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Fundamental Changes to EPA's Research Enterprise: The Path Forward

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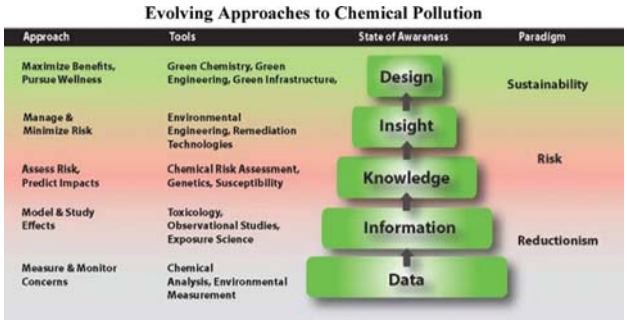

Since 2010, significant changes have been made to the U.S. Environmental Protection Agency's (EPA) research enterprise. All of EPA's actions and decisions are based on science and research. Whether it is crisis response, chemical assessment, or regulatory decision making—none of the Agency's work to protect human health and the environment would be possible without the data, tools, science, and information provided by its researchers and the broader scientific community. The Agency has recently undertaken a major effort to realign its research portfolio in order to more effectively address pressing environmental challenges and better serve the Agency's decision making functions into the future.

EPA has historically relied on its research programs to address issues of national significance. For example, Agency research informed air quality improvements that have prevented more than 200 000 premature deaths since 1970[1] and likely contributed to increasing U.S. life expectancy by an average of five months.[2] EPA research also informed actions that eliminated lead from gasoline and classified second hand smoke as a known carcinogen. More recently, EPA research has informed our understanding and response to major oil spills, mountain top mining, hydraulic fracturing, endocrine disruption, and more.

Unlike visible air pollution, rivers ablaze, and other egregious pollution problems faced decades ago, today's environmental challenges are increasingly subtle and complex. Interconnected issues such as environmental justice, global change, and endocrine disruption are rapidly becoming part of the environmental protection landscape. Fortunately, our state of scientific knowledge and technological capabilities are also evolving quickly. Advanced methods like computational toxicology, remote sensing, and high throughput chemical screening have given us new insights into the linkages between environmental, economic, and social systems and a new awareness of widespread global challenges.

To be truly effective, EPA's environmental research must evolve along with these new insights and be as dynamic as the challenges it aims to inform. Recognizing this as a priority, in 2010 the Agency's Office of Research and Development embarked on a series of steps to advance the evolution of its research programs. These steps are known collectively as the Path Forward for EPA research.

The actions taken on EPA's Path Forward outlined here do not represent the full extent of the Agency's efforts to continually improve and refine its research enterprise. These steps reflect recent changes to enhance the effectiveness of EPA's research programs in supporting the Agency's decision making and overall pursuit of protecting human health and the environment.

PRINCIPLES OF THE PATH FORWARD

Sustainability. EPA has traditionally taken a risk assessment and risk management approach to conducting its scientific work. Significant progress has been made toward developing, advancing, and incorporating risk methodologies into EPA's operational framework and research activities. For example, the landmark National Research Council (NRC) report entitled "Risk Assessment in the Federal Government: Managing the Process," otherwise known as the "Red Book," outlined a four-pronged risk paradigm—hazard identification, dose−response assessment, exposure assessment, and risk characterization—that became the framework for decision making at EPA for decades.[3] A later NRC report entitled "Science & Decisions," also known as the "Silver Book," laid out important concepts and practical steps to improve the risk assessment process, including strategies for optimizing approaches to dealing with uncertainty, variability, default assumptions and upfront problem formulation.[4] The Agency has depended upon these advances in our understanding of risk to make important decisions to protect human health and the environment.

At the same time, a rapidly growing body of literature has advanced sustainability science from an emerging area of research into an established scientific field, with the number of papers published on the topic increasing at a rate of nearly 15−20% per year between 1997 and 2007.[5] In recognition of this development, EPA has implemented several sustainability-related activities such as the Agency's Design for the Environment,[6] Pollution Prevention (P2),[7] and People, Prosperity, and the Planet (P3)[8] programs. However, many of these efforts were developed and launched in an isolated manner. Until now, the Agency has not systematically incorporated the concept of sustainability into the foundations of its research.

EPA's Path Forward has begun to address this need for systematic incorporation by realigning EPA's entire research enterprise around the concept of sustainability. This has required

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Agency scientists and managers to recognize the widely used definition of sustainability outlined by the Brundtland commission in 1987: meeting the needs of the current generation while preserving the ability of future generations to meet their own needs.[9] To fully embrace this definition, the three commonly recognized pillars of sustainability—economy, environment, and society[10]—have been systematically integrated into EPA's research portfolio. This approach is meant to complement and strengthen EPA's traditional expertise in assessing risk by enabling the development of analytical tools, methods, and frameworks for sustainability.

For EPA research, The Path Forward represents a new paradigm that builds upon risk with the tools of sustainability—but it does not diminish EPA's traditional risk-based approaches. This distinction has been characterized as "the difference between treating disease and pursuing wellness," and reflects the continued importance of understanding and managing risk in a way that supports, informs and advances the ultimate goal of sustainability.[11]

Systems. As our understanding of the nature of environmental and human health issues evolves, so must the tools and approaches we use to address them. It is now widely recognized that systems previously treated discretely—air, water, land, energy, climate, health—are inextricably intertwined. By acknowledging that society exists within highly complex and interdependent environmental systems, scientists can better understand and address problems that arise within those systems.[12] Applying this perspective to R&D efforts can address deficiencies of traditional reductionist approaches, such as failure to account for linkages, cross-system impacts and unanticipated consequences.

Many long-term goals of environmental research −preventing pollution before it occurs, reducing intrinsic chemical hazard, engineering systems that are inherently safe, and others, can best be realized by taking on a systems perspective. By considering systems both within their local contexts and across entire life cycles, scientists have the best chance of designing sustainable solutions to environmental problems that are resilient and do not lead to unintended consequences.[13]

Integrated Trans-Disciplinary Research. Understanding the environment as a series of complex, interrelated systems is necessary to conducting excellent research for sustainability, but it is not sufficient. The manner in which research is conducted must also reflect the nature of the systems which it seeks to understand. This requires breaking down traditional scientific silos and dissolving barriers that commonly exist between disciplines.

It is widely accepted that interdisciplinary scientific teams are well equipped to study the linkages between complex and dynamic scientific systems.[14] However, truly integrated research stretches past efforts that are merely *inter*disciplinary toward research that is *trans*disciplinary. This means seeking out collaborations that go beyond multiple scientific departments or laboratories by incorporating expertise and perspectives from multiple *sectors*.

Economists, lawyers, policy makers, communications specialists, information scientists, and other experts can prove invaluable to understanding and addressing critical environmental challenges when brought to the table at the earliest stages of research. This approach is not defined by merely borrowing ideas from other disciplines, but rather, by combining perspectives to form entirely new concepts and reach new levels of scientific understanding.[15] As more and increasingly diverse expertise, perspectives, experience, and knowledge are harnessed toward problem solving, the degrees of freedom in solutions development also increase, opening the door to new possibilities.

Solutions. Throughout its history, EPA has developed extensive capabilities in measuring, monitoring, assessing, characterizing, and understanding environmental risks. But the Agency has recognized that a primary reason to deeply understand a problem is to inform and empower its solution. The Path Forward calls for a new emphasis on the application of EPA's expertise in problem assessment to the development, creation, invention, and innovation of environmental solutions.

With this new orientation, solutions development is designed into the upfront problem formulation stage of environmental research. Those who depend upon the research to make decisions are engaged at every point in the process—assessment, monitoring, tools development, and so forth—to ensure that the ultimate delivered solution meets their needs most effectively.

Acting Catalytically. EPA's efforts alone will not be sufficient to meet the grand environmental and human health challenges faced today. By acting catalytically, the Agency can spark further action by others with a shared mission of protecting human health and the environment. In every project, program, grant, assessment, and report, the Agency must consider how its efforts will inform and empower the broader environmental protection community.

EPA has important tools to accomplish this goal. The federal government funds the majority of basic research in the United States (57% in 2008). In contrast to the private sector, which devotes the majority of its R&D funds toward development (75.3% in 2008), government agencies are poised to contribute significantly to the body of basic scientific knowledge that ultimately informs environmental innovation.[16] In addition to ongoing research within the Agency, EPA provides grants to external institutions. Since 1995, the Agency has issued more than 2000 external research grants to more than 464 primary institutions.

Taken together with EPA's vast environmental monitoring and measuring capabilities as well as the Agency's commitment to open publishing of data, these efforts are important catalysts for research, development, and innovation across industry, academia, and other scientific institutions.[17] The alignment of these efforts with sustainability goals can have potentially widespread influence across broader R&D community by catalyzing sustainable solutions beyond the walls of EPA.

Relevant, Responsive, Rapid Research. Excellent research that is not useful or usable is not excellent. All of EPA's research efforts—from over-the-horizon research, to targeted, problem-specific research, to technical support—must be designed to effectively meet the needs of those who use and depend upon it.

It can be challenging to balance the need to address urgent, place-specific challenges with the desire to produce broadly applicable, generalizable scientific results.[18] But by engaging relevant stakeholders early on and remaining coordinated with ongoing R&D efforts across the Agency, we can understand the specific needs of our clients and ensure our work fits into the broader context of EPA's mission at the same time. While exact timeframes will differ based on the nature of the scientific challenge being confronted, all of this scientific work must be conducted with a sense of urgency. Our mission of protecting human health and the environment is too important to be delayed.

Impact. Excellent work, done invisibly, cannot have impact. Communication must be an essential part of our work as scientists. It is critical to every aspect of design, definition, conduct, transfer, and implementation of scientific research.

Because it is challenging to ensure that uncertainty, caveats, and subtleties are not lost as data move outside the walls of a laboratory and into the public eye, many scientists have shied away from engaging in broader external communication. Other scientists have been influenced by a pervasive perception that outreach to the public is somehow unscientific, or that it demonstrates a lack of technical credibility. In some cases, scientists have avoided lay audiences altogether as a result of the so-called "Sagan-effect," which refers to well-known astronomer Carl Sagan and speculation that he was refused entry into the National Academy of Sciences because of his emphasis on popularizing astronomy among the masses.[19]

A popular model used in the field of information science is the Data, Information, Knowledge, Wisdom (DIKW) hierarchy[20]—often displayed as a pyramid with data at its base and wisdom at its peak.[21] In order to have impact, scientific insights cannot be confined to the lower portion of the pyramid. It is the responsibility of the scientific community to ensure that the data and observations we collect are able to be transformed into knowledge and insight that can be used by others in designing the products, processes, and systems of tomorrow (Scheme 1).The only way to accomplish this is to become objective and unrelenting communicators.

Scheme 1. Evolving Approaches to Chemical Pollution

Innovation. Because the major challenges to sustainability, human health, and the environment that we face are not incremental problems, they cannot be adequately solved by incremental solutions. To make real progress on any of today's most pressing issues—be it climate change, water quality and quantity, ecosystem degradation, or other challenges—transformative innovations are needed. In the absence of innovation, EPA's mission cannot be achieved.

Part of this task involves nurturing a culture at EPA that promotes the spirit of creativity and innovation among its scientists. Another part is remaining fully engaged with leading innovators in the external community. But perhaps the most important task is recognizing that the age-old myth that economic and environmental goals exist in opposition is not only false, but dangerous. This misconception has pervaded the public consciousness and stands squarely in the way of progress toward a healthier, more sustainable environment.

It has been proven time and again that scientific and technological innovation creates a stronger economy. In fact, pursuing sustainable innovation can increase profits, competitiveness, performance[22] and even job creation. For example, it is estimated that by 2007, 68 203 U.S. businesses had created over 770 000 jobs in the clean energy economy alone. And between 2006 and 2008, approximately $12.6 billion of venture capital investments was directed toward clean technology businesses.[23] Emerging areas of sustainable innovation like green chemistry, which is expected to grow into a $100 billion global industry by 2020,[24] are proving every day that the choice between the economy and the environment is indeed a false choice. Scientists must recognize the power of innovation to build a sustainable environment and strong economy simultaneously.

■ ACTIONS TAKEN ON THE PATH FORWARD

Since March 2010, EPA's Office of Research and Development has evolved significantly in alignment with the principles outlined above. Careful attention has been paid to remaining as flexible and agile as possible in order to respond to changing needs and dynamic challenges, including shrinking budgets. This adaptive management approach and emphasis on continual refinement underscores all Path Forward activities and will be necessary to foster effective research in the face of limited resources.

Aligning Research with Sustainability. Perhaps the most significant step taken on EPA's Path Forward has been the strategic realignment of Agency research efforts around the concept of sustainability. Steps taken toward this realignment include solicitation of expert advice on sustainability from the National Academies of Science, the development of scientific and analytical tools for implementation of sustainability within EPA, solicitation of extramural research that incorporates sustainability concepts, and efforts to improve leveraging and coordination of sustainability efforts across the federal government.

In 2010, EPA commissioned a landmark study from the National Academies to provide recommendations on how to systematically operationalize the concept of sustainability into all of the Agency's decision making. The request itself was characterized by EPA Administrator Jackson as "a step toward the more effective pursuit of all of our work, including our statutory requirements, by incorporating sustainability into our foundations.[25]" The final report entitled "Sustainability and the U.S. EPA", also known as the "Green Book," outlined several recommendations, including identification of key scientific and analytical tools, indicators, metrics, and benchmarks for sustainability that can be used to track progress toward sustainability goals.[26]

EPA scientists have begun to develop the scientific and analytical tools that will be needed in order to respond to and implement the recommendations of the Green Book. For example, a forthcoming white paper entitled "Sustainability Analytics," will introduce and describe the analytical methodologies and tools that can be used to implement sustainability at EPA, including life cycle analysis, ecosystem services valuation, full cost/full benefit accounting, green chemistry, green infrastructure, and more. This effort to develop the tools of sustainability mirrors past EPA efforts to develop the tools for assessing, evaluating, and managing risk.

EPA's extramural research efforts have also been aligned with the sustainability goals and concepts. For example, as part of the Path Forward, EPA has developed a new set of sustainability-focused peer review criteria as well as sustainability science guidance language and a sustainability primer that are included in all applicable research proposal solicitations.[27] Extramural researchers seeking grants through EPA's Science to Achieve Results program must now include a

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"discussion on how the proposed research embodies the principles of sustainability and will seek sustainable solutions that protect the environment," in their proposals.

The Agency has also engaged in efforts to better leverage and coordinate sustainability-related research activities across the federal government. For example, EPA's research office is an active member of a new interagency task force on Integration of Science and Technology for Sustainability (ISTS) under the Committee on Environment, Natural Resources, and Sustainability (CENRS) of the National Science and Technology Council (NSTC). The task force, which includes EPA and 11 other federal departments and agencies, is currently working to identify opportunities, recommend priorities, and coordinate federal science, technology, and research activities that promote sustainability. The ISTS is specifically charged with mapping current sustainability science efforts across the federal government, including tools, models, indicators, programs, projects, and initiatives.

Integrating Research Programs. The Path Forward also resulted in a reduction of EPA's 13 relatively isolated research programs to six fully integrated areas—all in alignment with the Agency's strategic priorities (Table 1). This integration of research across scientific disciplines was the critical step needed to be capable of executing research that incorporates holistic, systems thinking for sustainable solutions. EPA's realigned research portfolio on the Path Forward includes four fully integrated, trans-disciplinary programs and two highly targeted programs that meet specific and permanent research needs.

Table 1. Crosswalk of Former and Realigned Research Programs with the Agency's Strategic Goals

EPA Strategic Goal	Current Research Program	Former Research Program
Taking Action on Climate Change and Ensuring Air Quality	Air, Climate & 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	Homeland Security
	Human Health Risk Assessment	Human Health Risk Assessment

1 **Air, Climate, and Energy (ACE).** The ACE research program aims to address three interrelated goals: clean air, a sustainable climate, and meeting energy needs. Improving air quality has long been a key area of focus for EPA. The ACE program will continue to provide the science that informs national ambient air quality standards and build upon ongoing efforts in the areas of multipollutant mixtures, air emissions, and measurements in a way that integrates climate and energy considerations. The program will also seek to understand how future changes in our nation's energy scheme might impact efforts to protect human health and the environment.

2 **Chemical Safety for Sustainability (CSS).** The CSS research program is focused on developing scientific tools for integrated chemical evaluation strategies, improving chemical assessment methods and informing next generation risk assessment approaches. In addition to addressing high priority research needs for specific chemicals, the CSS program is designed to incorporate cutting-edge advances in exposure science, biology, and computing to develop faster, cheaper, and more efficient chemical evaluation methodologies as well as inform more sustainable approaches to green chemical design and production across life cycles.

3 **Safe and Healthy Communities (SHC).** The SHC program is organized around three broad themes: working with communities to develop sustainability approaches; developing decision analysis, methods, tools, and metrics to support sustainability in communities; and targeting high priority research needs. To advance these themes, SHC will focus on full-cost accounting, land use, sustainable buildings and community infrastructure, ecosystem services and benefits, technology for a greener economy, children's health, environmental justice, and many other areas.

4 **Safe and Sustainable Water Resources (SSWR).** The SSWR program informs how EPA can ensure that the Nation's water supply is both safe for use and sustainable for future generations. EPA has integrated its formerly separated programs on Drinking Water and Water Quality into a unified, sustainability-oriented program. Researchers in the SSWR program will focus on providing sound science to inform faster, smarter water resources management decisions for present-day problems and conduct science to inform proactive approaches to problems of the future. The SSWR program includes a focus on ensuring safe and sustainable water quality and availability as well as developing the science needed to build and maintain sustainable water infrastructure systems.

5 **Human Health Risk Assessment (HHRA).** Human health risk assessment is applicable to all of EPA's realigned research areas. The functions of the HHRA program will support needs across the other research areas but are also targeted to meet more specific Agency needs. The program will continue to generate Integrated Science Assessments, Integrated Risk Information System Assessments, and other documents that are widely used to help understand the potential risk to public health from exposure to environmental contaminants of concern.

6 **Homeland Security Research Program (HSRP).** In the wake of the September 11, 2001 terrorist attacks, EPA formed its Homeland Security Research Program to enhance the Nation's preparedness, response, and recovery capabilities from potential large-scale incidents involving chemical, biological and radiological threats. The HSRP program has a focused, well-defined, mission of informing the science and technology for prevention and response to security threats, and will incorporate sustainability and systems thinking into its research and activities wherever possible.

With this integration of research areas, traditional scientific silos have been broken down and EPA scientists are able to work collaboratively to address complex, integrated environmental challenges. Where broad programmatic boundaries remain intact by necessity, EPA has taken steps to ensure they are as permeable as possible in order to enable the cross-fertilization of ideas.

Obtaining External Validation. In their 2011 review of EPA's new strategic research directions, EPA's Science Advisory Board (SAB) and the Board of Scientific Counselors (BOSC) jointly endorsed the realignment of EPA's research programs and the overall direction of the EPA's research endeavor toward

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sustainability.[28] Their report stated that "consolidation and realignment of ORD research programs and adoption of such a systems approach to sustainability are bold and necessary steps." They also praised the incorporation of Path Forward principles into EPA's research program, such as responsiveness and innovation, saying that "ORD has involved regional and program office stakeholders in the design of the new programs. As a result, program and regional support for ORD's new approaches is evident," and that "EPA has thought seriously and operationally about ways to energize the creativity of ORD scientists and has begun to make innovation a fundamental part of ORD programs."

The SAB and BOSC also recommended several steps to ensure maximum effectiveness in implementing this realigned research portfolio, including outlining specific sustainability goals and metrics, clearly defining measures of success or failure as innovation projects are developed, and identifying additional cross-cutting research topics such as multiple stressors, measures of ecosystem function, and green infrastructure.

In addition to SAB and BOSC reviews and the "Green Book" report, EPA has commissioned a study from the National Research Council entitled "Science for EPA's Future.[29]" The study aims to assess the Agency's capability to "develop, obtain, and use the best available new scientific and technological information and tools that will be needed to meet persistent, emerging, and future mission challenges and opportunities across the agency's research and regulatory programs." The recommendations provided in this forthcoming report, in combination with recommendations and suggestions from other external validators will be critical to ensuring scientific integrity within the realigned program structure as well as its effectiveness and alignment with Agency priorities. This kind of independent feedback and response to peer review is also EPA's strongest mechanism for ensuring the Agency's work is scientifically credible and as objective as possible.

Fostering Innovation. Several steps have been taken on the Path Forward to foster, encourage, and incentivize innovation among EPA scientists and within the Agency's external partnerships. Soon after the Path Forward was launched, the appointment of a Chief Innovation Officer (CIO)—a new position within the Agency's research office—was announced. The CIO and small innovation support staff were tasked to seek out proactive mechanisms, partnerships, and projects to foster innovation within EPA and leverage environmental innovation opportunities relevant to the Agency's mission, including

1 **Pathfinder Innovation Projects (PIP).** In 2010, EPA launched an internal competition for researchers to win seed funding to work on innovative, high-risk, high-reward projects relevant to the Agency's mission. Participation in the first PIP solicitation was overwhelming, with more than 25% of scientists within EPA's Office of Research and Development participating in the submission of 117 proposals. 12 projects were awarded, covering a diverse array of subjects from remote sensing to human activity patterns and exposure, to metagenomics in water systems and more. A second round of Pathfinder Innovation Projects is underway and focused on the relationship between innovation and sustainability.
2 **Open Source Innovation.** EPA has launched its first two "challenges" on InnoCentive.com, an online platform that facilitates the solicitation of solutions to problems in return for a cash award. The Acrolein Challenge seeks a solution for detecting and analyzing acrolein in air at low concentrations and the Nonpoint Pollution Challenge seeks methods to efficiently measure the reduction of pollution from nonpoint sources into water bodies. This open source approach opens the door to environmental solutions that may otherwise not be available to EPA.
3 **Technology Innovation Clusters.** In 2011, EPA Administrator Lisa Jackson announced the Cincinnati Water Technology Innovation Cluster (WTIC) in collaboration with the Small Business Administration, the University of Cincinnati, and other partners from local governments and industry. The cluster aims to leverage the expertise, capabilities, and resources of the greater Ohio, Kentucky, Indiana region to develop innovative strategies and technology solutions to meet water resource and quality needs. For example, the Cluster cohosts activities targeted at local emerging technology companies and regional researchers such as workshops and forums on the topics of small business innovation research, state funding opportunities and proposal preparation. EPA researchers are involved in planning investigating the feasibility of developing additional innovation clusters in other regions.

The combination of these and other innovation-related activities has generated enthusiasm among staff and attention from the external community while simultaneously bringing EPA research closer to the cutting edge of innovation for sustainability.

Path Forward Case Study: Green Chemistry. In alignment with the Path Forward, EPA's green chemistry efforts have been designed and implemented as part of a coordinated campaign that, while grounded in scientific and technological research, also includes elements of public outreach, stakeholder engagement, and external communication (Figure 1). Taken together, these activities exemplify the collection of Path Forward principles and present a cohesive model for harnessing science, technology, and research to drive innovation, catalyze broader systems thinking, and advance sustainability goals.

1 **Sustainability.** Green Chemistry is an area of innovation with significant research challenges and opportunities related to sustainability.[30] Within EPA's internal research enterprise, significant effort has been focused on advancing the science and technological tools of green chemistry in alignment with sustainability goals. For example, a research team in EPA's Cincinnati laboratory is focused on developing decision support tools to estimate toxicity values for a wide range of toxicological end points[31] as well as new technologies and methods for solvent recovery, green synthesis of nanomaterials,[32] and more. In addition, a section on green chemistry is being incorporated into a forthcoming Agency white paper on the scientific and analytical tools needed to implement sustainability.
2 **Acting Catalytically.** EPA is engaged computational toxicology research both because it facilitates important data-gathering in a faster, cheaper, more effective manner and also because the information it provides can improve our understanding the inherent basis of hazard. By having this deeper understanding, the scientific community can use it to develop the protocols and approaches that allow next generation molecules to be more benign by design.

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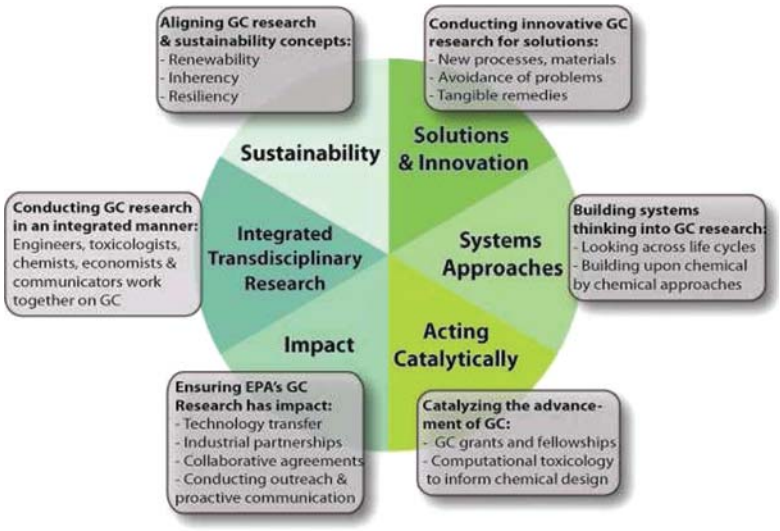

Figure 1. EPA's green chemistry (GC) efforts on the Path Forward.

For example, theTox21 program, collaboration between EPA, the National Institutes of Environmental Health Sciences, the National Institutes of Health, and the Food and Drug Administration, is aiming to screen nearly 10 000 chemicals with 25 assays in the next year.[33] The list of assayed chemicals will be made public on EPA's Web site as well as the Web sites of partner agencies. In addition, through its Science to Achieve Results extramural grants program, EPA has released two research solicitations in the areas of molecular design and material life cycle safety. These requests for applications explicitly direct grant applicants to submit proposals that are both innovative and involve the principles of sustainability. They also list green chemistry and green engineering research as illustrative examples of sustainability-oriented research topics.

3 **Impact.** During the past year and a half, EPA has produced a significant number of communications materials about the Agency's ongoing green chemistry research and activities. These materials are intended for lay and nontechnical audiences and can be repurposed for specific events or meetings to maximize the visibility and impact of EPA's work. For example, EPA has produced a video documentary about EPA green chemistry research that is available online as well as for distribution to interested stakeholders, overview factsheets, special addition newsletters, blog posts for the Agency Web site, and is working to develop a green chemistry resource directory for public information and use.

4 **Integrated Transdisciplinary Research.** In addition to the team of scientists conducting green chemistry research in EPA's Cincinnati laboratories, many individuals across multiple disciplines and EPA offices have been called upon to collaboratively engage in efforts to advance the field. For example, EPA researchers worked with multiple regional offices to hold region-based green chemistry workshops that bring together scientists and practitioners from industry, academia, education, and environmental groups to discuss green chemistry topics and brainstorm ways to advance the field.

5 **Solutions and Innovation.** EPA's research office continues to work closely with the Agency's program and regional offices to advance innovative green chemistry solutions beyond EPA. For example, along with the Agency's office of Chemical Safety and Pollution Prevention, EPA researchers administer the annual Presidential Green Chemistry Challenge Awards, which recognize excellent demonstrations of practical and innovative green chemistry solutions.

6 **Systems.** Look across systems and life cycles is a common theme throughout all of EPA's green chemistry research activities. For example, one of the priority research focus areas of EPA's chemical safety for sustainability research program is to "provide risk management options that better target where risks are more likely to occur throughout a chemical's life cycle from production to disposal.[34] EPA's green chemistry research also recognizes, for example, that areas like nanotechnology—with all of its benefits—can have environmental concerns as well.[35]

■ CONTINUING ON THE PATH FORWARD

The Path Forward calls for agility, continuous improvement, refinement, and perseverance to meet dynamic challenges and changing needs. In this regard, the Agency's work on the Path Forward will be an on-going endeavor. As can be seen from the description above, it is not a new program, project, or initiative; it is simply a part of the EPA's continuing obligation to ensure it uses the best science and pursues the most effective ways of accomplishing its mission to protect human health and the environment.

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Biography

Paul Anastas, Ph.D. is Science Advisor to the U.S. EPA as well as the Agency's Assistant Administrator for Research and Development, appointed by President Obama. Dr. Anastas is known widely as the "Father of Green Chemistry" for his groundbreaking work on the design and manufacture of chemicals that are nonhazardous and environmentally benign. Anastas is trained as a synthetic organic

chemist and is currently on public service leave from Yale University, where he holds the Theresa and H. John Heinz chair in Chemistry for the Environment and Directs the Center for Green Chemistry and Green Engineering.

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