

## 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 society, the natural world, supply chains, 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 and to lead the development of solutions to sustainability challenges. Thematic programs are aimed at building the knowledge base, while simultaneously encouraging interdisciplinary linkages, new partnerships, and education efforts.

### **Total Funding for SEES**

(Dollars in Millions)

FY 2013 Actual	FY 2014 Estimate	FY 2015 Request
<b>\$183.67</b>	<b>\$161.75</b>	<b>\$139.00</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 a multi-year 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 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 2013 Actual	FY 2014 Estimate	FY 2015 Request
Biological Sciences	\$31.00	\$31.00	\$21.00
Computer and Information Science and Engineering	13.85	11.00	11.00
Engineering	18.15	15.00	12.00
Geosciences	70.00	68.00	59.00
Mathematical and Physical Sciences	33.42	21.50	22.50
Social, Behavioral and Economic Sciences	7.25	5.25	3.50
International and Integrative Activities	10.00	10.00	10.00
<b>Total</b>	<b>\$183.67</b>	<b>\$161.75</b>	<b>\$139.00</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 FY 2011 NSF made over 50 SEES awards totaling approximately \$88 million. A project of note from FY 2011 is an RCN-SEES track award to Penn State for the “Marcellus Shale Research Network.” The project team is developing a sustainable Research Coordination Network to organize and generate knowledge from water chemistry and flow data collected in Pennsylvania in the area of extraction of natural gas from the Marcellus shale.

In its FY 2012 Budget Request, NSF proposed to expand SEES through significant investments in programs related to energy and collaborative networks. 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 2012 NSF made nearly 80 SEES awards totaling approximately \$157 million. The FY 2012 SEES awards include funding for a Dimensions of Biodiversity project led by Michigan State University, “Dimensions US-China: Disentangling the Components of Tree Biodiversity: Integrating Phylogenies, Functional Traits and Transcriptomes.” The research will inform forest management, strengthen collaboration between researchers in the United States and China, and fund a joint training workshop for graduate students and early career scientists in both countries.

In FY 2013, NSF initiated five SEES programs that complemented programs developed in FY 2012 and prior years. These investments extend the SEES investment area toward achieving its challenging goals, and focus on environmental, technological, and societal resilience; dissemination of results, responsiveness to societal needs, and workforce development. These five programs are:

- *Coastal SEES* - Designed to enable place-based system-level understanding of coastal systems on a variety of spatial and temporal scales;
- *Arctic (ArcSEES)* - Supports fundamental research that improves our ability to evaluate the sustainability of the Arctic human-environmental system;
- *Interdisciplinary Research in Hazards and Disasters (Hazards SEES)* - Provides support to advance understanding of fundamental processes associated with specific natural hazards and technological hazards linked to natural phenomena, and their interactions;
- *Sustainable Chemistry, Engineering and Materials (SusChEM)* - Enables the basic science and engineering discoveries needed to utilize new (non-petroleum based) sources of important raw materials; and
- *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.

In FY 2013, NSF made over 140 awards totaling approximately \$166 million. One such award was “Understanding large-scale patterns of future Ocean Acidification.” This award supports a team of researchers at the University of Hawaii to investigate the regional patterns of current and future ocean acidification using a hierarchy of Earth System Models.

#### **FY 2014 Estimate**

In FY 2014, SEES will continue to support important scientific and societal contributions, and make significant progress toward achieving programmatic goals. Of particular note is the Sustainability Research Networks solicitation issued in FY 2014 that will build linkages to expedite progress across the complicated landscape of urban sustainability, which has emerged as a critical need for the 21<sup>st</sup> century. The FY 2014 Estimate level for the SEES portfolio is \$161.75 million. While this is \$61.04 million below the FY 2014 Request, it is sufficient to fund activities while finding balance and accounting for competing priorities in a constrained budget environment. The revised FY 2014 level incorporates minor adjustments to SEES programs initiated in Fiscal Years 2010-2012. It also reflects more considerable reductions to SEES program areas brought on line in FY 2013, where decreased investments would have less impact on an established research community, including Coastal SEES, Hazards SEES, and SusChEM. The FY 2014 Estimate also reflects an earlier phase-out of the Sustainable Energy Pathways program in FY 2014 instead of FY 2015, as was previously planned. Overall, the revised FY 2014 level for SEES is aligned with both FY 2013 actual spending (\$183.67 million) and programmatic plans for future years. SEES remains an important priority and key investment area for NSF.

### **FY 2015 Request**

In FY 2015, SEES passes the mid-point of its planned lifetime and enters a transition period toward “sunsetting” in FY 2017, the last year in which funds will formally be associated with the SEES activity. The total request for SEES in FY 2015 is \$139.0 million.

In FY 2015, SEES will continue investment in all programs initiated in FY 2010-2013, with the exception of Sustainable Energy Pathways, which phases out in FY 2014. A modest increase of approximately \$3 million will support the Sustainability Research Networks (SRN) in FY 2015, in order to establish and maintain more stable year-to-year funding levels for the remainder of the SRN program. Earth Systems Modeling (EaSM) and Hazard SEES decrease; the new level of funding for Hazard SEES is brought more in line with other FY 2013 SEES programs. FY 2015 will be the last year of funding for the Ocean Acidification program. SEES programs will continue to support important scientific and societal contributions during the phase-down period, and will make significant progress toward achieving programmatic goals, through projects currently underway.

### **FY 2016 – FY 2017**

Further reductions are planned for FY 2016 and FY 2017. Long-term planning will continue to stress consolidation and coordination of existing activities; networking and dissemination of information from the 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. Competitions in Earth Systems Modeling, in Hazards, and in Water Sustainability and Climate will end, but important elements of these programs will form the basis of standing programs that will be piloted in the final years of the SEES initiative.

Planning for the follow-on activity related to water (i.e., SEES Water Sustainability and Climate program) is well-advanced, envisioning integration of scholarship from hydrologists, engineers, ecologists, agricultural scientists, and scientists that study the processes of social, behavioral, and economic sciences to focus research on the water/food/energy nexus. The fundamental research question is: *In the face of climate change and variability, as well as population and land use change, how does society best integrate the natural world and its ecosystems services with the built environment and humans to provide for a growing demand for water, food, and energy?*

NSF staff and managers will be exploring possibilities for follow-on activities for other SEES programs and sustainability themes to ensure a well-informed sunsetting of the SEES portfolio.

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 evaluation activities for the SEES portfolio include:

**Goal 1: Research and Education**

*Short-term:* Text and data analysis of project reports, principal investigator (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 indicators 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 data collected for selected indicators to measure progress towards the workforce development goal.

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, the SEES Implementation Group and Working Group Chairs, NSF's Evaluation Capability lead, and other staff throughout the Agency.
- Issued a Request for Quotes for external (contractor) support for design and implementation of an evaluation plan for the SEES portfolio (award pending).
- Sponsored and participated in 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 are 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 takes into consideration the findings and recommendations based on evaluation activities for purposes of outyear planning and budgeting. Evaluation findings guide development of future SEES and subsequent focus areas, as well as subject areas ready for a diminished emphasis and investment.