

**Earth and Environmental Systems Institute (EESI):
Strategic Plan 2014-2020 07/1/14**

Exploring how we live with a changing earth

The EESI vision

EESI will build an extraordinary community of people who cross boundaries to understand the earth system, how it affects people, and how people affect it.

To promote this vision in the next five years, EESI will emphasize the following initiatives, described on the ensuing pages:

- i. EESI Will Promote a Global Water Initiative (GWI)
- ii. EESI Will Promote the Area of Environmental Life Cycle Assessment
- iii. EESI Will Explore Online Graduate Education Opportunities in the Environmental Sciences
- iv. EESI Will Promote the Environmental Instrumentation Infrastructure
- v. EESI Will Promote the Use of New Cyber-infrastructure, Sensors and Big Data
- vi. EESI Will Promote Diversity
- vii. EESI Will Promote a Home for a University-wide Center in Climate Risk Management
- viii. EESI Will Promote Interactive Science Communication

What is EESI?

The Earth and Environmental Systems Institute brings together faculty and students derived from a cross-section of disciplines who are interested in understanding the Earth and how we live with it. In the next five years, we will continue to grow an intellectual environment that fosters groundbreaking research and excellence in student education. EESI currently hosts 22 tenure-line faculty associates, 25 research faculty, 11 postdoctoral researchers, and 12 administrative staff. Thirty-seven (37) faculty at Penn State choose to interact with the institute as EESI affiliates. To achieve its goals, EESI receives approximately \$1 million in University funds, most of which are used for faculty salaries. The institute brings in about \$3 million in extramural funds that support EESI activities. We seek to provide the space, tools, models, data, and people to promote excellent science and education directed toward questions related to our environment, as described in our Vision and Mission statements below.

The EESI vision

EESI will build an extraordinary community of people who cross boundaries to understand the earth system, how it affects people, and how people affect it.

The EESI mission

The EESI mission comprises four interrelated elements:

1. To encourage interdisciplinary examination of the links between Earth's chemical, physical, and biological processes from atomic to global scales by supporting faculty and student research on earth sciences and environmental issues;
2. To facilitate the modeling and manipulation of data in new and innovative ways through EESI's Environmental Computing Facility;
3. To disseminate research findings through publications, presentations, web pages, social media, workshops, seminars, testimony to public agencies, and advice to public and private organizations and agencies; and
4. To develop innovative, interdisciplinary research and education programs that benefit all stakeholders, including the Penn State community, the Commonwealth, scientific communities, government entities, and the public.

Achievements from our last strategic plan

EESI continues to lead in seeking and receiving outside funding. In fiscal year 2012/13, 61 proposals were submitted, with 29 of those receiving funding in the amount of \$13.2 million. In that same period, 111 awards totaling \$33.2 million were administered. Thus, depending upon the metrics used, EESI represents a return on investment of general funds at a ratio greater than about 8:1. The biggest funding successes in that period were: \$6.8 million for Center for Environmental Kinetics Analysis (National Science Foundation, NSF); \$8.7 million for a National Institute for Climate Change Research center (Department of Energy, DOE); \$8 million for the Penn State Astrobiology Research Center; \$2 million for Center for Remote Sensing of Ice Sheets (NASA); \$12 million for the Sustainable Climate Risk Management initiative (NSF); and \$5 million for the Susquehanna/Shale Hills Critical Zone Observatory (NSF). EESI is proud of its ability to target, develop, organize, fund, maintain, and grow large interdisciplinary endeavors such as these centers.

In addition to these financial successes, EESI met most of the goals outlined in the previous strategic planning period (2008-13). For example, we hired two faculty in geography to grow the discipline of earth systems ecology within the College of Earth and Mineral Sciences (EMS) (E. Smithwick, J. Balch). We would have liked to hire an ecohydrologist but due to financial cutbacks we were unable to do this. We established the Laboratory for Isotopes and Metals in the Environment (LIME) as a multi-user environmental analytical laboratory. We initiated an award for non-tenure line faculty for their achievements. We funded a speaker series, EarthTalks. We assisted faculty pursuing funding. We trained faculty in science communications.

Of particular note, we perfected the concept of an “*EESI hire*”: these faculty are hired using the model of a cross-college committee facilitated by EESI. The committee, which advertises broadly, interviews several candidates with the idea that they might end up in any one of several departments. When a final decision is made as to the top candidate, the candidate then chooses a tenure home and, with the agreement of that home department, an offer is made. This hiring paradigm has resulted in two superior qualities: i) excellence; ii) diversity.

Proposed Strategic Initiatives through 2020

EESI proposes 8 strategic initiatives which are listed below and discussed on the following pages.

- ix. EESI Will Promote a Global Water Initiative (GWI)
- x. EESI Will Promote the Area of Environmental Life Cycle Assessment
- xi. EESI Will Explore Online Graduate Education Opportunities in the Environmental Sciences
- xii. EESI Will Promote the Environmental Instrumentation Infrastructure
- xiii. EESI Will Promote the Use of New Cyber-infrastructure, Sensors and Big Data
- xiv. EESI Will Promote Diversity
- xv. EESI Will Promote a Home for a University-wide Center in Climate Risk Management
- xvi. EESI Will Promote Interactive Science Communication

Our Strategic Initiatives for 2014-2020

1. EESI will Promote a Global Water Initiative (GWI)

Water quantity, quality, and availability will dramatically change due to climate effects and intensification of land use during the coming decades. As regional, national, and global demands for freshwater continue to grow, water science will be needed to inform policy in regard to issues of critical societal importance. In short, we have entered a new epoch, the Anthropocene, where humans are profoundly influencing solute, water, energy, and sediment fluxes on the planet, and choices must be made that are sustainable for future generations. *EESI will lead an initiative to understand how global water resources will change in the Anthropocene.*

Penn State hosts more than 100 water scientists on campus but these scientists are widely distributed. Likewise, Penn State provides more than 100 water-related courses on campus but these courses are not always appropriately coordinated. At the same time, the portfolio of U.S. spending on water research annually approaches \$1 billion. EESI has long worked with partners such as the Penn State Institutes of Energy and the Environment (PSIEE) to promote water as a focal point for research and outreach on campus. During the next five years, EESI will promote a new *Global Water Initiative* at Penn State. This entity will coordinate water specialists and educational opportunities in water on campus for researchers who pursue a global focus — a traditional scale of emphasis in Earth and Mineral Sciences. One faculty member could be targeted to lead this initiative. EESI faculty will work with others across campus to develop the goals and direction and activities of the GWI.

To establish the GWI, targeted faculty hiring could be pursued in the following areas:

- a) Water at the land surface with an emphasis on remote sensing
- b) Water and risk in climate and energy issues
- c) Water and ecohydrology: hydrological/biological responses to environmental change
- d) Water, climate down-scaling, and climate mitigation
- e) Water and human dimensions (health, policy, economics, security, land use, food)
- f) Water and distributed sensor networks (could be a professor of practice)
- g) Water and earth systems ecology

EESI will seek to hire a cluster of water science faculty — either across campus or within EMS — while establishing the GWI. As part of this initiative, EESI will seek to broaden its relationship with the EMS department of Energy and Mining Engineering (EME), perhaps establishing some water-related faculty lines.

The hiring paradigm for these faculty lines will be the same as has been used previously to hire other EESI faculty: a committee will be charged by the EESI director and will have faculty representatives from Meteorology, Geosciences, Geography, and/or Energy and Mining Engineering. An advertisement will be published that targets a broad interdisciplinary area. Candidates will be asked which department they want as their tenure home: individual departments will participate with EESI in the interview process and will approve the ultimate hiring decision in collaboration with EESI. More than one hire at a time will be facilitated in a cluster approach, either for EMS only, or in a cross-campus initiative with PSIEE. In general, we will search for very junior candidates to keep the applicant pool diverse.

Possible outcomes: a new initiative to forge ties among water specialists on campus, new faculty hiring, cluster hires, and growth of the relationship between EESI and EME.

2. EESI Will Promote the Area of Environmental Life Cycle Assessment

Environmental Life Cycle Assessment (LCA) refers to the cradle-to-grave study of products, processes and systems. It is distinctive because it treats both upstream production and raw material supply as well as downstream phases including end-of-life, disposal, and recycling phases. LCA is utilized to assess the embedded impacts on earth and environmental systems. These may include air emissions, water contamination, or impacts on other ecosystem services. LCA is closely associated with “*industrial ecology*”: the idea that industrial processes can operate like functioning ecosystems where wastes from one industry become feedstocks for others. Most fundamentally, environmental LCA is a framework for measuring the environmental consequences of economic or industrial decisions to improve management of economic and environmental resources. *EESI will explore LCA and industrial ecology to promote collaborations among physical and social scientists seeking to understand how human and environmental systems will change in the Anthropocene.*

Over the last few decades, LCA has become increasingly popular due to funding from agencies such as the DOE, the Federal Aviation Administration, and the U.S. Department of Agriculture, all of which utilize life-cycle cost assessments for new engineered systems. For example, LCA is now playing a prominent role in the debate over the environmental impacts of unconventional natural gas extraction.

EESI and Penn State are well known for basic-science research. However, very little LCA work is completed at Penn State. To increase the impact of EESI environmental science, EESI will allocate strategic resources to build environmental LCA capability within EMS. This effort will emphasize a systems approach that integrates understanding of earth and atmospheric systems, economic drivers, and engineered products and processes.

This nexus between earth, engineered and economic systems is an area where EMS could become the leading institution in the world. The department of EME has long positioned itself as a locus of research aimed at understanding the environmental impact of extractive industries. Academic researchers active in LCA typically identify with the fields of industrial ecology (or ecology more broadly); engineering systems; civil/environmental engineering; or public policy. Likely departmental fits for foci in LCA therefore include EME, Geography, and Meteorology. If partnerships in funding can be forged, EESI will initiate efforts to hire faculty in the area of environmental LCA or industrial ecology. Likely partners for this effort could include the department of EME, the Rock Ethics Institute or PSIEE.

More broadly, EESI will promote industrial ecology — the study of how material fluxes within industry can be like an ecosystem. In this regard, EESI will consider working with EME and the Material Science and Engineering departments to promote state-of-the-art *green engineering* with an emphasis on cradle-to-grave systems thinking. For example, EESI could provide release funds to allow EESI faculty to work with faculty in Materials Science or Energy and Mining Engineering to team-teach freshman seminars, capstone classes for undergraduates, or graduate classes on topics related to industrial ecology.

Possible outcomes: faculty hiring, teams of faculty who teach freshman seminars or graduate courses in industrial ecology or LCA, an EarthTalks seminar series in LCA or industrial ecology.

3. EESI Will Explore Online Graduate Education Opportunities in the Environmental Sciences

Online courses are proliferating in form and purpose and content. One area of online education that has not received as much attention is graduate education. *EESI will teach environmental students in more engaging ways using new online approaches to create new opportunities.*

EESI will initiate efforts to explore the interface between research and online education — especially upper level undergraduate or graduate education. Some of Penn State's most successful online courses are aimed at using online tools such as geographic information systems. In a similar vein, EESI will explore how to place environmental modeling expertise online. Such education could have any of a number of forms: a semester-long online course, a one-credit module, or videos on YouTube or other venues. To implement these ideas, EESI could fund a postdoctoral associate to work for a year with an EESI associate to put a modeling course on line. Of especial importance would be courses that teach approaches that cross disciplines. EESI's niche could be to inaugurate these courses; the developer would then be in charge of maintaining and growing the course into the future. EESI could also put together a description of a set of tools, techniques, and approaches that describe how one develops an online course.

As an example, a group of faculty have already proposed a set of four courses that could form an online Water Resources Modelling Certificate. This might be a stepping stone toward efforts to develop an inter-college online Professional Master's degree in Water Resources. EESI could help by providing salary funding, release funding, or funding for someone from the John A. Dutton e-Education Institute to help in this endeavor.

Another way to implement these ideas might be for EESI to establish *EESI Online Scholars* — these graduate students in Meteorology, Geosciences, Geography, or EME would receive funds to work as interns in the Dutton Institute on environmental coursework.

Possible outcomes: online courses, modules, or videos in environmental modelling, a description of approaches for developing an online course, better understanding of how graduate research can be impacted by online opportunities, *EESI Online Scholars*

4. EESI Will Promote the Environmental Instrumentation Infrastructure

With PSIEE, EESI helped initiate the *Energy and Environmental Sustainability Laboratory* (EESL) to provide shared instrumentation and technical support for environmental analytical capabilities. EESL, a scaffolding designed to promote interdisciplinary environmental research and education campus-wide, will consist of several sub-facilities located around campus. *EESI will promote the growth of shared environmental instrumentation and technical support for Penn State researchers.*

The first laboratory within EESL for EMS, the *Laboratory for Isotopes and Metals in the Environment* (LIME), was funded by PSIEE to house three mass spectrometers and one spectrophotometer for chemical analysis. LIME will now be grown as one of several facilities within EESL. Ideas to grow EESL include i) investigating whether deployable instruments could be part of the initiative; ii) exploring how technical support can be maintained; iii) learning to promote education and research together; iv) exploring models for choosing shared-use instrumentation and facilities so as to promote research and education campus-wide; v) developing an “instrument trust fund” for maintenance of instruments. EESL will have large needs in terms of space and personnel.

An initial committee of cross-campus scientists (T. Richard, T. Bralower, K. Freeman, D. Kennett, M. Fantle, J. Stapleton, L. Kump, J. Kaye, C. Gorski, C. House, and Z. Karpyn) worked with EESI director Brantley to identify instruments to be purchased to grow EESL during 2014-2015. The committee defined the values underlying the EESL effort as follows:

- *to enable exciting and important environmental research in an environment that places student education at the center*
- *to reward past excellence in environmental research and teamwork as a harbinger of future success*
- *to make the whole better than the individual sum of the parts*
- *to promote both new ideas and conventional approaches*
- *to share instrumentation and technical support to keep costs down*
- *to reward those who have sought funding*
- *to target both big-ticket and low-cost instrumentation*
- *to create an open and fair process of instrumentation purchase and support*
- *to nurture junior faculty and faculty from under-represented groups in environmental science*
- *to invest in infrastructure that focuses on our current niche as well as to grow new niches*
- *to retain and attract the best talent possible*

The new instruments that will be implemented in EESL during late 2014 include: i) a thermal ionization mass spectrometer; ii) a laser ablation sample introduction unit; iii) an accelerator mass spectrometer; iv) a computer enhanced tomography analyzer; v) a gas chromatograph – mass spectrometer; and vi) an electron microprobe.

In the next five years, EESI will promote the growth of EESL, lead in promoting new purchases, and pursue new methods to fund and support this facility. EESI will also work to promote technical support faculty to enable utilization of the EESL instrumentation campus-wide. In addition, EESI will consider partnering with the Department of Materials Science and Engineering and Materials Characterization Laboratory to provide new hands-on courses that enable use of instrumentation. For example, such classes could pair two faculty from different disciplines to teach techniques, promoting the use, for example, of isotope measurements in material science along with surface analysis in environmental science. Similarly, EESI could promote the development of freshman seminars taught by cross-disciplinary teams of

professors derived from different departments (e.g. Materials Engineering and Geography).

Possible outcomes: campus-wide understanding of the needs and utility for shared instrumentation and technical support, access to state-of-the-art instrumentation, growth in sharing of instrumentation, promotion of new classes for hands-on use of instrumentation .

5. EESI Will Promote the Use of New Cyber-infrastructure, Sensors, and Big Data

With the growth of opportunities in cyber-infrastructure, sensors in the environment, and “Big Data,” EESI must be strategic in helping associates target data-rich and collaborative opportunities. *EESI will explore and teach new ways to collect, use, and model rich and vast datasets to understand earth systems.*

Some EESI scientists already use huge datasets or new cyber-infrastructures to model their data or promote their collaborations. In the future, even environmental scientists who have commonly used small sets of data or who do not collaborate using cyber-infrastructure will find new opportunities to use larger datasets for research collaborations. EESI is seeking ways to facilitate growth in usage of such “Big Data” and promote such opportunities. One specific opportunity is related to the exploding growth in use of environmental sensors: EESI will seek ways to help associates develop, explore, and use sensors in environmental systems. An “*EarthSense Initiative*” could be developed to provide funds for partnerships among material scientists, engineers, and environmental scientists.

In addition, funding agencies such as the National Science Foundation, NASA, and many others are now requiring formal data management plans for their funded projects. As a strategic and important step to aid associates and affiliates, EESI has helped associates and affiliates learn about the resources available through the Penn State Data Commons. EESI started this process of education through Brown Bags during 2013/2014 in an attempt to bridge the gap among computer scientists, domain scientists, and the Data Commons. The Data Commons already provides hundreds of easily accessible datasets.

Two specific personnel needs have been articulated in this general arena. The first is the need for an information science specialist who could interface between computer scientists and domain scientists, with a special focus on climate science. EESI could take the lead in identifying and hiring such a person, possibly in collaboration with other institutes or departments. The second need is for a person who could support EESI associates and affiliates in meeting data management requirements or data mining and manipulation opportunities. Such an individual would likely have a background in environmental science as well as computing infrastructure and technique. This information specialist would have broad knowledge and experience in data management, automated data processing, databases, and software programs such as Geographic Information Systems as well as a background in scientific programming and temporal data management. This individual could assist EESI associates and affiliates in organizing, documenting and exploring their data — as well as making data available for further scientific research and public access.

Possible outcomes: seminar or brown bag seminar series to promote management of data and utilization of Big Data or in the use of new cyberinfrastructures, hiring of two support staff with skills in the interface between environmental data and models / computer science.

6. EESI Will Promote Diversity

The percentage of undergraduate students from the U.S.A. derived from under-represented groups in EMS rose from 6.5% in 2008 to 13% in 2013 — high quality students are entering EMS fields from under-represented groups. Currently, more than 100 students from under-represented groups are matriculated as undergraduates in EMS. *EESI will work with departments and the College to attract a diverse set of students and faculty into the environmental sciences.*

The most likely points where EESI could impact the diversity of the graduate student pool in environmental sciences is i) at the point of making offers and ii) by promoting efforts to broaden the diversity of environmental faculty. The goal of diversity is embedded in the concept of an “EESI hire” as described above. The essential features of an EESI hire include advertising broadly and hiring junior scientists, both of which have been shown to result in increased diversity. EESI could also consider other funding collaborations with individual departments to enable hiring of diverse faculty as appropriate. In addition to hiring, EESI will consider targeting up to 1/3 of its graduate assistantships toward students from under-represented groups in the environmental sciences within EMS. This could result in development of a new norm where graduate programs could count on EESI to allocate research assistantships for students derived from under-represented groups.

Other areas of this strategic plan could also be used to benefit diversity initiatives. For example, if faculty pursued inter-university affiliations, online graduate education modules could be developed and promoted for minority-serving institutions as well as for Penn State students.

Possible outcomes: broader environmental searches targeting junior candidates, an increase in diversity of environmental scientists in EESI and EMS, research assistantships allocated for students derived from under-represented groups.

7. EESI Will Promote a Home for a University-wide Center in Climate Risk Management

Identifying sustainable, scientifically sound, technologically feasible, economically efficient, and ethically defensible strategies for managing risk in a world marked by anthropogenic climate change is of the highest strategic priority. *EESI will promote a stable University-wide center in climate risk management.*

Projecting climate change and its associated impacts has long been an area of strength for EESI scientists. This topic is also a focus of increasing interest across the University. EESI currently hosts CLIMA, the Center for Climate Risk Management, as well as SCRiM, the Network for Sustainable Climate Risk Management. CLIMA is an EESI center that competes for funding every three years; SCRiM is a five-year Sustainability Research Network funded by the National Science Foundation. This research area is extremely strong at Penn State, growing rapidly, and requires a more stable and enduring home. EESI will explore how to provide such a home through the establishment of a new, permanent center for climate risk management that can catalyze the necessary interactions and collaborations among climate researchers on campus and beyond.

Through this effort, EESI will promote an internationally-recognized center of excellence in climate risk management. A key part of this effort will involve hiring experts who are producing, analyzing, and communicating decision-relevant climate information. Possible research topics in this area include downscaling and regional-scale uncertainty quantification. Work in this area will provide expanded resources for climate researchers at Penn State and will open many new opportunities for engagement with stakeholders and decision-makers.

Possible outcomes: a more enduring model for a campus-wide center in climate risk management.

8. EESI Will Promote Interactive Science Communication

We are increasingly surrounded by information. The trick now is finding the *right information*. Scientists provide good and trustworthy information, yet it has become increasingly difficult to get attention from decision-makers for excellent science because of the cacophony of information streams. *EESI will learn and teach better approaches for inter-communication among scientists, non-scientists and environmental decision-makers.*

Within the last five years, EESI hired a science writer to promote the message of EESI scientists. This EESI writer became acutely aware of the needs and constraints on newspaper reporting where most newspapers have cut back on personnel, including those with scientific expertise. In this context, EESI explored new approaches to provide scientific content to newspapers. EESI also developed EESI Twitter and Facebook accounts. Furthermore, EESI initiated a “*swat team*” approach that allowed groups of EESI scientists to respond quickly to newspaper articles or letters to the editor. This team approach helped busy EESI faculty respond quickly. Most of these initial efforts have focused on climate science. Only a few, as yet, have been in national media.

In the next five years, this effort will be promoted so that swat teams i) will include scientists working outside climate science, ii) will impact national media outlets, iii) will become more nimble, and iv) will become more organized and less *ad hoc*. These steps will include developing several EESI thematic teams in trending areas. With these teams, we will become agile in providing topical coverage to media outlets with broader audiences. In addition, EESI will convene focus groups of faculty to discuss how to establish a systematic and impactful approach that helps faculty efficiently channel information about their work to EESI writers for the EESI website and other media outlets.

EESI will also promote science communication with workshops, outside speakers, or funded visits for high-profile media specialists. Examples of previous efforts include a visit by a science reporter for National Public Radio and a media training workshop for EESI faculty associates. An expanded workshop — covering basics of science communications as well as communication to policy makers — is planned for fall 2014. These efforts could also be extended to graduate students. For example, EESI could look into developing a seminar for graduate students to learn to write and discuss their work with a general audience. The seminar could be an optional stand-alone workshop or could be a new class or module. These efforts could reach across units in the College. Part of the course work could also emphasize professional ethics.

EESI will also consider running EarthTalks as a series targeting decision making theory or integrated assessment approaches in the environmental sciences. Such a series could aim at the chasm that sometimes exists between physical scientists, social scientists, and decision-makers. EESI could work with partners across campus to identify when policy makers and decision makers will be on campus so that we can schedule these EarthTalks at the convenience of visitors.

In a more exploratory vein, EESI could promote opportunities at the science-art nexus. To promote this interface, a “*PennStateCreate*” event could be inaugurated that would attract national caliber artists exploring the boundaries of art and science and would showcase student and faculty science and engineering in the context of data sonification, science performance art, or art as an investigative tool.

Possible outcomes: development of the communication skills of EESI associates and environmental scientists within EMS, swat teams of environmental writers, use of new

social media to communicate science, science communication workshops and seminars, stronger relationships among EESI faculty and staff and media outlets, graduate classes or modules in science communication, seminar series promoting communication, a PSU science-art festival

Implementation

Many of the initiatives described in this document could require million dollar investments. At this time EESI does not have this kind of funding structure. Therefore, the ideas in this document will require partnerships with departments, institutes, or other entities within the University, or will require awards of extramural funding. Nonetheless, this document describes a vision for the future. We welcome all EESI associates and affiliates to make proposals to EESI and to help EESI forge partnerships across the University or beyond to grasp these exciting opportunities.