

INNOVATIONS AT THE NEXUS OF FOOD, ENERGY, AND WATER SYSTEMS (INFEWS)

\$62,180,000
+13,500,000 / 27.7%

Overview

Growth of the global and U.S. population has placed an ever-increasing stress on three key and interconnected resources: food, energy, and water. There is a compelling and urgent need to understand, model, design, and manage the interconnected food-energy-water (FEW) systems, which incorporate natural, social, and human-built components. NSF can make important contributions by building the fundamental knowledge base; developing new ways to integrate heterogeneous data; analyzing, modeling, synthesizing, and controlling complex natural systems; expanding the workforce and piloting engineered solutions.

Of particular and timely interest are the production, resilience, safety, and security of FEW resources, and the systems in place to facilitate their generation, distribution, and consumption. Efficiency and conservation will be important goals to attain as stress on FEW systems increases from population and economic growth, changes in land use practices, and more frequent and large spatial and temporal variations in precipitation, temperatures, and key environmental variables tied to environmental change. Developing countries are under extreme pressure as they endeavor to manage the multiple stressors of poverty, resource competition, agricultural disease, and rising food costs. There are important security implications of increasing stress on these interconnected FEW systems.¹ Recent droughts in California and corresponding impacts on the water, agricultural (food), and energy sectors are timely examples that illustrate these concerns.

The interconnected FEW systems interact in several ways. Water is required for energy-related processes such as hydropower, cooling of electric power plants, and fuel production. Energy is needed for wastewater treatment, desalination, pumping groundwater, and for transport of water and foodstuffs. Water and energy are critical for agriculture and food production. Biofuel production consumes water and, in some instances, can result in food shortages. In addition, different land use practices, increased urbanization, and weather variability have major impacts on water, energy, and agriculture resources. These multifaceted interactions are impacted, on the one hand, by fundamental laws governing various physical, chemical, and biological processes and, on the other hand, by social, behavioral, and economic contexts and decisions made by individuals, organizations, and institutions.

Total Funding for INFEWS		
(Dollars in Millions)		
FY 2015	FY 2016	FY 2017
Actual	Estimate	Request
-	\$48.68	\$62.18

Goals

NSF's investment in INFEWS will:

1. Significantly advance our understanding of the FEW system through quantitative and computational modeling, including support for relevant cyberinfrastructure;
2. Develop real-time, cyber-enabled interfaces that improve understanding of the behavior of FEW systems and increase decision support capability;

¹ Quadrennial Defense Review 2014
(http://www.defense.gov/Portals/1/Documents/pubs/2014_Quadrennial_Defense_Review.pdf)

3. Enable research that will lead to innovative system and technological solutions to critical FEW problems; and
4. Grow the scientific workforce capable of studying and managing the FEW system through education and other professional development opportunities.

Approach

NSF is currently heavily invested in discovery research at a disciplinary level, as well as cross-cutting programs such as Water, Sustainability and Climate (WSC); Sustainable Chemistry, Engineering and Materials (SusChEM); Cyber-Innovation for Sustainability Science and Engineering (CyberSEES); Hazards and Disasters (Hazards SEES); Basic Research to Enable Agricultural Development (BREAD); Critical Resilient Interdependent Infrastructure Systems and Processes (CRISP); and the Dynamics of Coupled Natural and Human Systems (CNH). INFEWS offers a significant opportunity for NSF to build on these investments in order to create new and effective research programs to advance the FEW systems knowledge base. NSF has initiated, and proposes to continue, the following leadership and governance structure for INFEWS:

- A senior leadership committee composed of assistant directors/office heads to provide long-term planning and overall guidance;
- Working groups of division directors and program officers, each overseen by their respective assistant directors/office heads/division directors who are most relevant to the specific activity, to manage programs or activities and to coordinate among activities; and
- Interagency working groups to coordinate interagency activities and joint solicitations, as well as arrangements for engagement and collaboration with international partners.

An interdisciplinary research effort on the interconnected FEW systems, including safety and security of these systems, presents a unique opportunity for NSF to work, within both a national and an international context, toward building a platform for more accurate, process-based models that incorporate relevant social, political, economic, and cultural factors, and enabling innovative solutions to address these critical challenges.

NSF will build on ongoing internal partnerships among participating directorates to engage in collaborative multi-year activities involving two (or more) directorates. Management agreements will define directorate-planned contributions, remaining flexible on the requirement for participation. This flexibility will allow for partnerships with other agencies and international entities. NSF's approach and planned activities will be coordinated with other agencies through the National Science and Technology Council's Committee on Environment, Natural Resources, and Sustainability (CENRS).

Investment Framework

INFEWS Funding by Directorate

(Dollars in Millions)

Dir/Office	FY 2015 Actual	FY 2016 Estimate	FY 2017 Request
BIO	-	\$7.50	\$10.00
CISE	-	9.00	6.00
EHR	-	4.00	6.00
ENG	-	10.00	13.00
GEO	-	5.00	10.00
MPS	-	2.40	6.40
OISE	-	1.28	1.28
SBE	-	4.50	4.50
IA	-	5.00	5.00
Total, INFEWS	-	\$48.68	\$62.18

Totals may not add due to rounding.

FY 2015 – FY 2016

INFEWS represents a natural segue from many NSF programs, including those under the Science, Engineering, and Education for Sustainability (SEES) investment area. As such, INFEWS planning and development activities began in FY 2014 and continued throughout FY 2015. NSF senior management planned for the new investment area as community interest grew and was expressed in workshops and reports in a variety of disciplines. NSF senior management discussions with other federal agencies about common research interests and professional workforce needs were initiated and continue. In FY 2015, NSF supported 17 regional workshops to promote interdisciplinary collaborative approaches to FEW challenges and issued two Dear Colleague Letters (DCLs).² Workshops included scientists from Department of Energy (DOE), U.S. Department of Agriculture (USDA), U.S. Geological Survey (USGS), and other agencies and helped inform DCLs.

In FY 2016, NSF announced a multi-directorate INFEWS solicitation³ to support integrated research towards advancing the goals of the INFEWS investment. The USDA National Institute of Food and Agriculture (NIFA) helped develop the general solicitation and is committing funds to awards relevant to their mission.

The Directorates for Engineering (ENG) and Mathematical and Physical Sciences (MPS) announced a DCL (NSF 15-108) to support research activities in nitrogen, phosphorus, and water in the context of INFEWS in FY 2016. The goal is to advance knowledge of the nitrogen and phosphorus cycles; the production and use of fertilizers for food production; and the detection, separation, and reclamation/recycling of nitrogen- and phosphorus-containing species in and from complex aqueous environments. In FY 2016, the Directorate for Biological Sciences (BIO) plans to release a joint DCL with USDA/NIFA on breakthrough technologies for plant and animal phenotyping and microbiomes. Advanced phenotyping and microbiome technologies will enhance our fundamental understanding of these systems, which will potentially translate into improving agricultural productivity and efficient use of natural resources such as land, water, nitrogen, and phosphorus.

² www.nsf.gov/pubs/2015/nsf15108/nsf15108.jsp?amp%3BWT.mc_ev=click;www.nsf.gov/pubs/2015/nsf15040/nsf15040.jsp

³ www.nsf.gov/pubs/2016/nsf16524/nsf16524.htm?WT.mc_id=USNSF_27&WT.mc_ev=click

In FY 2016, INFEWS is also one of the priority research theme areas for the NSF Research Traineeship (NRT) program, as part of an effort to create innovative graduate education efforts in areas of national need.

FY 2017 Request

In FY 2017, NSF will continue to support INFEWS research activities. These activities will focus on how FEW systems are embedded in social, political, economic, and cultural contexts; innovation in the safety and protection of food, energy, and water resources, and the systems in place to facilitate their generation, distribution, and/or consumption; computational capacity and cyberinfrastructure needs for analysis of large-scale data, including modeling and simulation; and integration of research with education and training of the next generation workforce.

In FY 2017, BIO plans to issue a solicitation focused on phytobiomes, the microbiomes of plants and surrounding soils and environment, which impact the health and productivity of plants and plant ecosystems. Also, the FEW theme may be emphasized in NSF-wide programs, such as Experimental Program to Stimulate Competitive Research (EPSCoR), Research Experiences for Undergraduates (REU), Dynamics of Coupled Natural and Human Systems (CNH), Macrosystems Biology, and those related to data science (e.g., BIGDATA and Data Infrastructure Building Blocks (DIBBs)).

FY 2018 – FY 2021

In FY 2018 – 2021, NSF will continue to support INFEWS research activities. NSF will enhance interagency and international partnerships and foster cross-disciplinary knowledge-sharing and networking through awards, meetings, workshops, and other activities.

Evaluation Framework

The progress of the implementation of this investment will be monitored and reviewed quarterly to ensure that it is on track as part of a FY 2017 performance goal. For more information about monitoring key program investments, see the FY 2017 Annual Performance Plan in the Performance chapter. All specific investments under INFEWS will be subject to rigorous peer review using NSF's merit review processes, and under the review of cross-NSF teams from staff level to program and division director-level to an agency senior management steering committee. NSF will use lessons learned from large, cross-NSF investment areas (e.g., SEES, I-Corps™) to inform evaluation planning and design for INFEWS. Evaluation activities include:

- Consulting internally and externally regarding evaluation strategy and methodology;
- Characterizing the initial portfolio, using new NSF portfolio management tools;
- Developing evaluation research questions;
- Analyzing NSF project reports for indications of advancement/growth of research; and
- Collecting and analyzing workforce development metrics.

Planning for evaluation has been initiated. Contract support will be engaged as soon as practicable to ensure objectivity of evaluation design and implementation, and the collection of relevant baseline data.