

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

### Overview

A sustainable world is one in which human needs are met equitably without harm to the environment, and without sacrificing the ability of future generations to meet their needs. Meeting this formidable challenge requires a substantial increase in our understanding of the integrated system of supply chains, society, the natural world, and the alterations humans bring to Earth. Given the pressing national and global need to realize a sustainable human future, the National Science Foundation (NSF) has developed a coordinated research portfolio spanning the entire range of scientific domains at NSF: the Science, Engineering, and Education for Sustainability (SEES) program.

SEES is a broad investment in the scientific underpinnings of sustainability at numerous temporal and spatial scales. Multiple perspectives and areas of expertise are required to increase our understanding of integrated systems of human society and the natural world. Thematic programs are aimed at building the knowledge base, while simultaneously encouraging interdisciplinary linkages, new partnerships, and education and outreach efforts.

### **Total Funding for SEES**

(Dollars in Millions)

FY 2012		
Enacted/		
FY 2012	Annualized	FY 2014
Actual	FY 2013 CR	Request
<b>\$157.55</b>	<b>\$157.00</b>	<b>\$222.79</b>

### Goals

SEES has three main goals to advance sustainability:

1. Support interdisciplinary research and education that can facilitate the move towards global sustainability (Research and Education);
2. Build linkages among existing projects and partners and add new participants in the sustainability research enterprise (Collaboration); and
3. Develop a workforce trained in the interdisciplinary scholarship needed to understand and address the complex issues of sustainability (Workforce).

### Approach

SEES is planned to be a decade-long effort across NSF to coordinate and grow research and education associated with the environment, energy, and sustainability. NSF's work under SEES is a blend of activities – formal solicitations and less formal announcements of interest (e.g., Dear Colleague Letters) that span across scientific disciplines and require input and oversight from multiple NSF directorates. Research in such areas as complex environmental and climate-system responses and pathways continue to be supported and emphasized across NSF and are supplemented by increased emphasis on activities focused on sustainable and clean energy technologies and engineering processes. NSF also works with other federal agencies and national and international stakeholder groups whose function and mission complement NSF's role to ensure that sustainability goals are carried forward.

The portfolio approach—as opposed to a large single program—facilitates communication, coordination, monitoring, and impact across the major investment areas and also across NSF, as SEES activities are complex and highly interdisciplinary. The SEES organizational structure includes:

- A senior leadership committee composed of assistant directors/office heads who provide long-term planning and overall guidance;

- A cross-agency implementation group composed of division directors and lead program directors, who develop consistent guidelines, provide internal and external communication, and shape evaluation plans; and
- 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. When interagency or international partnerships, such as with the European Union (EU), have been established, then members of those entities may also be members of the working group to facilitate preparation of joint solicitations, establishment of Memoranda of Understanding (MOU)/Memorandum of Agreement (MOAs), or other arrangements for collaboration.

**Investment Framework**

**SEES Funding by Directorate**

(Dollars in Millions)

Directorate/Office	FY 2012		
	FY 2012 Actual	Enacted/ Annualized FY 2013 CR	FY 2014 Request
Biological Sciences	\$27.25	\$27.25	\$35.75
Computer and Information Science and Engineering	9.02	9.50	19.00
Education and Human Resources	6.00	6.00	0.50
Engineering	19.77	19.25	26.76
Geosciences	58.75	58.75	86.27
Mathematical and Physical Sciences	17.03	16.50	35.26
Social, Behavioral, and Economic Sciences	7.75	7.75	9.25
International and Integrative Activities	11.98	12.00	10.00
<b>Total</b>	<b>\$157.55</b>	<b>\$157.00</b>	<b>\$222.79</b>

Totals may not add due to rounding.

**FY 2010-FY 2013**

In FY 2010, NSF developed SEES in response to numerous major community reports, including the August 2009 National Science Board (NSB) report *Building a Sustainable Energy Future*, which emphasized the need for a coordinated program. Initial efforts focused on developing and coordinating a suite of research and education programs at the intersection of climate and environment, with specific attention to human behavior. These solicitations (Dimensions of Biodiversity; Regional and Decadal Earth System Modeling; Ocean Acidification; Water Sustainability and Climate; and the Climate Change Education Program) resulted in awards totaling approximately \$70 million.

In FY 2011, NSF maintained momentum in the SEES investment area by augmenting existing interdisciplinary programs (Coupled Natural and Human Systems (CNH), Research Coordination Networks (RCN)) and issuing a Dear Colleague Letter (DCL) that advanced the research and education activities proposed for 2011 and laid the groundwork for programs proposed for continuance and expansion in FY 2012.

In its FY 2012 Budget Request, NSF proposed to expand SEES through significant investments in programs related to energy and collaborative networks. During FY 2011, interdisciplinary working groups drafted and NSF released solicitations, although at reduced scope and funding levels, for four new activities consistent with the FY 2012 plans. These four new activities were: the NSF SEES Fellows

program, at the postdoctoral level; Sustainability Research Networks (SRN), that include existing and new centers of collaboration; Sustainable Energy Pathways (SEP) focused on integrated energy resource utilization; and a SEES-focused Partnerships for International Research and Education (PIRE) competition, which advances international networks.

In FY 2013, NSF initiated five SEES programs that complemented programs developed in FY 2012 and prior years. These investments are consistent with long term planning for the SEES investment area, and focus on environmental, technological, and societal resilience; dissemination of results, responsiveness to societal needs, and workforce development. These five programs are:

Two programs related to complex interactions in highly vulnerable areas:

- *Coastal SEES* is designed to enable place-based system-level understanding of coastal systems on a variety of spatial and temporal scales; yield outcomes with predictive value in coastal systems; and identify pathways by which outcomes could be used to enhance coastal sustainability.
- *Arctic (ArcSEES)* seeks both fundamental research that improves our ability to evaluate the sustainability of the Arctic human-environmental system as well as integrated efforts which will provide community-relevant sustainability pathways and engineering solutions.

Two programs related to environmental and societal resilience:

- *Hazards SEES* seeks to: (1) advance understanding of fundamental processes associated with specific natural hazards and technological hazards linked to natural phenomena, and their interactions; (2) better understand causes, interdependencies, impacts and cumulative effects of hazards on individuals, the natural and built environment, and society as a whole; and (3) improve capabilities for forecasting or predicting hazards, mitigating their effects, and enhancing capacity to respond to and recover from resultant disasters.
- *Sustainable Chemistry, Engineering and Materials (SusChEM)* will enable the basic science and engineering discoveries needed to utilize new (non-petroleum based) sources of important raw materials; replace rare, expensive and/or toxic chemicals and materials with earth abundant, inexpensive and benign alternatives; economically recycle chemicals and materials that cannot be replaced such as the rare earth elements; and devise environmentally friendly chemical reactions and processes that require less energy, water and organic solvents and generate less waste than current practice.

One program that will advance sustainability on many fronts:

- *Cyber SEES* aims to advance interdisciplinary research in which the science and engineering of sustainability are enabled by new advances in computing, and where computational innovation is grounded in the context of sustainability problems.

### **FY 2014 Request**

In FY 2014, the SEES portfolio increases by \$65.79 million, or 41.9 percent, over the FY 2012 Enacted level. Although no new programs will be added in FY 2014, existing programs established in FY 2011-FY 2013 will be augmented. In particular, the five programs initiated in FY 2013 will continue to grow. *Sustainable Chemistry* will support additional research on replacing and recycling earth abundant, single source critical elements; *Coastal SEES* will shift to full research proposals from incubator awards; and *Hazards SEES* will focus on the collaborative science of disaster mitigation, preparedness, and response. Also in FY 2014, *Dimensions of Biodiversity* and *Water Sustainability and Climate* will issue follow-on solicitations, per multi-year plans for these programs.

### **FY 2015 – FY 2019**

Up to \$3.0 million may be redirected for community planning for a new focus area in FY 2015 on sustainable and resilient food systems. This interdisciplinary challenge will focus on processes aimed at meeting current food needs without comprising the ability to meet needs of future generations; thriving in the face of challenges that affect the supply and/or distribution of food; and conserving, protecting, and regenerating the biogeophysical and human environments. Example activities include workshops, research coordination networks in the CNH track, supplements to existing SEES awards, and exploration of alternative programmatic means to advance fundamental research on this topic.

Long-term planning will continue to stress consolidation and coordination of existing activities; networking and dissemination of information from the rapidly growing SEES knowledge base to the scientific community, policy-makers, and the public; and the workforce development critical for producing the next generation of sustainability scientists and engineers.

At the conclusion of SEES, NSF, in collaboration with its partners across government, academia, and industry, expects to have made significant investment and progress towards a sustainable human future. With respect to the three over-arching SEES goals, NSF expects to see:

1. Goal 1, Research and Education: the sustainability science and engineering knowledge base available and accessible to scientists, decision-makers, and society at large;
2. Goal 2, Collaboration: the private sector will be able to more rapidly identify and deploy technologies and methods to address sustainability issues; and
3. Goal 3, Workforce: multidisciplinary approaches to sustainability education are common practice; the U.S. has a robust cadre of early career scientists and engineers to address sustainability issues.

### **Evaluation Framework**

NSF employs a variety of tools to evaluate the scientific impact and progress of the various programs in the SEES portfolio. NSF is conducting select evaluation activities using internal resources, and will seek external support for evaluation activities that require specialized expertise.

Examples of planned evaluation activities for the SEES portfolio include:

#### **Goal 1: Research and Education**

*Short-term:* Text and data analysis of project reports, PI meeting reports, workshop and symposia reports to analyze the growth of sustainability research under the SEES portfolio.

*Long-term:* Historical review to determine the types of sustainability activities that were conducted and supported by NSF before and after establishment of the SEES portfolio.

#### **Goal 2: Collaboration**

*Short-term:* Portfolio analyses to identify collaborations, evidence of increased interdisciplinarity, and new tools and data sets developed under the SEES portfolio.

*Long-term:* Network analyses to identify collaborations, and evidence of increased interdisciplinarity.

#### **Goal 3: Workforce**

*Short-term:* Develop and baseline a monitoring system to collect metrics associated with the goals of SEES workforce development programs (such as SEES Fellows).

*Long-term:*

- Comparative analysis to examine whether education and career pathways of individuals involved in SEES projects differ from individuals in the same disciplines who did not participate in SEES projects; and
- Use monitoring data to determine if a formal impact evaluation for large investments is indicated.

Currently, many of these evaluation activities are underway or have been successfully completed, including:

- Developed evaluation questions and draft logic model for SEES portfolio and WSC program;
- Received feedback on evaluation strategy from NSF's Advisory Committee for Environmental Research and Education during fall 2012 committee meeting; and
- Multiple transdisciplinary workshops, including: WSC PI Meeting: Synthesis, Observations, Systems and Modeling (Nov 2011); Geothermal at the Environmental, Energy and Economy Nexus (Nov 2011); Natural and Engineered Carbon Sequestration (Oct 2011); Research in Landscape Sustainability: Earth-surface processes in the SEES context (Oct 2011); Research at Intersection of Marine/Hydrokinetic Energy and Aquatic Environment (Oct 2011); Sustainability Science: Enhancing Cooperation between Non-Governmental Organizations and Scientists (Oct 2011); Earth System Modeling PI Meeting (July 2012); and SusChEM Workshop (Jan 2012).

Because solicitations are a key component of the SEES portfolio, NSF program directors will be looking for success indicators such as representation of multiple disciplines in proposals, development of new international collaborations, and increased number of proposals received indicating engagement of the field with new interdisciplinary solicitations. NSF is particularly interested in measuring results in terms of new and productive connections made between researchers in a range of disciplines, and the development of new knowledge and concepts that advance the over-arching goal of a sustainable human future; and development of a workforce capable of meeting sustainability challenges. NSF senior leadership will take into consideration the findings and recommendations based on evaluation activities for purposes of outyear planning and budgeting. Evaluation findings may inform development of future SEES focus areas, as well as subject areas ready for a diminished emphasis and investment.