

## SCIENCE, ENGINEERING, AND EDUCATION FOR SUSTAINABILITY (SEES)

**Goal:** To generate the discoveries and capabilities in climate and energy science and engineering needed to inform societal actions that lead to environmental and economic sustainability.

**Description and Rationale:** Major drivers for establishing the NSF SEES portfolio are the August 2009 report from the *National Science Board: Building A Sustainable Energy Future* and the *IPCC Fourth Assessment Report: Climate Change 2007*.

- The scope of the SEES portfolio parallels the NSB's call for integrated approaches that "increase U.S. energy independence, enhance environmental stewardship and reduce energy and carbon intensity, and generate continued economic growth." The NSB provided specific guidance to NSF that emphasized systems approaches to research programs, education and workforce development, public awareness and outreach, and the importance of partnerships with other agencies, states, universities, industry, and international organizations.
- The IPCC Synthesis Report presented a number of key scientific uncertainties that if resolved would improve our ability to predict future climate change, its consequences, and the potential success of mitigation and adaptation strategies.

The two-way interaction of human activity with environmental processes now defines the challenges to human survival and wellbeing. Human activity is changing the climate and the ecosystems that support human life and livelihoods. Reliable and affordable energy is essential to meet basic human needs and to fuel economic growth, but many environmental problems arise from the harvesting, generation, transport, processing, conversion, and storage of energy. Climate change is a pressing anthropogenic stressor, but it is not the only one. The growing challenges associated with climate change, water and energy availability, emerging infectious diseases, invasive species, and other effects linked to anthropogenic change are causing increasing hardship and instability in natural and social ecologies throughout the world.

Solutions to these emergent, coupled problems will have to be based on sound multi-disciplinary and quantitative principles derived from science, engineering, and technology. It is not only urgent, but also timely and achievable to generate understanding of the links between energy sources and systems, climate forcings and feedbacks of the Earth system, and social, educational, and policy responses. This research will lay the foundation for technologies to mitigate against, and adapt to, environmental change that threatens sustainability. By informing policy, education, and management decisions, we will address the major challenge of ensuring human wellbeing over the long term.

**Integrated Science and Engineering Research in Climate Change and Energy:** NSF has broad and long-standing investments in environment, energy, climate, social sciences, mathematics, and many other areas of research and education that provide insight into the challenges to sustainable well-being in the 21<sup>st</sup> century. Fundamental research that underpins the development of innovative solutions to pressing problems in sustainability will continue to be supported and emphasized across NSF. This research – in such areas as complex environmental and climate-system responses and pathways – will be complemented by activities focused on sustainable and renewable energy technologies.

NSF's unique mandate to support all areas of science, engineering, and science education allows it to now identify SEES research aimed at tackling the complex system level problems of sustainability. SEES research will investigate the fundamental role that social, economic, and political systems play in creating and addressing major issues in sustainability. It will include conceptual, theoretical, empirical, and computational research needed to further develop the basic science, engineering, education, and policy

knowledge base, as well as address the multifaceted challenges of sustainability (energy-economy-environment) at both individual and systems levels.

The NSB report outlined a range of SEES research investments in the area of sustainable energy: novel energy storage schemas; ecosystem impacts of energy technologies; improving the efficiency and yield of established sustainable energy systems, e.g. wind, solar; and the discovery and development of novel energy sources, e.g. biofuels, ocean/kinetic power. Energy-intelligent computational performance in computer and network systems will be explored as well as the use of information technology in smart sensing systems that have promise to save energy. Energy efficiency in manufacturing and materials will be stressed.

Some key scientific uncertainties identified in the IPCC report that SEES research will address include: interactions between the climate, human and natural systems; feedbacks in the climate and especially carbon cycles; impacts of ice sheets dynamics on climate change and sea level rise; regional climate change and causes; the difference between low probability/high impact vs. high probability/low impact events on risk-based approaches to decision making; interactions between socio-economic factors and the evolution and utilization of adaptive and mitigating strategies; barriers, limits and costs of adaptation; effects of lifestyle and behavioral changes on energy consumption and climate.

Scientific and engineering research in SEES will benefit from creative mathematical, statistical and computational methods for analysis and simulation. Supercomputing capability will be enhanced in support of improved predictability and communication at the climate-energy-society nexus. Many efforts will build on the climate research emphasis initiated in FY 2010, including research on regions highly susceptible to the impacts of environmental changes, such as coastal areas subject to sea-level rise, the Arctic where permafrost is changing rapidly, and the Antarctic where sub-ice sheet conditions are being explored and modeled.

In addition to advances in research, these awards will include activities that help prepare an informed, solutions-oriented citizenry and future work force to address the complex problems and decisions associated with sustainability. Experiences for undergraduate, doctoral and postdoctoral students will complement those supported by the Climate Change Education program.

**Management and Assessment:** As an investment portfolio, SEES will support research and education that span ten NSF directorates and offices. Because it will build on and initiate activities that are dispersed, there is a need to create an integrated management framework for the complex, highly interdisciplinary, yet integrated activities that will be effective in addressing the challenge of sustainability. For example, additional planning will occur during FY 2010 in order to consult with a wide spectrum of disciplinary communities, form partnerships, and identify shared priorities. Specific measures will therefore be established to provide coordination and guidance across this portfolio.

The organizational structure will include:

- A senior leadership committee composed of Assistant Directors/Office Heads to provide long-term planning and provide overall guidance;
- Working groups of program directors, each overseen by Assistant Directors/Office Heads/Division Directors who are most relevant to the specific activity to manage programs or activities; and
- Interagency working groups to coordinate interagency activities, which may require establishment of MOUs/MOAs and joint solicitations between the collaborating agencies.

Specific outcomes will include:

- Emergence of new areas of research, identified in FY 2010 and FY 2011, that help close key gaps in the knowledge base;
- Development of new models for the conduct of research, specifically employing integrative, systemic approaches. These will be used by investigators and evaluated between FY 2014 and FY 2016; and
- Generation of new integrated understanding of the interplay of environment, energy, and the economy. Communication and publication of results is expected primarily after awards conclude, beginning as early as FY 2014.

To develop the evaluation framework necessary to monitor progress toward these outcomes, the senior leadership committee will consider a matrix of assessment methods and measures that captures a range of outcomes and impacts. These outcome metrics and targets will be developed during FY 2010. The Advisory Committee for Environmental Research and Education, in addition to other existing NSF advisory committees, will provide input to the senior leadership committee and establish, as appropriate and timely, Committees of Visitors to assess outcomes of programs. NSF will engage the community through workshops in FY 2010 to gather input and explore potential approaches, including those emerging from NSF-funded work in the Science of Science and Innovation Policy program.

**Funding:** SEES is constructed as a portfolio of investments (e.g., individual investigators, small interdisciplinary teams, and larger groups) that include new as well as augmented ongoing activities in climate and energy research and education that are directly relevant to the SEES goal of informing societal actions needed for a sustainable Earth. This portfolio-based approach is intended to facilitate coordination, monitoring and impact across the major NSF investments.

Activities in FY 2011 include refreshing and integrating ongoing programs and issuing new solicitations for SEES. Identification of needs for further coordination and integration to address key science and engineering challenges will be an ongoing high priority.

### SEES Portfolio Funding Levels

(Dollars in Millions)

	FY 2010 Estimate	FY 2011 Request
Biological Sciences	\$121.00	\$126.00
Computer and Information Science and Engineering	17.00	29.36
Engineering	108.20	120.00
Geosciences	195.50	230.70
Mathematical and Physical Sciences	87.00	110.50
Social, Behavioral and Economic Sciences	20.78	27.98
Office of Cyberinfrastructure	5.50	5.00
Office of International Science and Engineering	2.50	8.20
Office of Polar Programs	65.26	69.26
Office of Integrative Activities	26.50	26.50
<b>Total, R&amp;RA</b>	<b>\$649.24</b>	<b>\$753.50</b>
Education and Human Resources	\$11.50	\$12.00
<b>Total, NSF</b>	<b>\$660.74</b>	<b>\$765.50</b>

Totals may not add due to rounding.