable Molecular Design

CSS researchers are collaborating with partners in the Air, Climate, and Energy (ACE) research program on potential green chemistry alternatives to hazardous air pollutants. For example, experts from both programs are working together to develop and evaluate safer cleaning agents, including halogenated solvents—chemicals used for major cleaning and degreasing operations by many industries and the military. Although highly effective cleaning agents, halogenated solvents pose unacceptable risks to people and ecosystems. CSS and ACE researchers are also working to develop chemical screening methods needed for volatile chemicals.

Cross-Program Collaboration: Next Generation Risk Assessment Approaches

Researchers from both the CSS and Human Health Risk Assessment (HHRA) research programs are working together to ensure that EPA's risk assessment methods keep pace with advances in molecular systems biology, the understanding of gene-environment interactions and the large volume of high-throughput, toxicity test data now becoming available. A collaborative project on the next generation of risk assessment methods will result in assessments that are designed to use the amount and quality of scientific evidence needed for the nature of the problem being addressed, ensuring more efficient use of resources.

Human Health Risk Assessment

EPA's Human Health Risk Assessment (HHRA) program provides state-of-the-science and independently peer-reviewed human health assessments for individual chemicals and chemical mixtures that are emitted into air, water and land. The HHRA program serves as an interface between EPA's research programs and EPA's decision-makers. The scientific assessments produced by HHRA researchers are used extensively by EPA program and regional offices, as well as other public and private entities, to make decisions, develop regulatory standards for environmental contaminants, and manage cleanups.

The program's four themes are aligned with the needs of EPA offices and produce health assessments for both specific chemicals and chemical mixtures:

Integrated Risk Information System (IRIS)

IRIS is a human health assessment program that evaluates qualitative and quantitative risk information on health effects that may result from exposure to chemicals in the environment. In addition to assessments of individual chemicals and chemical mixtures, the program is improving methods for statistical approaches, dose-response, and pharmacokinetics analyses used in IRIS assessments. IRIS assessments are technical documents that provide a scientific foundation for decision making at EPA, state, tribal, and local governments, and the private sector.

Integrated Science Assessments (ISAs)

Integrated science assessments summarize the current science for the six criteria air pollutants regulated by the Clean Air Act through National Ambient Air Quality Standards (NAAQS): ozone, particulate matter, sulfur and nitrous oxides, carbon monoxide, and lead. ISAs, together with the Agency's health risk assessments, provide the scientific foundation for the EPA Administrator's decisions on setting NAAQS. New approaches for developing multipollutant assessments are also underway. This work is closely coordinated with the ACE research program.

Challenges for Human Health Risk Assessment

The needs of decision-makers continue to grow for timely scientific evaluations of the risks of an ever-expanding number of environmental contaminants.

New approaches are needed to better assess exposures to multiple pollutants and cumulative risk.

Current risk assessment methods do not fully reflect scientific advances in molecular biology and computational sciences.

Communities need technical support to assess urgent issues of environmental contamination.

Community Risk and Technical Support for Exposure and Health Assessments

HHRA is developing health assessments and analytical tools to provide technical support for urgent issues of environmental contamination. HHRA researchers are developing approaches to incorporate additional, non-chemical stressors (e.g., stress, poverty) into community risk assessment and better understand the impact of those stressors. The goal of these efforts is to improve the way we characterize exposure and risk.

Methods, Models and Approaches to Modernize Risk Assessment for the 21st Century

HHRA is incorporating recent advances in molecular biology and computational sciences into risk assessment. It is also advancing approaches to better quantify dose-response relationships for both

cancer and non-cancer health effects to better support EPA decisions. HHRA scientists translate research conducted under the CSS program into practical applications for developing health assessments.

HHRA Research Examples

- **Rapid Risk Assessment and Applied Technical Support**
  Scientists in the HHRA program and in the Homeland Security program are frequently called upon to assist EPA programs and regions in responding to chemical and other environmental contamination issues that may require rapid response or crisis-level support. These situations potentially involve very high exposures to chemicals or other substances for significant segments of the population.

  Past examples of where HHRA's rapid response capabilities have been used include the World Trade Center Disaster, Hurricanes Katrina and Rita, and the BP Deepwater Horizon Oil Spill. While it is difficult to anticipate the type and scope of rapid response analyses that will be needed in the future, HHRA scientists are prepared to address these emerging needs on an ongoing basis.

- **Advancing Dose-Response Analysis**
  Increased demand for risk assessment and the recent explosion of scientific knowledge on the topic present a unique opportunity to modernize the practice of dose-response analysis. HHRA researchers are undertaking a systematic approach to addressing several decision-maker needs for quantitative dose-response characterization, including maximizing the use of available data and methods, better characterizing uncertainty and variability, and developing a better understanding of how to quantitatively address susceptibility.

Research results provide scientific and technical support to EPA's program and regional offices, EPA's Office of Environmental Information, EPA's Office of International and Tribal Affairs, and state, tribal, and local governments. They will also advance EPA's strategic goals to take action on climate change and improve air quality, protect America's waters, clean up communities, ensure the safety of chemicals, and address the crosscutting issues of children's health and environmental justice.

Homeland Security

Following the terrorist attacks of September 11, 2001, EPA was directed to tap its collective scientific and technical expertise to help protect human health and the environment from the effects of such events.

In response to this direction, EPA helps decontaminate buildings and large public areas, protect our nation's water supply, and rapidly provide scientific and technical information to key decision-makers, stakeholders and impacted communities on contamination and human health risks.

EPA's Homeland Security (HS) research program is designed to support this important leadership role in remediating chemical, biological, or radiological contamination from weapons of mass destruction. The program also conducts research on drinking water and wastewater systems—a reflection of EPA's role as federal lead for water infrastructure. Many of EPA's homeland security research products and technologies have broader applications for protecting the environment and human health and can be harnessed to increase the sustainability and resilience of communities.

The HS research program conducts research that increases EPA's capabilities in protecting human health and the environment, while actively coordinating with other federal agencies including the Department of Homeland Security, the Department of Defense, and the Centers for Disease Control and Prevention. While aimed primarily at homeland security issues, HS research can be applied to a broad set of environmental emergencies. Built on a systems approach to prepare for and recover from chemical, biological or radiological attack, HS research helps ensure that in a crisis, up-to-date scientific information on sustainable approaches (rapid, health protective, and cost-effective) to clean up is readily available to decision makers.

Challenges for Homeland Security

Terrorism poses potentially large scale threats to public health and the environment.

Natural disasters and industrial accidents can also release toxic materials to the environment.

Devising and adapting methods and technologies to effectively respond, requires understanding of the nature of each threat

HS research priorities are determined in consultation with EPA's Office of Homeland Security, and with other EPA program and regional offices—especially on-scene coordinators and laboratory personnel, the Office of Solid Waste and Emergency Response, and the Office of Water. The HS research program also consults with the President's Office of Science and Technology Policy, the Department of Defense, Department of Homeland Security, and other federal agencies and states.

The planning and conduct of HS research is organized into three themes:

Securing and Sustaining Water Systems

Research provides the science needed to help states, tribes, local municipalities and utilities design and operate water systems so that they are more resilient to disasters (due to terrorism, natural disasters, or other emergencies). This theme includes research that addresses scientific gaps in preparing water system operators to detect and respond to a contamination event, cleaning up the system including contaminated water, rapidly restoring it to service, and making water systems more inherently safe.

Characterizing Contamination and Determining Risks

In the event of a chemical, biological, or radiological attack, EPA is charged with site characterization, which includes defining the degree and extent of contamination. Research under the HS program develops innovative and efficient improvements to sampling and analytical methods used for site characterization. HS research also supports site clean-up activities by conducting risk assessment research, ranging from applied information gathering and technical support, to strengthening existing risk assessment approaches and developing new assessment methodologies.

Remediating Indoor and Outdoor Environments

Research is supporting many aspects of site remediation, such as determining how chemical, biological and radiological contaminants behave in the environment—and which decontamination methods are most effective in cleaning up. Also, research is underway to address the management of wastes following an event.

HS Research Examples

- **Enhancing rapid detection of chemical, biological, and radiological contamination**
  To mitigate the public health and economic impacts of contamination incidents, HS researchers are developing and testing technologies to enhance rapid detection of contamination in drinking water. This research includes the development of software, models, decision-support tools, and technologies that help secure and sustain water supplies.

- **Developing Provisionary Advisory Levels**
  To protect emergency responders and residents of impacted areas from short-term, high-dose exposures to chemicals, HS scientists are conducting research to determine safe exposure levels.

- **Developing and compiling sampling and analytical methods**
  By developing new and compiling existing approaches, HS researchers are improving EPA's capability to analyze the large numbers of samples often required to adequately characterize the environment following a terrorist attack or other disaster.

- **Testing and evaluating cost effective decontamination strategies**
  HS researchers are comparing methods to decontaminate buildings and public areas following an anthrax attack or dirty bomb explosion.

  By helping enhance community resilience to disasters, the HS program is integrally connected to the Sustainable and Healthy Communities research program. The program also directly informs preparedness for—and response to—attacks on our water systems (SSWR) and chemical releases into the air (ACE). Coordinating with the other research programs on measurement methods, decision support tools, modeling, and human health risk assessment is an integral part of HS research.

Research results also provide scientific and technical support to EPA's Office of Homeland Security, Office of Solid Waste and Emergency Response, Office of Water, other EPA program and regional offices, and state, tribal, and local governments. This research helps advance EPA's strategic goals to clean up communities, advance sustainable development, and protect America's waters.

The Path Forward to Sustainability

Together, EPA's six 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—represent an integrated, solutions-oriented approach to protecting human health and the environment and pursuing sustainability.

The programs were designed to be agile, integrative, and responsive to the needs of those that use and depend upon EPA's research. They also reflect the recognition that pursuing sustainability is both a need and an opportunity. By using the latest science to address the complex and emerging challenges of the 21st century, we can pursue the use and development of cutting-edge technology, cross-sector partnerships, and sustainable solutions for a healthier and more prosperous nation.

Scientific research helps catalyze positive change. Throughout history, scientific research has improved our quality of life, given us new technological capabilities, and helped our economy flourish. Research will continue to be instrumental to addressing the complex challenges facing society today. It will also be necessary to build a sustainable future. In alignment with EPA's mission of protecting human health and the environment, the Agency's Office of Research and Development has built this concept—science for a sustainable future—into the very foundation of all its research activities and scientific work.

References

1. National Research Council, *Sustainability and the U.S. EPA*, National Academies Press, Washington DC, 2011.

2. U.S. Environmental Protection Agency (2010). *FY 2011-2015 EPA Strategic Plan, Achieving Our Vision*. Available: www.epa.gov/planandbudget/strategicplan.html.

3. U.S. Environmental Protection Agency (2011). *The Benefits and Costs of the Clean Air Act from 1990 to 2020*. Available at: www.epa.gov/air/sect812/prospective2-2.html.

4. C. Arden Pope, III, Ph.D., Majid Ezzati, Ph.D., and Douglas W. Dockery, Sc.D. (2009). *Fine-Particulate Air Pollution and Life Expectancy in the United States*. N Engl J Med 2009; 360:376-386

5. U.S. Environmental Protection Agency. *EPA's Report on the Environment*. Available: www.epa.gov/ncea/roe/index.htm.

6. U.S. Environmental Protection Agency. Basic information about the Toxic Substance Control Act Inventory. Office of Pollution, Prevention and Toxics (OPPT) in the Office of Chemical Safety and Pollution Prevention (OCSPP), Washington, DC. Available at: http://www.epa.gov/oppt/existingchemicals/pubs/tscainventory/basic.html#background.