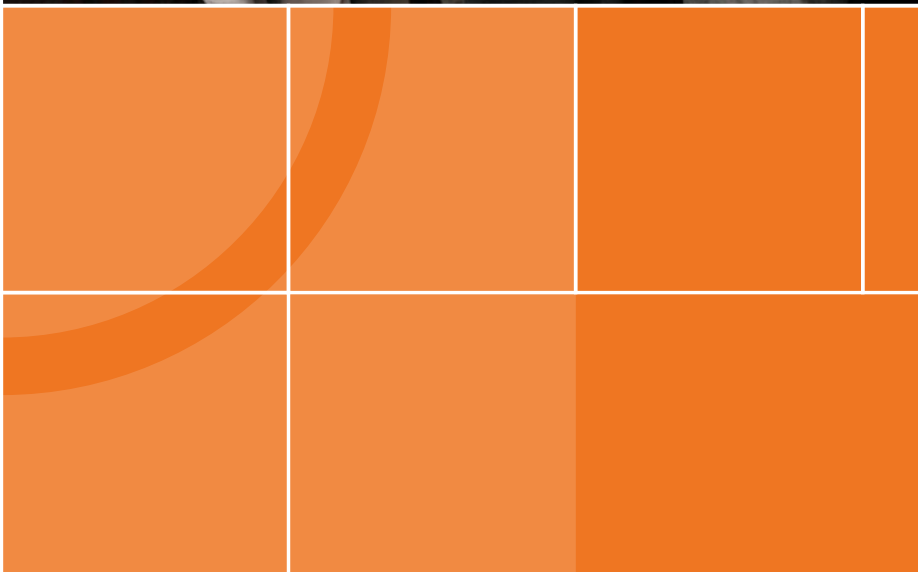
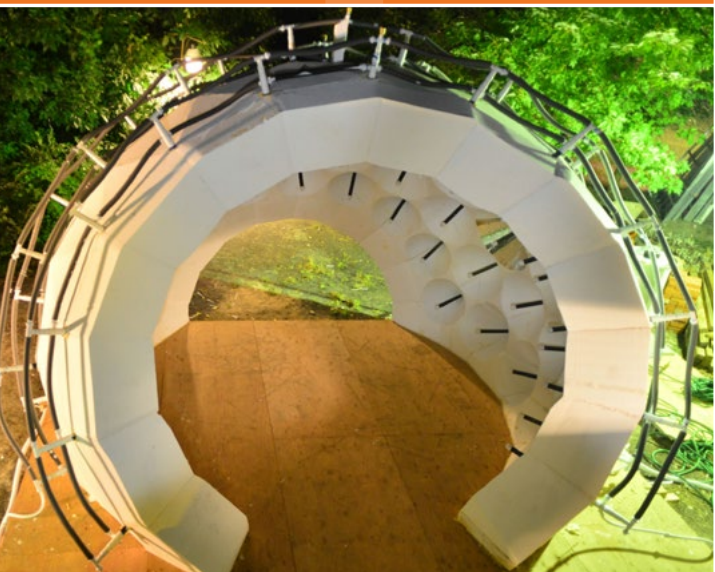
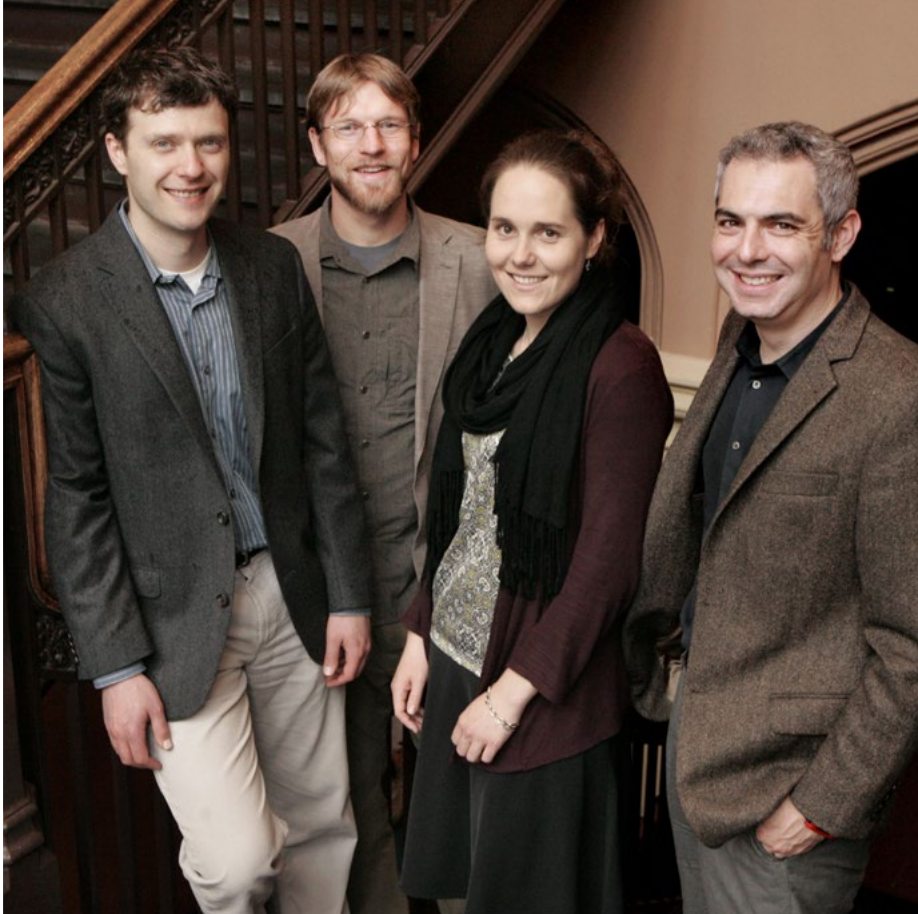


annual report

academic year
2013 - 2014



andlinger center
for energy + the environment



Emily Carter
Founding Director

I see positive differences made by the Andlinger Center for Energy and the Environment nearly every day. I'd like to tell one story here that exemplifies the excitement I feel. Each spring the center asks faculty members to propose research for center funding, and this year we issued the call jointly with the Princeton Environmental Institute. Among the many excellent proposals, one was jointly submitted by all four of the center's recently hired junior faculty members. In entirely different fields – mechanical, electrical, and civil engineering, plus architecture – these four outstanding young researchers came to know each other because of the Andlinger Center and spontaneously found common interests. With their Andlinger funding, the four will design long-life, low-cost, and low-carbon-foot-print structures that derive multiple functions from single components (page 8). So much of our mission is captured here: to build a vibrant, cross-disciplinary community of researchers and provide them the support needed to make real progress in solving problems of energy and the environment. Throughout this report, you will find many more examples of the center's impact – not only providing technological solutions, but also becoming a trusted source of expertise and preparing future leaders.

The crucial work of bringing together and supporting top people extends to our students. We were thrilled in June to graduate the first recipient of the Program in Technology and Society, Energy Track certificate. This certificate program (page 6), administered jointly with Princeton's Keller Center, gives students a grounding in the crucial connections between energy technologies and society. At the same time, we continue to fund undergraduate internships and projects and to support graduate fellows. These students are in many ways the center's most valuable "product." We immerse talented people in a culture of high-impact, cross-disciplinary research and send them out as new leaders across many fields.

Our educational efforts go beyond FitzRandolph Gate. In June 2014, we launched the first Energy Technology Distillate, a series of broadly accessible briefs on emerging energy technologies (page 9), couched within economic, policy, and environmental contexts. The first is on grid-scale electricity storage and its potential role in enabling renewable energy.

As all these endeavors proceed, we are working feverishly to finish construction and logistics for moving into our new home – the spectacular 129,000 square feet of laboratory, classroom, and office spaces taking shape at the corner of Olden and Prospect Streets (page 15). My colleagues and I have no doubt this amazing building, due for completion in the summer of 2015, will accelerate our work many times over.

The building also affords me an opportunity to issue an invitation: Come see us. We will host celebratory events next academic year, but in the meantime please come to our seminars, collaborate through our Princeton E-affiliates Partnership, and work with our students. Solving problems of energy and the environment takes not just a village but collaborations among all of us.

Emily Carter
Founding Director

mission and goals

to develop solutions to ensure our energy and environmental future

With opportunities and needs in almost every aspect of the center's work, we use these goals to influence our decisions and focus our attention on activities that support our goals.

foster a vibrant, intellectual community that engages people from many academic disciplines

accelerate innovative multidisciplinary research through funding, infrastructure, and intellectual discourse

train the next generation of leaders by educating students in their own disciplines and in a broader context

partner with industry, not-for-profit, and government to reach practical technology and policy solutions

become *the* center that the U.S. government turns to for information and advice



Forrest Meggers

Faculty Appointments

The Andlinger Center for Energy and the Environment expanded its junior faculty ranks to four assistant professors during the 2013–2014 academic year. Assistant Professors **Daniel Steingart**, **Barry Rand**, and **Claire White** were joined by **Forrest Meggers**, following a worldwide search conducted in 2013 jointly with the School of Architecture. Andlinger Visiting Professor **Michael Schwartz** spent a second year with us, contributing to our teaching and the Energy Technology Distillates project.

Forrest Meggers began on February 1, 2014 as assistant professor of architecture and the Andlinger Center for Energy and the Environment. He was previously an assistant professor in the School of Design and Environment at the National University of Singapore. Meggers earned an M.S. in environmental engineering from the University of Iowa and a Dr. Sc. with a specialization in building systems from ETH Zurich. Forrest quickly became engaged in the center's work. In the spring semester, he offered a new 200-level undergraduate course focused on the design of sustainable building systems, and in May he organized a symposium exploring architectural technology, entitled *Backwards+Forwards: The history and future of technical research in architecture and buildings at Princeton*.

ACEE Faculty News

During his first academic year at Princeton, **Barry Rand** was selected to receive a 3M non-tenured faculty award for his research studying the optical and electronic properties of ultrasmall metal nanoclusters (diameters less than 2 nanometers) that act as emitters within thin film light emitting devices (LEDs). Rand began as an assistant professor of electrical engineering and the Andlinger Center for Energy and the Environment on July 1, 2013. He has already garnered two Department of Energy grants, one from Basic Energy Sciences exploring the impact of local environment on charge transfer states at molecular donor-acceptor heterojunctions, and another from the Office of Energy Efficiency and Renewable Energy developing indium-tin-oxide-free white organic LEDs on flexible substrates with enhanced light outcoupling. Rand also served as academic advisor to undergraduate students enrolled in the Program in Technology and Society, Energy Track.

Daniel Steingart, assistant professor of mechanical and aerospace engineering and the Andlinger Center for Energy and the Environment, was awarded a grant through the Department of Energy's Advanced Research Projects Agency-Energy. Together with collaborators at Brookhaven National Laboratory, Georgia Institute of Technology, and the University of California-San Diego, Steingart is developing unique alkaline battery chemistry for use in electric vehicles (EVs). This new technology uses abundant and inexpensive materials structured to enable longer battery cycle life. If successful, the new alkaline chemistry could result in low-cost EV batteries that require minimal shielding and packaging. Dan also contributed to our inaugural Energy Technology Distillate, *Grid Scale Electricity Storage: Implications for Renewable Energy* (page 9), and conceived, organized, and hosted the first E-filiates Partnership Retreat, a closed meeting with the aim of fostering strong connections among students, postdoctoral researchers, faculty, and E-filiates corporate partners.

Claire White successfully launched her Princeton research lab and secured research funding through the National Science Foundation for a project that centers on the creation of sustainable cements with superior resistance to sulfate attack. White, appointed assistant professor of civil and environmental engineering and Andlinger Center for Energy and the Environment in August 2013, also led Andlinger Center efforts to bring high school students into research labs for a summer learning experience through the Laboratory Learning Program, featured in the news story “High school students embark on scientific journeys through Princeton summer program.” <http://www.princeton.edu/main/news/archive/S40/80/41198/index.xml?section=featured>

Michael Schwartz, CEO of New Wave Energy Capital Partners and former Senior Vice President of Commercial Policy, Strategy, and Strategic Initiatives at Duke Energy, was reappointed for academic year 2013–14 as the Gerhard R. Andlinger Visiting Professor in Energy and the Environment. Schwartz continued teaching graduate and undergraduate courses including two new courses he developed for the center. Mike’s valuable insights into the industrial sector brought a unique perspective to our inaugural Energy Technology Distillate.

Andlinger Center Associated Faculty Selected Awards and Honors

Emily Carter – 2014 Remsen Award from the American Chemical Society Maryland Section; 2014 Linnett Visiting Professor of Chemistry, University of Cambridge; 2013 Hoyt C. Hottel Lecturer in Chemical Engineering, Massachusetts Institute of Technology; Mathematics of Planet Earth 2013 Simons Public Lecturer; Sigillo D’Oro (Golden Sigillum) Medal, Italian Chemical Society

Michael Celia – Honorary Membership, International Society for Porous Media

Paul Chirik – Closs Lecturer, University of Chicago

Pablo Debenedetti – Elected Fellow of the American Institute of Chemical Engineers; Benjamin Garver Lamme Award, American Society for Engineering Education

Claire Gmachl – Distinguished Teaching Award, School of Engineering and Applied Science; Princeton University President’s Award for Distinguished Teaching; Top-cited Paper Award, *Chemical Physics Letters*

Niraj Jha – Distinguished Alumnus Award from the Indian Institute of Technology, Kharagpur, India

Stephen Pacala – Presidential Award from the American Society of Naturalists; Best Theory Paper of the Year Award from the Ecological Society of America; British Ecological Society Honorary Award; Appointed Lifetime Fellow of the Ecological Society of America

H. Vincent Poor – Elected Fellow of the Royal Society of Edinburgh

Barry Rand – 3M Non-tenured Faculty Award

Robert Socolow – Elected Fellow of the American Academy of Arts and Sciences

Daniel Steingart – Xerox University Affairs Committee Award

Claire White – Keynote Speaker, Goldschmidt Conference



José Avalos



Egemen Kolemen



Fabian Wagner



Sander van der Linden

Recruiting

With two successful junior faculty searches in 2013–2014, the Andlinger Center achieved one of its major strategic goals ahead of target: to recruit six joint junior faculty members. A joint search with the Department of Chemical and Biological Engineering resulted in the recruitment of **José Avalos**. Avalos, whose research focuses on synthetic biology and metabolic engineering for the production of biofuels and bio-derived chemicals, joins the faculty as an assistant professor on November 1, 2014. He was previously a postdoctoral researcher in the Department of Chemical Engineering at the Massachusetts Institute of Technology, where he was a recipient of a National Institutes of Health Ruth L. Kirschstein National Research Service Award. Avalos earned a B.S.E. in chemical engineering and biotechnology at the Universidad Iberoamericana in Mexico, a M.Sc. in biochemical research from Imperial College, and a Ph.D. in biochemistry, cellular, and molecular biology from the Johns Hopkins School of Medicine.

A second search, jointly conducted with the Department of Mechanical and Aerospace Engineering and the Princeton Plasma Physics Laboratory (PPPL), concluded with the hiring of **Egemen Kolemen**, a specialist in the field of control of fusion plasmas. Kolemen joined the faculty on September 1, 2014. He was previously employed through PPPL as a research scientist stationed at the DIII-D Tokamak at General Atomics in San Diego. He received a B.S. in mechanical engineering from Bogazici University in Istanbul and a Ph.D. in mechanical and aerospace engineering from Princeton University.

In addition to our junior faculty searches, we opened a search joint with the Woodrow Wilson School of Public and International Affairs for a visiting senior scholar in the field of energy and public policy. The search resulted in the appointment of **Fabian Wagner** as the Gerhard R. Andlinger Visiting Professor in Energy and the Environment in August 2014. Wagner is a senior research scholar at the International Institute for Applied Systems Analysis in Austria, where he leads the Mitigation of Air Pollution and Greenhouse Gases Program. He will share his expertise in energy systems modeling and international energy policy, collaborating with faculty and students on research and teaching three courses during the 2014–2015 academic year, including a new graduate course on international environmental conventions and science support.

Finally, the Andlinger Center welcomed its first postdoctoral appointee. **Sander van der Linden**, appointed on September 1, 2014, as a postdoctoral research associate in the Woodrow Wilson School of Public and International Affairs and the Andlinger Center for Energy and the Environment, focuses his research on behavioral issues in energy and the environment. van der Linden previously held a visiting research scholar appointment at the Yale Project on Climate Change Communication. He earned a B.A.Sc. in management studies from the School of Economics and Management at the University of Amsterdam, a M.Sc. in public policy and human development from Maastricht University and the United Nations University in the Netherlands, and a Ph.D. in social and environmental psychology from the London School of Economics and Political Science. van der Linden has been hired in a joint effort between the Andlinger Center for Energy and the Environment, the Department of Psychology, and the Woodrow Wilson School, to conduct research and teach on the topics of behavior and decision-making regarding energy and sustainability.

Internship Recipients and Faculty Advisors

Summer 2014

Melina Acevedo '16

(Andrew B. Bocarsly, Chemistry)

Lucas Amber '15

(Daniel A. Steingart, Mechanical and Aerospace Engineering and the Andlinger Center for Energy and the Environment)

Sean Coffers '15

(Forrest M. Meggers, School of Architecture and the Andlinger Center for Energy and the Environment)

Margaret Cutlip '16

(Yueh-Lin (Lynn) Loo, Chemical and Biological Engineering)

Jimin Hong '15

(Michael E. Mueller, Mechanical and Aerospace Engineering)

Carl Nist-Lund '15

(Craig B. Arnold, Mechanical and Aerospace Engineering)

Francis Ricci '15

(Emily A. Carter, Mechanical and Aerospace Engineering, Applied and Computational Mathematics, and the Andlinger Center for Energy and the Environment)

The Andlinger Center's educational activities continue to grow under the direction of **Niraj Jha**, associate director for education. The Energy Track of the Program in Technology and Society, run jointly by the Andlinger Center and Princeton University's Keller Center, was launched in Spring 2013. During the past academic year it began to flourish, garnering interest from 33 undergraduate students. There are now 48 courses from which humanities and social science students, along with students studying engineering and the natural sciences, can learn about energy technologies, engineering approaches to energy and environmental challenges, and the societal and environmental implications of such technologies. In June, the first program certificate was awarded to **Margaret Bertasi**, a senior graduating with an A.B. in history. Her culminating work presented to program students and faculty at the Program in Technology and Society symposium was entitled "The Environmental Effects and Societal Changes from Coal Use in 19th Century Britain." The parallels between the *visible*, coal-induced air pollution that spawned the U.K. environmental movement over 100 years ago and today's *invisible*, fossil-fuel-induced carbon dioxide emissions was spine-tingling for those in the audience.

The Andlinger Center also offers undergraduate and graduate level courses under the ENE subject code. There are currently 28 ENE courses: 23 undergraduate and five graduate courses. The center introduced several new courses last year. **Michael Schwartz**, the Gerhard R. Andlinger Visiting Professor in Energy and the Environment, introduced two new courses, ENE 558: *U.S. Shale Gas and Tight Oil: Implications and Opportunities* in the fall and ENE 587: *Managing the Transition to a Clean Energy Economy: Renewable Power in the U.S.* These courses had respective enrollments of 29 and 18, quite high for elective graduate courses. This past spring, **Forrest Meggers**, assistant professor of architecture and the Andlinger Center for Energy and the Environment, presented his new course, ENE 202: *Designing Sustainable Systems: Applying the Science of Sustainability to Address Global Change*, to 33 undergraduate students. Andlinger Center faculty also offered ENE cross-listed courses within their home departments. **Barry Rand**, assistant professor of electrical engineering and the Andlinger Center for Energy and the Environment, developed and taught a new graduate class, ELE 557/ENE 557: *Solar Cells: Physics, Materials, and Technology*. **Daniel Steingart**, assistant professor of mechanical and aerospace engineering and the Andlinger Center for Energy and the Environment, taught MAE 221/ENE 221: *Thermodynamics*.

The **Peter B. Lewis Fund for Student Innovation in Energy and the Environment** and the **Dede T. Bartlett P03 Fund for Student Research in Energy and the Environment** support summer internships for undergraduates. Recipients perform research on campus for a minimum of eight weeks under the guidance of faculty advisors and receive stipends and funds for research expenses. In the summer of 2014, seven students received more than \$50,000 in stipends and funds for research materials and supplies. The students come from departments within and beyond the School of Engineering and Applied Science and their research projects span a range of topics, including investigations into: bismuth as an electrocatalyst for carbon dioxide reduction, hybrid electric vehicle batteries, geothermal wells in the Princeton area, organic solar cell efficiency, modeling soot, magnesium-ion batteries, and development of software to compute biofuel thermochemical kinetics. More information about these innovative student projects is available on the center's website at <http://acee.princeton.edu/news/2014-undergraduate-interns>.

Maeder Graduate Fellowship Recipients

2013-2014 Academic Year

Warren Rieutort-Louis

(Sigurd Wagner, Electrical Engineering)

2014-2015 Academic Year

Janam Jhaveri

(James C. Sturm, Electrical Engineering, Princeton Institute for the Science and Technology of Materials)

Jennifer Obligation

(Paul J. Chirik, Chemistry)

The **Maeder Graduate Fellowship in Energy and the Environment** supported **Warren Rieutort-Louis** in 2013–2014. Rieutort-Louis is earning his Ph.D. in the Department of Electrical Engineering and spent the year continuing his research on solar-powered, mechanically-flexible electronic skins based on thin films of semiconducting materials that can cover large surfaces. This past spring a committee selected the next Maeder recipients from a competitive pool of applicants: **Janam Jhaveri**, a graduate student in the Department of Electrical Engineering, and **Jennifer Obligation**, a graduate student in the Department of Chemistry. Information about the fellowship and these recipients can be found at <http://acee.princeton.edu/news/maeder-2014>.

Other Activities

The Andlinger Center also distributed funds to the university's Pace Center for Civic Engagement for a sustainable solar energy service project, Science Action's video program, and Global China Connection's student conference. In April of 2014, in partnership with the Office of the Dean for Research, the Office of the Dean of the College, the Princeton Environmental Institute, and the Office of Sustainability, a new Campus as a Lab program was launched with a request for proposals aimed at campus-based sustainability, energy, and environmental projects that offer another mechanism for undergraduate and graduate student research training.



Students in the course *Materials in Civil Engineering* study a model of the Andlinger Center during a construction site tour.



High school students from Princeton University's Laboratory Learning Program work on designs aimed at reducing the energy required for cooling and heating.

Photo by Denise Applewhite

Seed Funding

The Andlinger Center awards internal funds to catalyze and support faculty and student research aimed at solving a broad range of energy and environmental problems. Under the leadership of **Peter Jaffé**, the center's associate director for research, applications are peer-reviewed and competitively distributed to spur collaboration among faculty members from different departments and disciplines, recognizing that the challenges we face require teams with diverse expertise, perspectives, and ideas. These funds fostered a wide variety of new research directions in 2013–2014.

This past year the Andlinger Center for Energy and the Environment and the Princeton Environmental Institute partnered to issue a joint call for proposals to fund projects that foster innovative research, teaching, and mentorship in energy and the environment. The collaboration allowed both units to reach a wider audience and provide more funding than either could alone. The Andlinger Center awarded five interdisciplinary projects up to \$100,000 each.

- Professors **Daniel Steingart**, **Marcus Hultmark**, and **Michael Mueller** are developing new electrochemical technologies used in energy storage systems such as batteries
- Professors **Forrest Meggers**, **Sigrid Adriaenssens**, **Elie Bou-Zeid**, **Claire Gmachl**, and **George Scherer** are leading a group of architecture and engineering students to design and construct a novel outdoor pavilion that will provide a cool space without air conditioning
- ACEE faculty **Daniel Steingart**, **Forrest Meggers**, **Barry Rand**, and **Claire White** are experimenting with the design of long-life, low-cost, and low-carbon-footprint structures which derive multiple functions from single components
- Professors **Claire White** and **Sankaran Sundaresan** are researching methods for engineering tiny particles that maintain nanosized fracture openings created during oil and gas hydrofracturing processes
- Professors **David Medvigy**, **Ignacio Rodríguez-Iturbe**, and senior climate modeler **Elena Shevliakova** are researching and modeling potential ecological services provided by seasonally dry tropical forests

Funding was provided by the **Addy/ISN North American Low Carbon Emission Self-Sufficiency Fund**, the **Andlinger Center for Energy and the Environment Director's Fund**, the **Andlinger Innovation Fund**, the **Class of 1983 Fund for Energy and the Environment**, the **Nancy A. Curtin '79 and John Stafford Research Innovation Fund**, the **de Carvalho-Heineken Family Fund for Environmental Studies**, the **John Drzik '83 and Ann Thorsell '83 Fund for Innovation**, the **Parallax Fund for Energy and the Environment**, the **Renee and Mark F. Rockefeller '89 Fund for the Environment**, and the **Ruehl Family Fund for Energy and the Environment**. More information about the faculty teams and their work can be found on our website.

The *Intelligent Glazing for Intelligent Buildings* project began in 2013 and is ongoing. Professors **James Sturm**, **Naveen Verma**, and **Sigurd Wagner** are developing a building energy management system in which invisible light and temperature sensors and actuators are incorporated into window panes for self-powered operation and wireless communication. Funding for this project is provided by the **Andlinger Center for Energy and the Environment Director's Fund**.

Externally-Funded Sponsored Research Awards 2013–2014:

Emily A. Carter

Air Force Office of Scientific Research, “Unlocking Solar Water Splitting via Embedded Correlated Wavefunction Theory”

Department of Energy, “Quantum Mechanical Evaluation of CZTS Photovoltaic Materials”

National Science Foundation “Correlated Wavefunction Methods for Gas and Condensed Phases”

Guy Nordenson

Rockefeller Foundation, “New Directions in Coastal Resilient Design Strategies: Four Integrated Designs,” collaboration with City College of New York, Harvard University, and the University of Pennsylvania

Barry Rand

Department of Energy, “Exploring the Impact of the Local Environment on Charge Transfer States at Molecular Donor-Acceptor Heterojunctions,” collaboration with Pennsylvania State University

Department of Energy, “ITO-Free White OLEDs on Flexible Substrates with Enhanced Light Outcoupling”

Start-up funds allow new faculty to equip their labs, build their research programs, and support students and postdoctoral research associates. In 2013–2014, the Andlinger Center contributed more than \$228,000 to start-up funds for new junior faculty. Support for these funds came from the **Addy/ISN North American Low Carbon Emission Energy Self-Sufficiency Fund**, the **Andlinger Center for Energy and the Environment Director's Fund**, and the **Andlinger Innovation Fund**.

Water Innovation and Research Summit

The 2014 Water Innovation and Research Summit was co-hosted by **Peter Jaffé**, the Andlinger Center’s associate director for research, **David Langiulli**, director of corporate and foundation relations, **Rengarajan Ramesh**, managing director of Wasserstein & Company, and **Scott Bryan**, the chief operating officer of Imagine H₂O, a nonprofit organization whose mission is to spur the development of transformational technologies that solve water-related problems. Leaders from industry and academia met to discuss water infrastructure, the water-energy nexus, and industrial water. The event was aimed at forming long-term partnerships to apply research to real-world solutions. More information can be found in the news story “Princeton and Imagine H₂O Host Water Innovation and Research Summit.” <http://www.princeton.edu/engineering/news/archive/?id=13126>

Extramural Sponsored Research

While the Andlinger Center provides seed funding to promote and support faculty and student research in its beginning stages, the center’s faculty also seeks extramural research funding, including for projects that build on work previously seeded through ACEE. ACEE faculty members have had an unusually high success rate of 41 percent to date when competing for external grants. During the 2013–2014 academic year, faculty within the center brought in more than \$6.7 million through 11 new research grants. During the same period, 21 new proposals were submitted.

Energy Technology Distillates

One of the goals of the Andlinger Center is to become a leading source of reliable, timely information on energy and the environment for policymakers, corporate leaders, educators, students, and other interested citizens. We took a significant step toward achieving this goal in June 2014 with the publication of our first Energy Technology Distillate, *Grid-Scale Electricity Storage: Implications for Renewable Energy*. This first distillate is a collection of concise articles about electricity storage written for the interested non-expert, co-authored by expert faculty and researchers at Princeton, with Professor Emeritus **Robert Socolow** leading the effort. We will release additional distillates covering basic concepts, as well as technological, economic, environmental, and policy considerations associated with other emerging energy technologies, in the years to come. With this project the Andlinger Center is leveraging the wealth of expertise available to us through Princeton’s world-class faculty and researchers. It is our hope that by becoming a trusted source of information, the Andlinger Center can encourage collaboration among academia, government, industry, and other entities to facilitate the practical technology and policy solutions we need.

Externally-Funded Sponsored Research Awards 2013–2014 continued:

Daniel Steingart

Brookhaven National Laboratory, “Experimental Design and Software Development for In Situ Characterization in Alkaline or Flow-Assisted Electrochemical Energy Storage Systems”

Department of Energy, “Fast Aqueous Multiple Electron Ubiquitous Systems,” collaboration with Brookhaven National Laboratory, Georgia Institute of Technology, and University of California-San Diego

NASA, “Structural Batteries for Hybrid Electric Propulsion Systems” (transferred from City College of New York)

National Science Foundation, “GOALI: A Comparative Study of Electrochemical Codeposition with In Situ Electron Microscopy,” collaboration with IBM (transferred from City College of New York)

Claire White

National Science Foundation, “Sulfate Attack Mechanisms in Geopolymers: Measurements and Modeling at the Nanoscale”

Return on Investment

One way the Andlinger Center tracks the results of its efforts is to monitor the impact that seed funding has on future research activities. While not an inclusive list, the results from the previous year, described below, have been aggregated from submissions supplied by our award recipients since the start of our seed funding and student research programs. These funds are awarded to Princeton faculty, students, and researchers, who are then polled annually about the ways in which Andlinger Center funds resulted in projects, awards, publications, patent activity, post-graduate student activities, and collaborations.

Many of the awardees are continuing their research in spin-off projects, some with external funding. Andlinger funds have inspired proposals that have been funded by the National Science Foundation, the Department of Energy, ICL Industrial Products, Inc., and the National Research Council. Projects have also propelled Ph.D. research in carbon capture and storage and senior thesis work for which one student was awarded the Goudie senior thesis prize for outstanding work relating to energy and the environment.

Researchers have published results of their Andlinger-funded research in *AAAS Science*, *ACS Applied Materials & Interfaces*, *Proceedings of the Combustion Institute*, *Energies*, *Environmental Sciences: Processes and Impacts*, *Inorganic Chemistry*, *Journal of Heat Transfer*, *Nanoparticle Research*, *Optics Letters*, and *Physical Chemistry Chemical Physics*. Others have presented at conferences including the AGU 2014 Fall Meeting, AGU Science Policy Conference, AMS 31st Conference on Hurricanes and Tropical Meteorology, AGU 2013 Fall Meeting, AIAA Fluid Dynamics and Co-located Conferences, 19th Australasian Fluid Mechanics Conference, 67th Annual Meeting of the APS Division of Fluid Dynamics, 9th International Symposium on Turbulence and Shear Flow Phenomena, IASS Conference 2014, and 12th International Conference on Computational Structures Technology.

While many students and postdoctoral researchers supported by seed funds are still at Princeton, some have gone on to graduate school or to take positions in industry and academia. Undergraduates have joined graduate programs at Harvard University (Ph.D. in chemistry), Massachusetts Institute of Technology (one for an M.S. in transportation and one for a Ph.D. in chemistry with an NSF Graduate Research Fellowship), Northwestern University (Ph.D. in chemistry), The Ohio State University (M.S. in public health), Georgia Institute of Technology (Ph.D. in materials science and engineering), and the Colorado School of Mines (M.S. in Engineering). Undergraduates have also gone on to work at the Natural Resources Defense Council, Cardinal Scholars, Columbia University Medical Center, Crossix Solutions, and SunEdison. Graduate students and postdoctoral researchers have secured positions as assistant professors at Arizona State University (civil and environmental engineering), Texas Tech University (civil and environmental engineering), and Pennsylvania State University (statistics), and as research scholars at Massachusetts Institute of Technology (chemical engineering), the École des Ponts, Paris, the U.S. Naval Research Laboratory, and ExxonMobil.

Collaboration is a trademark of many of the Andlinger seed funding opportunities. Indeed, researchers have reported new partnerships with WhalePower Corporation, Gas Technology Institute, Bielefeld University, King Abdullah University of Science and Technology, University of Massachusetts-Dartmouth, National Wind Resource Center

Return on Investment
(since inception in 2011)

Total amount awarded:
\$3.4 million

Projects supported:
31 faculty, 24
undergraduate students,
and 4 graduate fellowships

Derivative funding:
More than \$2.8 million

Journal publications: 20

Journal articles under
review: 5

Conference presentations:
18

Patent disclosures and
applications: 2

at Texas Tech University, University of São Paulo, École des Ponts’ Laboratoire Navier, IBM, U.S. Naval Research Laboratory, Harvard China Project at Harvard University, Energy Research Institute at the National Development and Reform Commission in Beijing, Center for Earth System Science at Tsinghua University, International Institute of Advanced System Analysis in Austria, Peking University, and ICL Industrial Products, Inc. Many new interdepartmental and interdisciplinary collaborations within Princeton pair faculty and graduate students across every department in the School of Engineering and Applied Science, as well as the Department of Chemistry, and the School of Architecture.

2013–2014 Highlight Seminar Series

September 16

Jerald Schnoor, University of Iowa

Water Implications of Biofuels in the U.S.

October 14

Markus Pauly, University of California-Berkeley

Plant Biotechnology for Biofuels

November 11

Willett Kempton, University of Delaware

Running Society on Variable Generation: How Can We Optimize for High Reliability and Least Cost?

December 9

Menachem Elimelech, Yale University

Membrane-Based Processes at the Water-Energy Nexus

January 6

Bruce Logan, Penn State University

Microbial Fuel Cell and Reverse Electrodialysis Technologies for Renewable Power Generation from Biomass and Salinity Gradients

February 10

Benjamin Hobbs, Johns Hopkins University

Modeling Electricity Markets & Policy with Optimization: Why It’s Important (and Fun as Well)

March 10

Richard Sayre, New Mexico Consortium

Making Next Generation Biofuel Systems Work: It’s All in the Biomass

2013-14 Highlight Seminar Series continued

April 28

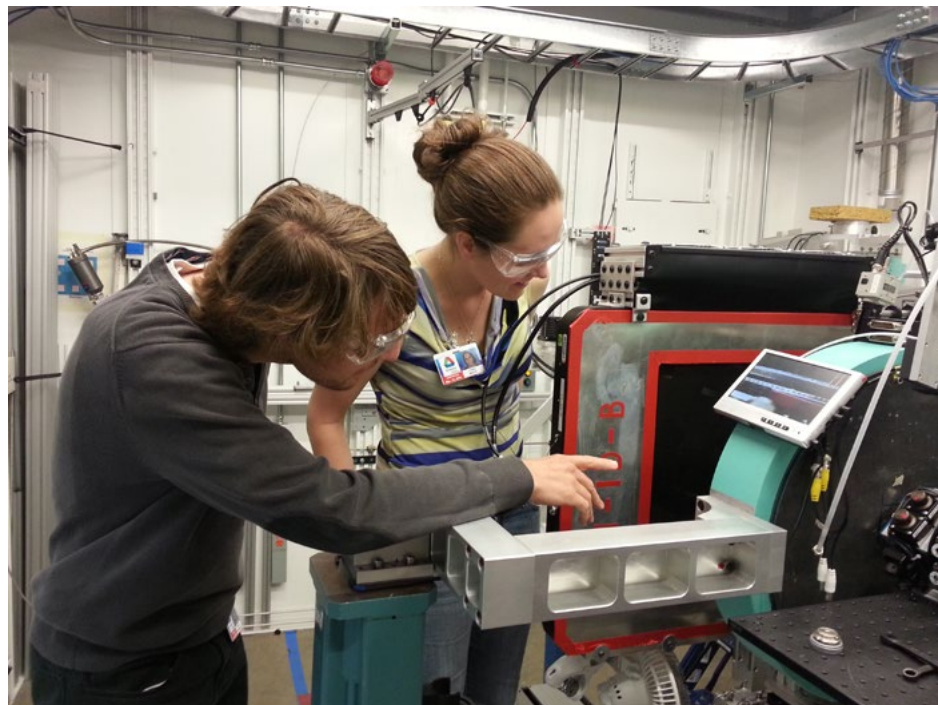
David Perreault, MIT

Powerful Circuits: Developments in High Frequency Power Electronics

May 12

Christine Shoemaker, Cornell University

Using Monitoring and Optimization for Managing Environmental Risks Including Applications to Geological Carbon Sequestration



Professor Claire White with a postdoctoral researcher at the Advanced Photon Source, Argonne National Laboratory.

Princeton E-filiates Partnership (E-filiates) aims to enhance collaboration and promote technology transfer between Princeton University and its corporate partners to address global energy needs and environmental concerns. The program is led by the Andlinger Center's associate director for external partnerships **Lynn Loo** and is supported by **Robin Hauer**, the assistant director, who manages its day-to-day activities. Power Survey Company and Southern Company are the most recent members, joining members PSEG, Inc., E.I. du Pont de Nemours and Company, Lockheed Martin Corporation, and Archewild.

The E-filiates second annual meeting was held on November 15, 2013. **Cheryl A. LaFleur '75**, then-commissioner of the Federal Energy Regulatory Commission, was the keynote speaker; she addressed the challenges and opportunities presented by the transformation of the nation's portfolio of generation resources before an audience of 150 people. The annual meeting included faculty presentations by Professors **Christodoulos Floudas**, **Ning Lin**, and **George Scherer**; a presentation by **Willem Rensink**, a member of the Shell GameChanger team that identifies and incubates revolutionary ideas to proof of concept; and panel discussions on emerging energy technologies and climate adaptation at the local and national levels. A poster session that featured more than 50 students and postdoctoral researchers was another highlight of the meeting and allowed for extensive interaction among industrial and academic attendees. Planning for the E-filiates third annual meeting that will take place on November 14, 2014 began in the spring.

The E-filiates annual request for research proposals in 2013 resulted in three funded projects, each granted up to \$150,000. The first, led by **Claire White**, assistant professor of civil and environmental engineering and the Andlinger Center for Energy and the Environment, investigates how to avoid the development of microcracks in slag-based geopolymer concrete. These cracks, which reduce the cement's durability, are one of the most significant problems for alternative cements that produce less greenhouse gas during manufacture. The second major project is headed by **Warren Powell**, professor of operations research and financial engineering. He is in charge of a team that is



Ralph Izzo, Chairman, President and CEO of PSEG, speaking at the E-filiates second annual meeting in November 2013.

The E-affiliates Advisory Committee convened twice to determine project funding, draft the 2014 Request for Proposals, plan the 2014 annual meeting, and identify strategies for growth of the program.

investigating the expected dynamics of the New Jersey electricity grid when a high level of solar energy is added to the current mix of sources. In addition to these projects, **Amy Craft**, an energy economist at the Woodrow Wilson School of Public and International Affairs, also received funds for a project to assess the costs and benefits of distributed generation in comparison with centralized power.

E-affiliates hosted and sponsored other activities over the 2013–2014 academic year. In February 2014, E-affiliates held a retreat in the style of a Gordon Research Conference. The retreat fostered strong connections and open discussion between students, postdoctoral fellows, faculty, and representatives from E-affiliates member companies. In April 2014, E-affiliates joined with Columbia University to sponsor the Second Distributed Energy Valuation Roundtable that was moderated by PSEG's **Scott Jennings**, also the 2013–2014 E-affiliates visitor-in-residence and **Travis Bradford**, a faculty member from Columbia University. Thirty participants, including federal and state regulators and policymakers, CEOs and executives of public utility companies, independent power producers, distributed energy providers, heads of industry advocacy groups, and faculty experts from Princeton and Columbia Universities met to discuss distributed energy valuation and associated economic and policy considerations.



Professor Dan Steingart speaks during a panel discussion about emerging energy technologies at the E-affiliates annual meeting.

129,000 gross square feet

Designed by Tod Williams
Billie Tsien Architects

Designed to LEED silver
standards

Space for cleanroom,
imaging & analysis, and
research laboratories

200-seat lecture hall,
meeting rooms, classrooms

Faculty, visitor, researcher,
and student space

Administrative offices and
facilities support

Building and Equipment

With a projected completion date of summer 2015, the physical embodiment of the Andlinger Center for Energy and the Environment is rapidly coming together adjacent to the Engineering Quadrangle at the corner of Olden and Prospect Streets. The construction site is buzzing with activity as the exterior envelope of the building nears completion and the interior work continues in earnest. Despite the long and challenging past winter, the steel beam skeleton of the 129,000 square-foot research complex has been enclosed, concrete floors have been poured, and various subcontractors have begun their work on building systems and services. The exterior walls are covered with handmade bricks crafted in Soderberg, Denmark by Petersen, a company founded in 1791. The soft grey bricks will provide a quiet background for the gardens to come. Laboratory, classroom, meeting, and lecture hall spaces have been structurally defined and construction activities continue to result in a more refined glimpse into what the building will look and feel like upon completion.

Inside the structure, the stainless steel exhaust ductwork has been installed in the cleanroom portions of the building and the electromagnetic field shielding is being placed in the imaging center. These infrastructure components represent major building milestones. The ductwork will support the continuous air exchange and filtration needed to support areas that require a highly controlled level of contamination. The shielding enables operation of powerful electron microscopes and other instruments, without electromagnetic interference from other tools in the building. These highly specialized laboratory facilities will house state-of-the-art particle- and vibration-sensitive equipment used for synthesis and characterization of materials and devices for cutting-edge energy and environment applications.



Andlinger Center construction,
June 2013.

Building and Equipment continued

Work is also progressing on the 200-seat lecture hall, the center's future venue for symposia, seminars, and other events. We are very pleased that the hall will be named in honor of **Paul A. Maeder '75** in recognition of his many contributions to the center. In keeping with the overall design of the building, the space will help to create connections as people gather together and exchange ideas.

In the winter, the Andlinger Center purchased a Leica 3D confocal microscope that provides dual core confocal and interferometry technology to provide the highest precision measurements of smooth surfaces down to 0.1 nm resolution. One example of its use will be to study the structural evolution of battery electrodes, critical to improving electricity storage options. Further equipment purchase recommendations for the shared facilities within the Andlinger Center will be fully reviewed and prioritized by faculty and technical staff in preparation for purchase during the fall semester.

As the building takes shape both inside and out, the center is planning for the occupancy and future operations of the space. The School of Engineering and Applied Science recently led an effort to have the existing, shared micronano-fabrication lab and imaging and analysis center undergo external review with a goal of understanding best practices to support operational excellence when these units enlarge and move into the Andlinger Center. Planning is also underway for various shared research labs that will serve as crucibles for collaborative research in areas including energy storage and conversion, organic electronics, photonics, solar cells, ecohydrology, and environmental sensing instrumentation.



Andlinger Center construction,
June 2014.

Andlinger Center for Energy and the Environment

Professor Emily A. Carter
Founding Director

Professor Peter Jaffé
Associate Director for Research

Professor Niraj Jha
Associate Director for Education

Professor Yueh-Lin (Lynn) Loo
Associate Director for External Partnerships

Jennifer L. Poacelli
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Ralph Izzo
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Claire White

Assistant Professor of Civil and Environmental
Engineering and the Andlinger Center for Energy and
the Environment

associated faculty

Associated Faculty members are elected by the Executive Committee based on their significant service contributions to the Andlinger Center. All members of the Executive Committee are named Associated Faculty.

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Director, Program in Materials Science and Engineering
Associate Director, Academic Affairs, Princeton Institute for the Science and Technology of Materials

Michael A. Celia

Theodora Shelton Pitney Professor of Environmental Studies
Professor of Civil and Environmental Engineering
Director, Program in Environmental Engineering and Water Resources

Pablo G. Debenedetti

Class of 1950 Professor in Engineering and Applied Science
Professor of Chemical and Biological Engineering
Dean for Research

Claire Gmachl

Eugene Higgins Professor of Electrical Engineering

Yiguang Ju

Robert Porter Patterson Professor of Mechanical and Aerospace Engineering
Director, Program in Sustainable Energy

Chung (Ed) Law

Robert H. Goddard Professor of Mechanical and Aerospace Engineering

A. James Link

Associate Professor of Chemical and Biological Engineering

Denise L. Mauzerall

Professor of Civil and Environmental Engineering and Public and International Affairs

H. Vincent Poor

Michael Henry Strater University Professor of Electrical Engineering
Dean, School of Engineering and Applied Science

Richard A. Register

Eugene Higgins Professor of Chemical and Biological Engineering
Chair, Department of Chemical and Biological Engineering

Ignacio Rodriguez-Iturbe

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Jorge L. Sarmiento

George J. Magee Professor of Geoscience and Geological Engineering
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James C. Sturm

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Director, Princeton Institute for the Science and Technology of Materials

Sigurd Wagner

Professor of Electrical Engineering

supporters

The Andlinger Center for Energy and the Environment is grateful to the following supporters whose gifts help to realize the vision of the center. (Those with an asterisk are new or renewed in 2013–2014.)

Gerhard R. Andlinger '52 Founding Gift

Lydia and William M. Addy '82 P14 to establish the *Addy/ISN North American Low Carbon Emission Energy Self-Sufficiency Fund* to support innovative research, equipment, policy development, and teaching

Dwight Anderson '89 to establish the *Anderson Family Professorship in Energy and the Environment*

Anonymous gifts for construction of the Andlinger Center building

Anonymous gift for environmental policy research

Anonymous gift for the highest priorities of the center, including research, equipment, and a visitors program

Anonymous gift for research

Anonymous gift to establish the *Parallax Fund for Energy and the Environment* to support faculty and student research

Anonymous gift to establish the *Peter B. Lewis Fund for Student Innovation in Energy and the Environment* to support student projects, particularly field work and laboratory research

Anonymous gift to establish the *Sustainability Fund* to support student research

Tia Barancik '83 to establish the *Class of 1983 Fund for Energy and the Environment*

John E. Bartlett '03 to establish the *Dede T. Bartlett P03 Fund for Student Research in Energy and the Environment*

Peter Bartlett '77 and **Erin P. Bartlett P09 P10 P14** for discretionary spending

Charles A. Bernheim '67 for discretionary spending*

John E. Cross '72 and **Molly Tiffany Cross** for discretionary spending

Nancy A. Curtin '79 and **John Stafford** to establish the *Nancy A. Curtin '79 and John Stafford Research Innovation Fund*

John O. Dabiri '01 to establish the *John O. Dabiri '01 Family Fund for Excellence in Energy and Environmental Research*

Charlene de Carvalho-Heineken P09 P14 to establish the *de Carvalho-Heineken Family Fund for Environmental Studies* to support faculty and student research

John P. Drzik '83 and **Ann L. Thorsell '83** to establish the *John Drzik and Ann Thorsell Fund for Innovation*

High Meadows Foundation to establish the *Andlinger Center for Energy and the Environment Director's Fund*

Kerry and William F. Holekamp P14 to support equipment purchases

The Thomas W. Horton Family to support equipment purchases

Peter C. Klosowicz '76 to establish the *Peter C. Klosowicz '76 Fund for Energy and the Environment* to support research and teaching

Paul A. Maeder '75 for construction of Maeder Hall* and to establish the *Paul A. Maeder '75 Fund for Innovation in Energy and the Environment* to support graduate fellowships

Jay P. Mandelbaum '84 P17 to establish the *Laurie and Jay P. Mandelbaum '84 Fund for Energy and the Environment*

Lisa Lee Morgan '76 M.Arch. '79 to support research in renewable energy

Nicholas J. Nicholas, Jr. '62 P83 P00 to establish the *Nicholas Family Fund for the Environment* to advance public understanding of important issues related to energy and the environment*

Nicholas G. Nomicos '84 and **Kathleen Connor Nomicos '84** to establish the *Nicholas and Kathleen Nomicos Class of 1984 Fund for the Andlinger Center for Energy and the Environment* to advance public understanding of important issues related to energy and the environment

Mark F. Rockefeller '89 to establish the *Renee and Mark F. Rockefeller '89 Fund for the Environment* to support faculty and student research

Ernest H. Ruehl, Jr. '85 to establish the *Ruehl Family Fund for the Environment* to support faculty and student research

Elchin A. Safarov and **Dilyara Allakhverdova P15** for discretionary spending*

Gloria and Karl F. Schlaepfer '49 P85 to establish the *Schlaepfer Family Fund* for equipment*

Kent C. Simons '57 to establish the *David P. Simons Fund for Energy and the Environment*

Lewis W. van Amerongen '62 to establish the *Lewis W. van Amerongen '62 Fund for the Environment* for equipment*

Our online research directory of Princeton faculty, whose portfolios include energy or energy-related environmental issues as a component of their overall research pursuits, continues to grow with 113 entries at the end of June 2014. The Andlinger Center serves as a clearinghouse and a point of entry for external organizations and individuals who seek information about energy-related research at Princeton, and also for campus community members who seek opportunities for collaboration. The online research directory (acee.princeton.edu/research) charts the intellectual foundation of the center.

The faculty members in the research directory, as of this report date, represent the following schools, departments, programs, and centers:

School of Architecture
School of Engineering and Applied Science
Woodrow Wilson School of Public and International Affairs

Department of Astrophysical Sciences
Department of Chemical and Biological Engineering
Department of Chemistry
Department of Civil and Environmental Engineering
Department of Computer Science
Department of Ecology and Evolutionary Biology
Department of Economics
Department of Electrical Engineering
Department of Geosciences
Department of Mechanical and Aerospace Engineering
Department of Near Eastern Studies
Department of Operations Research and Financial Engineering
Department of Physics
Department of Psychology
Department of Sociology

The Andlinger Center for Energy and the Environment
The Center for Architecture, Infrastructure and Urbanism
The Institute for the Transregional Study of the Contemporary
Middle East, North Africa and Central Asia
Lewis-Sigler Institute for Integrative Genomics
Keller Center
Princeton Environmental Institute
Princeton Institute for the Science and Technology of Materials

The Program in Applied and Computational Mathematics
The Program in Architecture and Engineering
The Program in Atmospheric and Oceanic Sciences
The Program in Engineering and Management Systems
The Program in Engineering Physics
The Program in Environmental Engineering and Water Resources
The Program in Environmental Studies
The Program in Geological Engineering
The Program in Planets and Life
The Program in Plasma Physics
The Program in Population Studies
The Program in Science and Global Security
The Program in Science, Technology, and Environmental Policy
The Program in Sustainable Energy
The Program in Technology and Society
The Program in Urban Studies

Geophysical Fluid Dynamics Laboratory
Princeton Plasma Physics Laboratory

Faculty associated with the Andlinger Center are often cited in local, national, and international news publications or have their research highlighted in journals and scientific publications. In 2013–2014, 78 faculty listed in the research directory were referenced more than 200 times in sources such as *The Chronicle of Higher Education*, *NPR*, *The New York Times*, *The Wall Street Journal*, and *The Washington Post*. A few that represent the range of sources and topics are:

Professor **Andrew Bocarsly** was quoted in “The Hidden Value of Carbon Dioxide” in *Chemical & Engineering News* (<http://cen.acs.org/articles/91/i26/Hidden-Value-Carbon-Dioxide.html>).

Professor **Denise Mauzerall**’s research was featured in “Reorganization of Crop Production and Trade Could Save China’s Water Supply” in *Science Newsline* (<http://www.sciencenewsline.com/articles/2014062520190033.html>).

Professor **Michael Oppenheimer** was quoted in “U.N. Climate Panel: Governments, Businesses Need to Take Action Now Against Growing Risks” in *The Washington Post* (http://www.washingtonpost.com/business/economy/un-climate-panel-governments-businesses-need-to-take-action-now-against-growing-risks/2014/03/30/0feb5cba-b788-11e3-b84e-897d3d12b816_story.html).

Director of the Princeton Plasma Physics Laboratory and Professor **Stewart Prager** was featured in “Fusion’s Restless Pioneers” in *Science* (<http://www.sciencemag.org/content/345/6195/370.full>).

Professor **Alexander Smits** was interviewed in *EcoRI*’s “Forecast Calls for More Vertical Wind” (<http://www.ecori.org/massachusetts-energy/2014/1/12/forecast-calls-for-more-vertical-wind.html>).

Professor **Ali Yazdani**’s research was featured in “Decoding the Secrets of Superconductivity” by the Simons Foundation’s publication *Quanta Magazine* (<http://www.quantamagazine.org/quanta/20140430-decoding-the-secrets-of-superconductivity/>).

Professor **Mark Zondlo**’s research was highlighted in “On Fracking Front, A Push to Reduce Leaks of Methane” by *Yale Environment 360* (http://e360.yale.edu/feature/on_fracking_front_a_push_to_reduce_leaks_of_methane/2754/).

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In the Nation's Service and in the Service of All Nations