A Focus on Science, Engineering, and Education for Sustainability

PAGES 1–3

In a sustainable world, human needs would be met without chronic harm to the environment and without sacrificing the ability of future generations to meet their needs. Addressing the grand challenge of sustainability, the U.S. National Science Foundation (NSF) has developed a coordinated research and education framework, called the Science, Engineering, and Education for Sustainability (SEES) portfolio (http://www.nsf.gov/sees). The growing family of SEES activities, currently consisting of 11 programs, represents a major interdisciplinary investment by NSF that reflects the following topical themes: environment, energy and materials, and resilience. The SEES research and education program portfolio emphasizes the use of systems-based approaches to address critical challenges at the nexus of environmental, energy and materials, and economic systems, including social and behavioral dynamics and questions of human resilience and vulnerability.

The SEES portfolio seeks to increase capabilities for understanding, predicting, and responding to changes in the linked natural, social, and built environment. Within the above three themes of SEES, NSF supports a variety of new programs that are proceeding down three pathways to advance sustainability: (1) building the knowledge base, (2) growing the workforce of the future, and (3) forging critical partnerships. Through SEES's goals and themes, proposed linkages and partnerships, and planned future trajectory, scientists can enact targeted plans for ensuring the sustainable future of human society. The research and education communities are strongly encouraged to create interdisciplinary proposals that address aspects of sustainability.

Building the Sustainability Knowledge Base

The growing and pervasive challenges of global change demand a better understanding of the interactions among human and environmental processes—collectively, the spheres of sustainability science and engineering. In this arena, NSF recognizes its important role in support of the basic foundational disciplinary research, as well as the interdisciplinary research that links natural and behavioral sciences, engineering, and education.

Through SEES, NSF is supporting development of the knowledge base needed to tackle the multifaceted challenges of sustainability at both individual component and full complex systems levels. The program portfolio includes support for (1) research at the environment-society interface; (2) innovative strategies for energy generation and materials, distribution, and use; and (3) the study of societal factors such as vulnerability, resilience, and sensitivity to regional change.

NSF, working closely with the community through its advisory committees, has identified various research focus areas as key investment priorities that will strengthen societal understanding of the relationships between human behavior and natural processes. Specific challenges identified for current support include Earth system modeling, fresh water security, ocean acidification, sustainable energy, biodiversity, coupled natural and human activities, and climate science education. Areas under consideration for future focused investment include natural hazards, sustainable materials, and vulnerable regions (e.g., arctic and coastal regions), as well as the resilience of populations (e.g., in developing countries) to forthcoming changes.

Scientists and organizations whose research focuses on the scientific challenges of sustainability are encouraged to get involved through submission of interdisciplinary proposals under a range of SEES solicitations in NSF's upcoming cycles of funding opportunities.

Growing the Sustainability Workforce

Future U.S. economic competitiveness, energy independence, and sustainable growth depend on a talented and motivated workforce with strong competencies in science, technology, engineering, and mathematics. Various educational and career growth opportunities under SEES, whether embedded in research efforts or targeted human capacity initiatives, will promote a future science and engineering workforce that both reflects the nation's diversity and has the skills necessary to advance knowledge and examine solutions needed to overcome critical scientific and societal sustainability challenges. Interdisciplinary experiences for undergraduate, graduate, and doctoral students; postdoctoral fellows; and early-career scientists are an important part of the SEES investment portfolio.

Further, SEES-supported fellowships, research network development, and partnerships with other organizations specifically target development and retention of early career scientists at critical transition points in their education and career pathways. Future activities may also include opportunities for middle- and late-career scientists to retool their capabilities in support of sustainability science and engineering research and education.

Forging Sustainability Partnerships

NSF works with other federal agencies and national and international stakeholders whose functions and missions complement the SEES investment and the nation's goals. NSF and 12 other federal agencies have an overarching domestic program to respond to environmental change through the United States Global Change Research Program (USGCRP), which is currently finalizing its next 10-year strategic plan for the 2012–2022 period (http://www.globalchange.gov/). SEES represents a significant new contribution by NSF to USGCRP. In other examples, NSF is partnering with the U.S. Department of Energy in support of Earth system modeling and energy research, particularly as it pertains to renewable and sustainable energy pathways; the U.S. Department of Agriculture on Earth system modeling and in areas of relevance to food production and security; and the U.S. Geological Survey on hydrological and related sciences.

Many of the intellectual and practical SEES challenges are global in scope and require a comparative understanding of geographic, ecological, and cultural variability. Several national and international global change research programs are promoting research that is substantially improving the understanding of Earth systems processes and the ways that these systems are changing. However, as the needs of stakeholders engaged in global change research and policies increase, new systems for international coordination of both basic and applied research are coming to the fore. In response, funding organizations from many countries, including the United States, are moving toward more active coordination of funding for sustainability research. The International Council of Scientific Unions; the International Social Science Council; various bodies such as the United Nations Educational, Scientific, and Cultural Organization and United Nations Environment Programme; and the International Group of Funding Agencies for Global Change Research's Belmont Forum (http://www.belmontforum.org) are spearheading a new alliance among global environmental change stakeholders. This combined effort seeks to establish a new framework to coordinate research for sustainability (http://www.icsu.org/earth-system-sustainability-initiative).

Harnessing the complementary international efforts will foster cross-fertilization of ideas and will provide access to international expertise, facilities, and data. In 2012 and beyond, NSF's Partnerships for International Research and Education program will focus on sustainability research with other countries by facilitating the exchange of ideas, materials, instrumentation, researchers, and students. The global impact of many of these partnerships will be enhanced by linking with NSF's newly announced Sustainability Research Networks that will support collaborative team approaches to meeting environmental and societal challenges.

The Path Forward

Scientific agencies and organizations are increasingly bringing knowledge, discoveries, and progress to the marketplace. Included in SEES's efforts are activities aimed at bolstering university-industry interactions that connect fundamental research developments with regional and national innovation centers. To be most valuable, the knowledge gained through enhanced focus on sustainability must be provided to the public and businesses on relevant time and space scales.

NSF also places significant emphasis on computational and data-rich science and engineering, with the goal of providing a sustainable, community-based and open cyberinfrastructure for researchers and learners. This is another major challenge because the number and volume of data sets have grown to proportions beyond the range of traditional data handling tools. Transformative approaches and innovative technologies are needed for heterogeneous data to be integrated, made interoperable, explored, and repurposed by researchers in disparate fields. This will facilitate a myriad of uses across institutional, disciplinary, spatial, and temporal boundaries. Geospatial data, metadata, enabling software/hardware, and training are essential elements relied on by the sustainability workforce and must be optimized to increase researchers' productivity and capabilities. To aid in this, NSF's Earth Cube initiative (http://www.nsf.gov/geo/earthcube/), which involves a new partnership between NSF's Directorate for Geosciences and Office of Cyberinfrastructure, seeks to develop a sustainable cyberinfrastructure for data-enabled science and engineering central to furthering scientific understanding of the Earth system. To this end, a growing set of funding opportunities for geoinformatics projects in sustainability are available.

Sustainability science, engineering, and education require a multifaceted consideration of the natural environment, human populations, energy and materials use, built environment, and human behavior so that the challenges brought on by large-scale environmental change and modern resource demands—economic, technological, agricultural, and cultural—can be met. NSF's SEES portfolio transcends basic sustainability research and education through new partnerships and by bridging the gap with societal application and adaptation. Confronting today's grand challenge of sustainability, NSF's growing family of SEES programs supports natural and social sciences, engineering, and education, involving every one of NSF's directorates and offices. To ensure a healthful future, SEES relies on the energetic engagement of research and education communities from AGU and other scientific organizations to help create, nurture, grow, and disseminate the emerging knowledge base on sustainability.

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