



# annual report

academic year 2015 - 2016



**andlinger center**  
for energy + the environment

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**Yueh-Lin (Lynn) Loo**  
Director of the  
Andlinger Center  
for Energy and the  
Environment,  
Theodora D. '78 and  
William H. Walton  
III '74 Professor in  
Engineering,  
Professor of Chemical  
and Biological  
Engineering

As I took part in the celebrations for the new building of the Andlinger Center for Energy and the Environment at Princeton University, I had chills thinking about how far the center has come. This beautiful place was only an idea when Gerhard R. Andlinger '52 gave a generous gift in 2008 to start the center. Under the leadership of Emily A. Carter, founding director and now dean of the School of Engineering and Applied Science, the center grew to include new faculty, new research projects, and exciting programs. On this sturdy foundation, I am humbled to lead the Andlinger Center in the enormous task of bringing energy to the world while mitigating the effects of climate change.

This annual report reflects the hard work that went into establishing the center, from the great faculty hired to the seed funding that has catalyzed important research. As I speak to colleagues in the center and across the University, I am energized by the dedication and passion people have shown towards the center's mission of developing solutions for our energy and environmental future. To step up to this challenge, I have in mind three words: **excel**, **engage**, and **inform**.

To **excel**, we are building an unparalleled research community where scientists, engineers, social scientists, and humanists exchange ideas and thereby enhance discovery, invention, and impact. To **engage**, we are cultivating stronger ties to other researchers and practitioners beyond the center's walls and across and outside the Princeton campus. To **inform**, we are expanding educational opportunities for our constituents, including students, researchers, professionals outside academia, and the public at large.

Impact requires collaboration; this is key to solving our complex energy and climate change issues. These intertwined problems touch upon science, engineering, economics, policy, and human behavior. So it's imperative that we work together to develop market-ready solutions and technologies that will heal our environment and provide clean energy for everybody.

This is an ambitious undertaking that will require many people, including **you**.

I hope I will have the opportunity to connect with you in the coming year. Please visit us. Attend our events. Talk to our experts. And collaborate with us. We can achieve a better tomorrow when we all work together.

**Yueh-Lin (Lynn) Loo**

Director of the Andlinger Center for Energy and the Environment  
Theodora D. '78 and William H. Walton III '74 Professor in Engineering  
Professor of Chemical and Biological Engineering

## to develop solutions to ensure our energy and environmental future

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- + foster a vibrant and interdisciplinary community
- + accelerate innovation through funding, infrastructure, and intellectual discourse
- + train the next generation of leaders in a broad context
- + partner with industry, not-for-profit, and government
- + become the leader and expert for information and advice

## building opening celebration and symposium

Marking the culmination of years of planning and construction, the building dedication of the Andlinger Center for Energy and the Environment at Princeton University took place on the morning of May 18, 2016. The center's new home has specialized laboratories and state-of-the-art central facilities that incorporate many sustainability features, such as green roofs to capture rain water and radiant ceiling panels to decrease heating and cooling loads. Designed with courtyards and gardens, the building is a manifestation of the center's mission: to preserve the planet for future generations through innovative, sustainable energy and environmental technologies, as well as policy research and education that are collaborative and cross disciplinary and professional borders.

The dedication dovetailed with the center's Building Opening Celebration and Symposium, a three-day event held from May 18 to 20. The symposium featured 17 speakers, with the center's jointly-appointed faculty highlighting their research in sustainable energy, as well as industrial, academic, and governmental leaders outlining their visions for the future of energy and the environment. Andlinger faculty presented on novel developments of batteries, environmentally-sustainable concrete and building materials, improved thin-film LEDs and solar cells, energy-efficient building systems, the control of fusion plasmas, and advanced biofuels. The symposium also hosted a panel discussion on the center's latest Energy Technology Distillate, entitled "Fusion Energy via Magnetic Confinement." The celebration culminated with a poster session highlighting research from postdocs and graduate students on subjects ranging from electric boat motors to innovative alternatives for low-carbon-emission concrete.



Guests, faculty, and speakers enjoyed lunch in one of the courtyards at the Andlinger Center during its Building Opening Celebration and Symposium.



Between talks at the Building Opening Celebration and Symposium, visitors chatted in the lobby of Maeder Hall at the Andlinger Center.

Photo by David Kelly Crow

Photo by David Kelly Crow



Mitchell Small



Martin O.L. Hansen



Emily A. Carter



Yueh-Lin (Lynn) Loo

### Faculty and Research Appointments

In July 2015, the **Energy Systems Analysis Group (ESAG)** joined the Andlinger Center for Energy and the Environment, moving across the Princeton University campus from the Princeton Environmental Institute (PEI). ESAG's research focuses on systems-level engineering and policy analysis for long-term solutions to major environmental and other societal problems associated with energy conversion and use. ESAG analysis helps clarify environmental and economic implications of emerging energy systems and identifies energy technologies and strategies that could put the global energy system on a more sustainable path. The group is led by **Robert Williams**, senior research scientist, with core members **Eric Larson**, senior research engineer, and **Thomas Kreutz**, senior energy systems modeler.



ESAG, from left to right: Eric Larson, Thomas Kreutz, and Robert Williams.

**Mitchell Small** began his joint appointment at the Andlinger Center and the Department of Civil and Environmental Engineering in September 2015 as the Anderson Family Visiting Professor in Energy and the Environment and visiting senior research scholar. Small conducts research in environmental statistics, mathematical modeling of environmental systems, risk assessment, and decision support. He is the H. John Heinz III Professor of Environmental Engineering at Carnegie Mellon University. During the fall semester, he taught CEE 490/ENE 490: *Mathematical Modeling of Energy and Environmental Systems* to 24 undergraduates and graduate students across disciplines at Princeton.

In February 2016, **Martin O.L. Hansen** was jointly appointed to the Andlinger Center and the Department of Mechanical and Aerospace Engineering as the Anderson Family Visiting Professor in Energy and the Environment and visiting research scholar. Hansen is affiliated with DTU Wind Energy at the Technical University of Denmark. Hansen's background includes classical fluid mechanics, with a focus on wind turbines and wind turbine aerodynamics. He taught ENE 453: *Wind Turbine Aerodynamics and Technology* and contributed to a forthcoming Energy Technology Distillate on wind energy.

**Emily A. Carter**, the founding director of the Andlinger Center, was named dean of the School of Engineering and Applied Science, effective July 2016. Since her appointment as the center's director in 2010, Carter oversaw the establishment of many programs and initiatives, the hiring of faculty and staff, and the construction of the new building in which the center currently resides at the corner of Olden Street and Prospect Avenue.

**Yueh-Lin (Lynn) Loo**, the Theodora D. '78 and William H. Walton III '74 Professor in Engineering and professor of chemical and biological engineering, was appointed director of the Andlinger Center, effective July 2016. In an earlier role as associate director for external partnerships at the center, Loo launched and led Princeton E-filiates Partnership. A leader in organic and plastic electronics, Loo researches the development and processing of materials for low-cost, lightweight, and flexible solar cells and circuits. In recent work, Loo's group has developed transparent solar cells to power technology that changes a material's color in response to electrical signals. Such "smart" windows will decrease energy use associated with the heating, cooling, and lighting needs of buildings.



Mark Zondlo

Starting September 2016, **Mark Zondlo**, associate professor of civil and environmental engineering, assumed the role of the Andlinger Center's associate director for external partnerships. Zondlo, who came to Princeton in 2008, is also an associated faculty member at the University's Program in Atmospheric and Oceanic Sciences, Mid-Infrared Technologies for Health and the Environment — a National Science Foundation Engineering Research Center, the Princeton Institute for the Science and Technology of Materials, and PEI. Zondlo chaired the engineering school's strategic planning committee to review the school's relationships with external entities. Before coming to Princeton, he was a senior research scientist at Southwest Sciences, Inc. in Santa Fe, New Mexico, where he developed different laser-based techniques to detect atmospheric trace gases. In his research work at Princeton, Zondlo develops atmospheric sensors and conducts field experiments to understand air quality, climate change, and the nitrogen cycle.

### Faculty Recruitment

The Andlinger Center successfully recruited its first senior faculty member, **Elke Weber**, an internationally-renowned behavioral scientist, who joined the center in September 2016. Weber is jointly appointed to the Andlinger Center, the Woodrow Wilson School of Public and International Affairs, and the Department of Psychology. She is the Gerhard R. Andlinger Professor in Energy and the Environment, and professor of psychology and public affairs. Weber comes to Princeton from Columbia University, where she had been the Jerome A. Chazen Professor of International Business, a professor at the Earth Institute and the psychology department, and co-director of the Center for Decision Sciences at the business school and the Center for Research on Environmental Decisions at the Earth Institute. Weber's work straddles the disciplines of psychology and economics. She brings to the Andlinger Center her unique expertise on measuring and modeling the behaviors of individuals and groups as they deal with uncertainty and tradeoffs in decisions that impact the environment, with implications for environmental and energy policy.

During the past year, the center also successfully recruited **Minjie Chen**, an expert in power electronics with a focus on renewable energy integration, grid-interface power electronics, and high-performance power-management systems. Chen, appointed at the rank of assistant professor, will join the Andlinger Center and the Department of Electrical Engineering in February 2017. Chen is currently finishing a postdoctoral year at the Massachusetts Institute of Technology, where he also received his Ph.D. in electrical engineering and computer science.

### Faculty and Research Staff News

**José Avalos**, assistant professor of chemical and biological engineering and the Andlinger Center for Energy and the Environment, was named a 2016 Sloan Research Fellow. Awarded by the Alfred P. Sloan Foundation, the fellowships recognize promising early career scientists, who have been nominated by their colleagues, and seek to stimulate fundamental research.

**Emily A. Carter** was awarded the Joseph O. Hirschfelder Prize in Theoretical Chemistry. Carter was recognized for her overall body of work, including her current research in sustainable energy and her contributions to theoretical and computational chemistry. For example, her work has helped scientists understand photoelectrocatalysis, a light-driven electrochemical process that is further accelerated by the presence of a catalyst. In February 2016, Carter was elected to the National Academy of Engineering, among the highest professional distinctions accorded to an engineer.

### Staff Additions

**Sharon Adario** joined the Andlinger Center in August 2015 as the center's communications specialist. She was previously a reporter for Wall Street Journal, Al Jazeera America, and The Star-Ledger.

**Sarah Jackson** joined the center in September 2015 as an administrative assistant. She previously worked at Princeton's Office of Finance and Treasury as an office assistant.

During the past year, **ESAG** — in collaboration with the University of Queensland, Australia, and with funding from the Department of Energy (DOE) and Southern Company, a Princeton E-filiates Partnership member — developed a preliminary design for, and analyzed the economics of, a project that would demonstrate the technical feasibility of a new industrial process for converting a mix of lignite and biomass into jet fuel and electricity, while capturing byproduct CO<sub>2</sub> for underground storage. As a result, **Robert Williams**, senior research scientist, was invited by West Virginia Senator Joe Manchin's staff to review an amendment to a broad energy bill that authorizes the DOE to provide funding for much more detailed front-end engineering and design studies needed to proceed with demonstration energy projects coprocessing coal and sufficient biomass to realize negative greenhouse gas emissions. The Senate passed the bill in April 2016. Congress might pass a final version of the energy bill in late 2016.

**Egemen Kolemen**, assistant professor of mechanical and aerospace engineering and the Andlinger Center for Energy and the Environment, received funding from DOE's Early Career Research program along with 49 scientists across the country. Kolemen, who is also associated with DOE's Princeton Plasma Physics Laboratory, had his project, "Physics-Based Real-time Analysis and Control to Achieve Transient-Free Operations for the ITER Era," selected by the Office of Fusion Energy Sciences.

**Forrest Meggers**, assistant professor of architecture and the Andlinger Center for Energy and the Environment, along with Dorit Aviv, who earned a master's degree in architecture in 2014 from Princeton, and Axel Killian, an assistant professor of architecture, hosted and organized "Ultrastructures" in September 2015. The conference and accompanying exhibition explored the complex and intriguing connections between the macro level of buildings and design and the micro level of physical processes. One component of Meggers' work is to consider innovative ways to cool buildings, which was shown in two structures on display, the Cool Oculus and the Thermoheliodome.

**Barry Rand**, assistant professor of electrical engineering and the Andlinger Center for Energy and the Environment, won a Young Investigator Program award from the Office of Naval Research. The purpose of the award is to fund early career academic researchers whose scientific pursuits show outstanding promise for supporting the Department of Defense, as well as to promote their professional development. Rand also received the Defense Advanced Research Projects Agency's Young Faculty Award.

**Claire White**, assistant professor of civil and environmental engineering and the Andlinger Center for Energy and the Environment, received a five-year CAREER grant from the National Science Foundation (NSF) to investigate more sustainable and resilient alternatives to Portland cement, a fundamental constituent in concrete and whose production accounts for five to eight percent of global carbon dioxide emissions. The NSF supports junior faculty members, such as White, "who exemplify the role of teacher-scholars through outstanding research, excellent education, and the integration of education and research within the context of the mission of their organizations," through this grant program.

**Sander van der Linden**, postdoctoral research associate and lecturer at the Andlinger Center, the Woodrow Wilson School of Public and International Affairs, and the Department of Psychology, co-authored "Climate Change's Unseen Consensus," a U.S. News & World Report article in February 2016 that highlighted the observation that many middle and high school science teachers remain unaware of the scientific consensus on climate change and are teaching as if the issue is still up for debate. He also published a letter in The New York Times in October 2015 on the psychological benefits of recycling.

#### **Andlinger Center Associated Faculty Selected Awards and Honors**

##### **Craig B. Arnold**

*Professor of Mechanical and Aerospace Engineering  
Director, Princeton Institute for the Science and Technology of Materials  
Platinum Innovation Award from Vision Systems Design*

##### **José Avalos**

*Assistant Professor of Chemical and Biological Engineering and the Andlinger Center for Energy and the Environment  
Sloan Research Fellow*

##### **Emily A. Carter**

*Founding Director, Andlinger Center for Energy and the Environment  
Gerhard R. Andlinger Professor in Energy and the Environment  
Professor of Mechanical and Aerospace Engineering and Applied and Computational Mathematics  
Named dean of the School of Engineering and Applied Science (effective July 1, 2016); Almlöf–Gropen  
Lecturer, Centre for Theoretical and Computational Chemistry at the University of Oslo and the  
University of Tromsø, Norway; R. H. Betts Memorial Award Lecturer, University of Manitoba, Winnipeg,  
Canada; Fred Kavli Innovations in Chemistry Lecturer, American Chemical Society; Elected to National  
Academy of Engineering*

##### **Michael Celia**

*Theodora Shelton Pitney Professor of Environmental Studies  
Professor of Civil and Environmental Engineering  
Director, Program in Environmental Engineering and Water Resources  
Elected to National Academy of Engineering*

##### **Paul Chirik**

*Associate Director for External Partnerships, Andlinger Center for Energy and the Environment  
Edwards S. Sanford Professor of Chemistry  
Presidential Green Chemistry Challenge Award from the Environmental Protection Agency*

##### **Pablo Debenedetti**

*Dean for Research  
Class of 1950 Professor in Engineering and Applied Science  
Professor of Chemical and Biological Engineering  
Phi Beta Kappa Teaching Award from Princeton; Elected Fellow to American Physical Society; 2016  
John A. Quinn Lecturer in Chemical Engineering, University of Pennsylvania*

**Claire Gmachl**

*Eugene Higgins Professor of Electrical Engineering*

*Director, Mid-InfraRed Technologies for Health and the Environment — a National Science Foundation Engineering Research Center*

Walter Curtis Johnson Award for excellence in undergraduate teaching from Princeton's Department of Electrical Engineering

**Yiguang Ju**

*Robert Porter Patterson Professor of Mechanical and Aerospace Engineering*

*Director, Program in Sustainable Energy*

Best Paper Award (with Gerard Wysocki, associate professor of electrical engineering) from the 2015 Japanese Symposium on Combustion; Named Associate Editor, American Institute of Aeronautics and Astronautics Journal

**Egemen Kolenen**

*Assistant Professor of Mechanical and Aerospace Engineering and the Andlinger Center for Energy and the Environment and the Princeton Plasma Physics Laboratory (PPPL)*

Department of Energy's (DOE) Early Career Research Program award; Co-recipient (with PPPL Research Physicist Luis Delgado-Aparicio) of Torkil Jensen Award from General Atomics/DOE

**Chung (Ed) Law**

*Robert H. Goddard Professor of Mechanical and Aerospace Engineering*

2015 Highly Cited Researcher, Thompson Reuters/Essential Science Indicators

**Yueh-Lin (Lynn) Loo**

*Theodora D. '78 and William H. Walton III '74 Professor in Engineering*

*Professor of Chemical and Biological Engineering*

Named director of the Andlinger Center for Energy and the Environment (effective July 1, 2016)

Peng Chen Scholar and Distinguished Visiting Professor, Peking University at Shenzhen

Visiting Professor, Nanjing Technological University

**Margaret Martonosi**

*Hugh Trumbull Adams '35 Professor of Computer Science*

Long-Term Influential Paper Award from the 2015 International Symposium of Computer Architecture

**Guy Nordenson**

*Professor of Architecture and Structural Engineering*

Named among the “25 most admired educators for 2016” by the Design Features Council

**Catherine A. Peters**

*Professor of Civil and Environmental Engineering*

*Director, Program in Geological Engineering*

Elected Fellow of the Association of Environmental Engineering and Science Professors

**H. Vincent Poor**

*Dean, School of Engineering and Applied Science*

*Michael Henry Strater University Professor of Electrical Engineering*

2015 Fellow of the National Academy of Inventors; John Fritz Medal from the American Association of Engineering Societies

**Warren Powell**

*Professor of Operations Research and Financial Engineering*

*Director, Program in Engineering and Management Systems*

Best Paper Prize from the Society for Transportation Science and Logistics

**Barry Rand**

*Assistant Professor of Electrical Engineering and the Andlinger Center for Energy and the Environment*

Young Investigator Program award from the Office of Naval Research; Young Faculty Award from the Defense Advanced Research Projects Agency

**Naveen Verma**

*Associate Professor of Electrical Engineering*

Excellence in Teaching award from Princeton's Engineering Council and Graduate Engineering Council

**Claire White**

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

CAREER Award from the National Science Foundation

The educational programs at the Andlinger Center for Energy and the Environment at Princeton University continue to flourish and grow under the direction of **Niraj Jha**, associate director for education and professor of electrical engineering, and **Moira Selinka**, the center's education and outreach coordinator. The center houses two certificate programs, offers a suite of energy- and environmental-related courses under the ENE subject code, and supports a graduate fellowship and undergraduate summer internship program.

### **Certificate Programs**

The Energy track of the Program in Technology and Society (ETS), run jointly by the Andlinger Center and the University's Keller Center, continues to serve students across many disciplines — humanities, social sciences, physical and natural sciences, and engineering — who are interested in understanding and working on energy solutions. During the 2016 academic year, the ETS certificate saw 28 undergraduate students taking its courses. There are now 63 ETS courses from which students can learn about energy technologies, engineering approaches to energy and environmental challenges, and the societal and environmental implications of such technologies. In June 2016, the ETS program graduated **Kristin Lukins**, a senior pursuing an A.B. in economics. Her thesis, entitled “The Effect of Government Incentives on Consumption of Alternative Fuel Vehicles in the United States,” entailed a close review and analysis of data related to tax and other federal incentives for purchasing hybrid or electric vehicles. The work pulled together her personal experience with and interest in hybrid vehicles with policy and data analysis. Lukins presented her work at the ETS symposium in May 2016 and started working at a California tech company after graduation.

The Program in Sustainable Energy focuses on studies of current energy resources, the development of energy systems that support sustainable economic growth, the nexus of energy security and environmental harmony, and an understanding of global climate and environmental change. Science and engineering students interested in pursuing graduate studies or careers in fields related to energy, as well as humanities and policy students who desire a more technical grasp of the world's energy landscape, are exposed to a broad spectrum of energy technologies through this certificate program. The center graduated 12 engineering students this year from three areas of concentration (chemical and biological engineering, civil and environmental engineering, and mechanical and aerospace engineering). Many of them moved onto careers in the energy sector, including positions at PSEG, New Jersey's largest utility company and member of Princeton E-ffiliates Partnership, and 24M, a battery company.

## Summer Intern Comments

### Jason Mulderrig '18

"The most rewarding part of my summer working on the research project was being able to focus exclusively on one project and guide that project from infancy to maturity in a relatively short period of time."



### Sherry Bai '19

"I found the differences between learning through courses and learning through research particularly striking. While courses can be enjoyable and fulfilling, the process of independently working on an experimental project and piecing together the results of that work is rewarding and enlightening in a fundamentally different way."



## Course Updates

The center introduced several new courses in 2015-2016. This addition brings the total number of ENE courses the Andlinger Center offers to 36, with 28 at the undergraduate and eight at the graduate levels.

**Egemen Kolemen**, assistant professor of mechanical and aerospace engineering and the Andlinger Center for Energy and the Environment and the Princeton Plasma Physics Laboratory, introduced ENE 308: *Engineering the Climate: Technical and Policy Challenges* to 16 undergraduate students. **Fabian Wagner**, the Gerhard R. Andlinger Visiting Professor in Energy and the Environment, offered an original course, ENE 414: *Renewable Energy Systems*, and **Martin O.L. Hansen**, jointly appointed to the Andlinger Center and the Department of Mechanical and Aerospace Engineering as the Anderson Family Visiting Professor in Energy and the Environment and visiting research scholar, offered an original course, ENE 453: *Wind Turbine Aerodynamics and Technology*. In addition, **Mitchell Small**, jointly appointed to the Andlinger Center and the Department of Civil and Environmental Engineering as the Anderson Family Visiting Professor in Energy and the Environment and visiting senior research scholar, developed and taught a new course, CEE 490/ENE 490: *Mathematical Modeling of Energy and Environmental Systems*, to 24 students.

Enrollments in existing courses continue to grow. ENE 202: *Designing Sustainable Systems: Applying the Science of Sustainability to Address Global Change*, taught by **Forrest Meggers**, assistant professor of architecture and the Andlinger Center for Energy and the Environment, saw an all-time high enrollment of 87 students across 23 areas of concentration this spring.

## Summer Internships

The Andlinger Center continues to offer competitive summer internship opportunities to undergraduate students through the support of 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**. Recipients perform research on campus for a minimum of eight weeks under the guidance of faculty advisors. In the summer of 2016, eight students received more than \$51,000 in stipends and support for research materials and supplies. The students came from departments within and beyond the School of Engineering and Applied Science.

**Sherry Bai '19** investigated the impact of doping on organic solar cells, **Eric Chen '19** performed Hall effect measurements for energy-relevant semiconductors, and **Andrew Ma '19** worked on improving OLED light-outcoupling efficiencies. All three worked in the lab of **Barry Rand**, assistant professor of electrical engineering and the Andlinger Center for Energy and the Environment.

**Maeder Graduate  
Fellowship Recipients and  
Faculty Advisors**

2015-2016 Academic Year

**Wenkai Liang |  
Chung (Ed) Law**

Mechanical and Aerospace  
Engineering

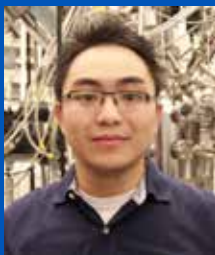


Wenkai Liang

2016-2017 Academic Year

**Clark Chen | Bruce Koel**

Chemical and Biological  
Engineering



Clark Chen

**Theo Keeley-LeClaire '18** studied a novel method of controlling the alcohols (isobutanol, a biofuel) produced during the metabolism of sugars by the yeast, *S. cerevisiae*, and **Andy Liu '19** modified yeast mitochondria to increase the yield of isobutanol for biofuels. Both worked in the lab of **José Avalos**, assistant professor of chemical and biological engineering and the Andlinger Center for Energy and the Environment.

**Isabella Grabski '18** studied the dissociation of carbon dioxide on a metal catalyst to reduce CO<sub>2</sub> released into the atmosphere. She worked in the lab of **Emily A. Carter**, founding director of the Andlinger Center and dean of the engineering school.

**Jason Mulderrig '18** performed wind-tunnel tests to analyze and improve energy harvester design in the lab of **Alexander Smits**, the Eugene Higgins Professor of Mechanical and Aerospace Engineering.

**Sam Smiddy '17** studied foam-driven fractures of an elastic matrix to reduce the environmental cost of hydraulic fracturing in the lab of **Howard Stone**, the Donald R. Dixon '69 and Elizabeth W. Dixon Professor of Mechanical and Aerospace Engineering and chair of mechanical and aerospace engineering.

Cumulatively, the center's summer internship program has provided research opportunities to 38 undergraduates; among them are 16 female students. Additional information about these and past student projects is available on the center's website at <http://acee.princeton.edu/acee-news/funds-for-summer-research-awarded-to-eight-undergraduates>.

**Maeder Graduate Fellowship in Energy and the Environment**

Graduate students who perform research related to energy and/or the environment as impacted by energy are eligible to be nominated for the **Maeder Graduate Fellowship in Energy and the Environment**, which is supported by the **Paul A. Maeder '75 Fund for Innovation in Energy and the Environment**. Each year, faculty members nominate their very best graduate students. The student may be enrolled in any doctoral program on campus, and nominations from departments outside of engineering are encouraged.

**Wenkai Liang**, a fourth-year graduate student in the Department of Mechanical and Aerospace Engineering, was the recipient of the 2016 Maeder Graduate Fellowship in Energy and the Environment. His project focuses on analyzing the oxidation network of hydrogen-oxygen fuel mixtures and developing models to predict hydrogen explosions. He is advised by **Chung (Ed) Law**, the Robert H. Goddard Professor of Mechanical and Aerospace Engineering. Liang won the Sayre Graduate Prize at Princeton and co-authored a paper on combustion that was published in *Fuel* this year.

**Clark Chen** and **Ryan Edwards** were named the recipients of the 2017 Maeder Graduate Fellowships. Chen and Edwards are graduate students in the departments of chemical and biological engineering, and civil and environmental engineering, respectively.

**Ryan Edwards |**  
**Michael Celia**  
Civil and Environmental  
Engineering



Ryan Edwards

Chen's project is titled "Rational Design of Transition Metal Oxyhydroxide Catalysts for the Oxygen Evolution Reaction." His advisor is **Bruce Koel**, professor of chemical and biological engineering. Chen filed a patent application in the area of energy storage and co-authored two papers that appeared in Physical Chemistry Chemical Physics last year.

Edwards' project is titled "Investigating the Fate of Hydraulic Fracturing Fluid in Shale Gas Formations." His advisor is **Michael Celia**, the Theodora Shelton Pitney Professor of Environmental Studies, professor of civil and environmental engineering, and director of the Program in Environmental Engineering and Water Resources. Edwards served as a policy consultant for the National Governors Association and co-authored a 2015 paper on carbon capture and sequestration in shale-gas wells that appeared in Environmental Science and Technology as part of a joint Andlinger-funded seed project.

Since its inception, the Maeder Fellowship program at the Andlinger Center has supported seven graduate students, two of whom are female. Additional information about the fellowship, these and past recipients can be found at <http://acee.princeton.edu/acee-news/maeder-graduate-fellowships-awarded>.

### Laboratory Learning Program

Each summer, Princeton provides research opportunities to highly motivated high school students through its Laboratory Learning Program. Faculty members in the engineering and natural science disciplines offer projects to which interested students from around the country can apply. The program offers a chance for high school students to participate in scientific research at the university level using state-of-the-art equipment and procedures. In summer 2015, eight students participated at the Andlinger Center via the Laboratory Learning Program, bringing the total number of students who have participated in the program at the Andlinger Center since 2014 to 16.

Two young women from New Jersey — one from the Newark Academy in Livingston and the other from High Technology High School in Lincroft — worked on projects led by **Claire White**, assistant professor of civil and environmental engineering and the Andlinger Center for Energy and the Environment. One student investigated alternative cements created from recycled byproducts of other industries that may produce concrete with a smaller carbon footprint. Another designed a computer program to analyze X-ray images of microcracks in cement, which could offer new insights into ways to improve its durability.

Four high school students joined the lab of **Forrest Meggers**, assistant professor of architecture and the Andlinger Center for Energy and the Environment. This group included students from Princeton High School in Princeton, New Jersey; Central Bucks High School West in Doylestown, Pennsylvania; The Hill School in Pottstown, Pennsylvania; and Hollow Hills High School West in Dix Hills, New York. The students investigated how evaporation can be leveraged through materials science to allow buildings to sweat and remove humidity,

researched the design of a concrete wall system with integrated solar cells to produce renewable energy, and evaluated the performance of buildings using wireless temperature and humidity sensors together with energy tools, such as infrared thermal imaging cameras.

A student from High Technology High School and one from High School South in West Windsor, New Jersey experimented with control software for salt water microfluidics in the lab of **Daniel Steingart**, assistant professor of mechanical and aerospace engineering and the Andlinger Center for Energy and the Environment. In addition to honing problem-solving and data-analysis skills, the students used this opportunity to explore future career options related to issues in energy and the environment.

### Other Activities

In addition to the research opportunities outlined above, the Andlinger Center funded the following students and their research projects:

**Carrie Chen '16** and **Ethan Vasquez '16**  
to install a solar energy suitcase system  
for a health clinic in Uganda

**Gregory A. Magana '17**  
to develop a solar energy feasibility  
calculator

**Benjamin C. Sorkin '17**  
to design and test a high efficiency  
marine propulsion system, and a hybrid  
electric race car for an international  
competition on behalf of Princeton  
Racing Electric, a racing team on campus  
composed of approximately 34 students



Benjamin C. Sorkin '17 tested a high efficiency marine propulsion system in Lake Carnegie at Princeton earlier this year.

Photo by David Kelly Crow

### Seed Funding

The Andlinger Center for Energy and the Environment at Princeton University awards funds to catalyze and support projects proposed by Princeton University faculty, researchers, and students that are aimed at solving a broad range of energy and environmental problems.

These projects foster innovative research, teaching, and mentorship in energy and the environment. Three new research projects were supported in 2015–2016, bringing the total number of projects supported since the inception of this initiative to 35 and a total of \$2.8 million invested. This year's projects entail:



Claire White

#### **Claire White**

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

*“Role of Alkalis in Destabilizing the Binder Phase in Low-CO<sub>2</sub> Concrete”*

Portland cement is a fundamental constituent in concrete and whose production emits up to one ton of carbon dioxide for every ton produced, accounting for five to eight percent of global carbon-dioxide emissions. This project involves exploring the molecular scale of low-carbon cements, derived from blast furnace slag, by using computer simulations and laboratory experiments on synthetic gels, with the goal to identify which chemical compositions lead to the most stable (durable) structures at the molecular level.



Howard A. Stone

#### **Howard A. Stone**

*Donald R. Dixon '69 and Elizabeth W. Dixon Professor of Mechanical and Aerospace Engineering and the Chair of the Department of Mechanical and Aerospace Engineering*

*“Innovations for Semi-solid Flow Batteries”*

Flow batteries, composed of chemicals dissolved in liquids stored in tanks, are a type of rechargeable battery that can potentially be widely used on the electric grid because they are long lasting and store large amounts of power. But current models have low energy densities. A recent innovation in flow batteries for achieving higher energy densities utilizes a suspension of solid particles of Li-ion compounds (which are used in lithium ion batteries) along with conductive carbon nanoparticles. This type of battery, a semi-solid fuel cell (SSFC), raises new questions involving rheology — the study of the flow of matter — and transport and materials design to optimize performance. The project aims to develop a standard flow battery configuration that can be used to rapidly test materials ideas relevant to SSFCs, while simultaneously measuring all the relevant mechanical properties.

Externally-Funded  
Sponsored Research  
Awards 2015-2016

Egemen Kolemen

*Assistant Professor of  
Mechanical and Aerospace  
Engineering and the Andlinger  
Center for Energy and the  
Environment and the Princeton  
Plasma Physics Laboratory  
Department of Energy (DOE),  
"Physics-Based Real-Time  
Analysis and Control to Achieve  
Transient-Free Operations for the  
ITER Era"  
DOE, "Real-Time Electron  
Temperature and Density Profile  
Measurements for NSTX-U"*

Eric Larson

*Senior Research Engineer at the  
Energy Systems Analysis Group  
Stanford University, Global  
Climate and Energy Project,  
"Sustainable Transportation  
Energy with Net Negative Carbon  
Emissions: An Integrated  
Ecological and Engineering  
Systems Analysis"*

Forrest Meggers

*Assistant Professor of  
Architecture and the Andlinger  
Center for Energy and the  
Environment  
Siemens Schweiz AG, subaward  
from ETH Zurich, "3-For-2 -  
Beyond Efficiency"  
Siebel Energy Institute,  
collaboration with Politecnico  
di Torino in Turin, Italy, "NICO:  
Nature Inspired Control  
Optimization"*

**Sarah Jane White**

*Visiting Associate Research Scholar, Department of Geosciences*

"An interdisciplinary project to ensure the environmental sustainability of organometal halide perovskites, a class of potentially transformative solar energy materials"

Renewable energy sources, such as solar power, are critical for the sustainable future of our planet. Organometal halide perovskites is a class of photovoltaic material that is poised to revolutionize the world of solar energy because they are cheap, easy to make, and may help prevent the most damaging impacts of climate change. However, the instability of these cells and their subsequent release of lead to the environment leads to concerns for the environment and human health. The project's goal is to understand the chemical and physical mechanisms of perovskite degradation on a molecular level, and how changes in the chemical and physical structure of perovskite affect this degradation. Impacts on the environment can be assessed by determining concentrations and speciation of degradation products, then modeling their fate and transport in the environment.

Funding was provided by the **Andlinger Innovation Fund**, a gift from **Charles Bernheim '57**, the **Clifford and Helen Cross Memorial Charitable Lead Annuity Trust**, the **Nancy A. Curtin '79** and **John Stafford Research Innovation Fund**, the **Peter C. Klosowicz '76 Fund for Energy and the Environment**, the **Sally Liu '87** and **Bay Chang '87 Fund for Energy and the Environment**, the **Laurie and Jay P. Mandelbaum '84 Fund for Energy and the Environment**, the **Parallax Fund for Energy and the Environment**, the **Ruehl Family Fund for the Environment**, the **Schlaepfer Family Fund**, a gift from the **Richard and Enika Schulze Foundation**, the **David P. Simons Fund for Energy and the Environment**, and an anonymous gift for research.

**Campus as a Lab**

**Forrest Meggers**, assistant professor of architecture and the Andlinger Center for Energy and the Environment, and **Kelly Caylor**, associate professor of civil and environmental engineering, along with students, designed a research project to create a multi-sensor to track temperature, humidity, air quality, and pollutants in a given space through the Campus as a Lab initiative. The initiative supports and promotes research to improve sustainability on campus. The device was deployed in various outdoor and indoor spaces around the Princeton campus with an eventual goal to determine how outdoor air impacts indoor air and develop new building systems that could improve air quality and the environment. This project builds on Meggers' previous Campus as a Lab project that modeled the airflow in large indoor spaces and monitored the energy efficiency of various buildings on campus. Funding for these projects came from an anonymous gift to the Andlinger Center.

## Barry Rand

*Assistant Professor of Electrical Engineering and the Andlinger Center for Energy and the Environment*

Binational Science Foundation, collaboration with the Weizmann Institute of Science in Rehovot, Israel, "Uncovering the Device Physics of Metal Halide Perovskite Solar Cells"  
National Science Foundation (NSF), "Exploiting Multiple Exciton Effects in Organic Solar Cells"  
Office of Naval Research, Young Investigator Program, "Understanding Processing and Device Function of Metal Halide Perovskite Thin Film Solar Cells"

## Daniel Steingart

*Assistant Professor of Mechanical and Aerospace Engineering and the Andlinger Center for Energy and the Environment*

alpha-En Corporation, "Determination of Aqueous / Aprotic Lithium Plating Properties"  
DOE, the Advanced Research Projects Agency-Energy, "Fast Electrochemical Acoustic Signal Interrogation for Battery Lifetime Extrapolation and Extension"

## Claire White

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

NSF, "CAREER: SusChEM: Controlling Carbonation Degradation in Sustainable Cements by Stabilizing Amorphous Calcium Carbonate"

## Extramural Sponsored Research

The Andlinger Center's faculty seek extramural research funding, including for projects that build on work previously seeded through the center.

During the 2015–2016 academic year, Andlinger Center faculty brought in more than \$3 million through 11 new research grants.

## Energy Technology Distillates

The Andlinger Center continues to pursue its goal of becoming a leading source of reliable, timely information on energy and the environment for policymakers, corporate leaders, educators, students, and other interested citizens through its Energy Technology Distillates project.

In May 2016, the third Energy Technology Distillate, "Fusion Energy via Magnetic Confinement," was published. This new Distillate is a collection of concise articles about nuclear fusion energy with a focus on magnetic confinement reactors. It was co-authored by 10 graduate students at Princeton. They were led by **Robert Socolow**, professor emeritus and senior research scholar in the Department of Mechanical and Aerospace Engineering.

With this project, the Andlinger Center leverages the wealth of expertise available through Princeton's world-class faculty and researchers. With the goal of becoming a trusted source of information, the Andlinger Center is encouraging collaboration among academia, government, industry, and other entities to facilitate the development of practical technology and policy solutions the world needs.

## Return on Investment

One way the Andlinger Center tracks the results of its efforts is by monitoring the impact seed funding has on future research activities. While not a complete list, the results described below have been aggregated from information supplied by award recipients. Princeton faculty, students, and researchers are 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 spinoff projects. Awardees report over \$4 million in derivative external funding. Andlinger funds have inspired proposals that have been funded by the departments of Defense and Energy (DOD and DOE), the University of São Paulo, IBM, National Science Foundation, ICL



Four graduate students and Robert Socolow, professor emeritus and senior research scholar in the Department of Mechanical and Aerospace Engineering, presented the latest Energy Technology Distillate on fusion energy at the Building Opening Celebration and Symposium. From left to right: Wei Peng, Janam Jhaveri, Cleo Chou, Jane Baldwin, and Socolow.

Photo by David Kelly Crow

## Return on Investment

(since inception in 2011)

Total amount awarded:  
\$4.5 million

Projects supported:  
48 faculty projects  
38 undergraduate students  
7 graduate fellows

Derivative funding:  
More than \$4 million

Journal publications: 42

Conference presentations:  
28

Patent disclosures and  
applications: 6

Industry Partners, University of Minnesota, the Office of the Director of National Intelligence, and the Oak Ridge Institute for Science and Education.

Researchers have published results of their Andlinger-funded research, totaling 42 articles since 2011. In the past year, articles were published in *Energies*, *Nano Letters*, *Power Sources*, *Journal of the Electrochemical Society*, *Biogeochemistry*, *New Phytologist*, *Proceedings of the National Academy of Sciences USA*, *The Journal of Physical Chemistry Letters*, *Bulletin of the American Physical Society*, *Proceedings of the Royal Society of London*, *Philosophical Transactions of the Royal Society*, *Proceedings of the National Academy of Sciences*, *Oxford University Press*, *Annual Review of Political Science*, *World Health Organization*, and the *Bulletin of the Atomic Scientists*.

Graduate students have assumed postdoctoral positions at Columbia University, Imperial College London, and École des Ponts, while postdoctoral researchers have secured faculty positions at the University of Cambridge, New Jersey Institute of Technology, University of South Carolina, and Princeton.

Collaboration is a trademark of many Andlinger-funded projects. Indeed, our researchers have reported new partnerships with École des Ponts, University of Cambridge, Temple University, São Paulo University, IBM, ICL Industry Partners, Southern Company, University of Minnesota, DOE, Oak Ridge National Laboratory, Mide Company, Weizmann Institute of Science, Columbia University, Yale-NUS College, University of Vermont, University of Austin, International Institute for Applied Systems Analysis, and the Technion Israel Institute of Technology.

## Research Turns into Spin-Off Company

A research project studying how sound can determine the health of a battery has moved from the labs at the Andlinger Center into a spin-off company. The science and engineering behind the new start-up, Feasible, was first developed and studied in the lab of **Daniel Steingart**, assistant professor of mechanical and aerospace engineering and the Andlinger Center for Energy and the Environment, and the company has been tapped to join Cyclotron Road, an energy-technology incubator sponsored by the Lawrence Berkeley National Laboratory and the Department of Energy (DOE). **Andrew Hsieh '14** and **Barry Van Tassell**, postdoctoral research associates in Steingart's lab, are participating in Cyclotron Road. The other company co-founders are Steingart and **Shaurjo Biswas**, another postdoctoral research associate in Steingart's lab. The project also received assistance from



Egemen Kolemen (left), assistant professor of mechanical and aerospace engineering and the Andlinger Center for Energy and the Environment and the Princeton Plasma Physics Laboratory (PPPL), speaks with Al von Halle, head of electrical engineering at PPPL.

Photo by Frank Wojciechowski

**Clarence W. Rowley III**, professor of mechanical and aerospace engineering, and **Jason Fleischer**, associate professor of electrical engineering.

The start-up is developing for commercial use acoustical diagnostic tests that can assess the state of charge, state of health, and physical structure of any closed battery. The technology is a possible game changer in battery development and production because it is low-cost, scalable, and does not require the batteries to be taken apart.

While participating in Cyclotron Road, Hsieh and Van Tassell will have access to mentors, commercial partners and investors, and world-class research facilities. The program also provides up to two years of seed funding and salary.

#### About Feasible

- Company launched in 2015.
- Co-founders: **Daniel Steingart**, assistant professor of mechanical and aerospace engineering and the Andlinger Center for Energy and the Environment; and **Andrew Hsieh '14**, **Barry Van Tassell**, and **Shaurjo Biswas** – all three postdoctoral research associates in Steingart's lab.
- Money raised: \$500,000 from Cyclotron Road and \$225,000 from the National Science Foundation.
- As a precursor to Feasible, Steingart's lab received a one-year \$500,000 grant from DOE's Advanced Research Projects Agency-Energy that enabled the fundamental phenomenon of battery-sounds interactions to be understood and exploited to the point where private entities saw sufficient value and opportunity for the company to launch and develop its technologies.

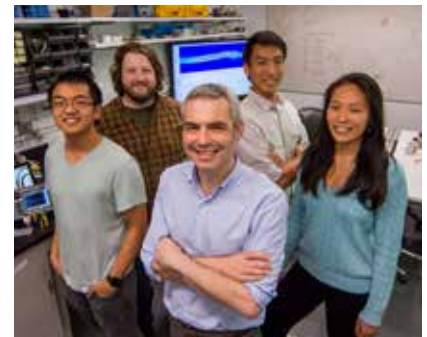


Photo by David Kelly Crow

In the lab of Daniel Steingart, assistant professor of mechanical and aerospace engineering and the Andlinger Center for Energy and the Environment, from left to right: Michael Wang '16; Barry Van Tassell, postdoctoral research associate; Steingart; Andrew Hsieh '14, postdoctoral research associate; and Sharon Gao '15.

## 2015-2016 Highlight Seminar Series

### **Eli Yablonovitch (September 21, 2015)**

*Director of the National Science Foundation Center for Energy Efficient Electronics Science  
University of California, Berkeley  
“Can Opto-Electronics Provide the Motive Power for Future Vehicles?”*

### **Eric Oelkers (October 26, 2015)**

*Professor of Aqueous Geochemistry  
University College London  
“Carbon Storage in Basalts: The CarbFix Story 2006-2015”*

### **William Braham (November 16, 2015)**

*Professor of Architecture  
Director of Master in Environmental Building Design Program  
University of Pennsylvania  
“Thermodynamic Principles for Environmental Building Design, in Three Parts”*

### **Karen Scrivener (February 8, 2016)**

*Professor of Material Science and Engineering  
École Polytechnique Fédérale de Lausanne  
“Meeting the Future Challenges for Concrete”*

### **Venkat Srinivasan (March 7, 2016)**

*Head of the Energy Storage and Distributed Resources Department  
Lawrence Berkeley National Laboratory  
“Energy Storage: Present Status and Future Prospects”*

### **Ned Sauthoff (March 21, 2016)**

*Director of U.S. ITER Project  
Oak Ridge National Laboratory  
“Burning for Fusion Energy: In Pursuit of Self-Heated Plasmas and Beyond”*

### **David Keith (April 7, 2016)**

*Gordon McKay Professor of Applied Physics*

*Professor of Public Policy*

*Harvard University*

*“Reducing the Risks of Solar Geoengineering”*

### **James Liao (April 25, 2016)**

*Ralph M. Parsons Foundation Professor and Department Chair  
Department of Chemical and Biomolecular Engineering  
University of California, Los Angeles  
“Metabolic Engineering for Sustainable Energy”*

**The Andlinger Center also provided administrative and financial support for two additional seminars:**

### **Robert Pitz-Paál (July 2, 2015)**

*Director of the DLR Institute of Solar Research  
“Advanced Measurement Systems to Evaluate Concentrated Solar Power Plants”*

### **Tomás Palacios (February 22, 2016)**

*Professor of Electrical Engineering and Computer Science  
Massachusetts Institute of Technology  
“System-Level Applications of Two-Dimensional Materials: Challenges and Opportunities”*



Photo by Frank Wojciechowski

Eli Yablonovitch, director of the National Science Foundation Center for Energy Efficient Electronics Science, University of California, Berkeley, gave the first lecture of the 2015-2016 Highlight Seminar Series.

Princeton E-affiliates  
Partnership Member  
Companies during  
2015-2016:  
ExxonMobil  
PSEG  
Southern Company  
Power Survey Company  
Princeton Power Systems

Princeton E-affiliates Partnership

Princeton E-affiliates Partnership (E-affiliates), which is administered by the Andlinger Center for Energy and the Environment, aims to enhance collaboration and promote technology transfer between Princeton University and its corporate partners to address global energy needs and environmental concerns.

In late October 2015, E-affiliates hosted its newest member, ExxonMobil, on campus for a series of workshops over two days. Princeton faculty members and researchers shared their areas of expertise with over 50 scientists and engineers from ExxonMobil with the goal of discovering areas of mutual interest and developing collaborative projects. The workshops resulted in five projects funded by ExxonMobil for over one to three years, with discussions on future projects continuing.

Details on the five projects:

- 1. Polymer photovoltaics with **Yueh-Lin (Lynn) Loo**, director of the Andlinger Center for Energy and the Environment, Theodora D. '78 and William H. Walton III '74 Professor in Engineering, and professor of chemical and biological engineering.

The research will examine new polymeric photovoltaic (solar) materials and their applications as coatings and building materials. The goal is to understand how structural heterogeneities in these polymer-based materials impact the performance of solar cells that incorporate them.

- 2. Extending battery lifetime and cycle efficiency with **Daniel Steingart**, assistant professor of mechanical and aerospace engineering and the Andlinger Center for Energy and the Environment.

The research will investigate batteries used in electric vehicles and how they degrade by using recently developed investigative tools created in Steingart's lab. The project will also examine how these batteries may be used on the electric grid.

- 3. Arctic sea-ice modeling with **Alistair Adcroft**, research oceanographer, and **Olga Sergienko**, research glaciologist, at Princeton's Atmospheric and Ocean Sciences Program/NOAA-Geophysical Fluid Dynamics Laboratory.

The research will focus on creating and advancing sea-ice models in order to understand the conditions and factors governing Arctic sea-ice cycles. The goal is to create more accurate long-range and seasonal forecasts of sea-ice melting and formation.

- 4. Role of the ocean in the future of atmospheric carbon dioxide levels with **Daniel Sigman**, Dusenbury Professor of Geological and Geophysical Sciences and professor of geosciences.



Eric Herbolzheimer, section head of engineering physics and senior scientific advisor at ExxonMobil Research and Engineering Company, and Yueh-Lin (Lynn) Loo, director of the Andlinger Center.

Photo credit: ExxonMobil

The research will investigate how past periods of warming have impacted the ocean's role in the global carbon cycle. These findings will provide clues to how quickly the ocean will absorb carbon dioxide that is emitted by human activities.

5. Plasma physics with **Egemen Kolemen**, assistant professor of mechanical and aerospace engineering and the Andlinger Center for Energy and the Environment and the Princeton Plasma Physics Laboratory, and **Yiguang Ju**, Robert Porter Patterson Professor of Mechanical and Aerospace Engineering and the director of the Program in Sustainable Energy.

The goal of this research is to examine the role and effectiveness of low-energy plasmas on energy-related chemical processes. One such example is how plasma can convert natural gas into larger molecules for use in producing chemical feedstocks or fuels.

Hosted by **Paul Chirik**, associate director for external partnerships and the Edwards S. Sanford Professor of Chemistry, the E-ffiliates Fourth Annual Meeting was held on November 20, 2015. **Franklin (Lynn) Orr**, the undersecretary for science and energy at the Department of Energy (DOE), presented the keynote address. He discussed the department's 2015 Quadrennial Technology Review, a report that outlined various renewable energy technologies, infrastructure, and electricity storage. During his speech, Orr urged scientists, economists, and policy-makers to look beyond their own research, collaborate, and consider the energy infrastructure as an intertwined system with multidisciplinary components. Orr said such concerted efforts could diversify primary energy sources, lower costs, and increase efficiency of renewable energy. The annual meeting also included presentations by **Marcus**

**Hultmark**, assistant professor of mechanical and aerospace engineering; **Daniel Steingart**, assistant professor of mechanical and aerospace engineering and the Andlinger Center for Energy and the Environment; **Fabian Wagner**, the Gerhard R. Andlinger Visiting Professor in Energy and the Environment; and **Sander van der Linden**, a postdoctoral research associate and lecturer at the Andlinger Center, the Woodrow Wilson School of Public and International Affairs, and the Department of Psychology. Panel discussions on the future of solar photovoltaics and energy economics were also featured at the event. After the talks and panel discussions, more than 30 students and postdoctoral researchers presented their work at a poster session. Academic and industrial attendees mingled extensively and had lively discussions about the projects on display. Industry representatives from ExxonMobil, PSEG, and Power Survey Company attended.

E-ffiliates hosted its annual retreat on January 28 and 29, 2016. The informal gathering fostered strong connections and open discussion between students, postdoctoral fellows, faculty, and representatives from E-ffiliates member companies. Attendees were treated to panel discussions on the future of oil and achieving



Left to right: Joseph J. Berry, senior research scientist at the National Renewable Energy Laboratory and a panelist at the E-ffiliates Fourth Annual Meeting, is seen here speaking to graduate student Gabriel Man on his research during the event's poster session.

Photo by David Kelly Crow

a carbon-neutral future while considering different pathways and challenges. **Vijay Swarup**, vice president of research and development at ExxonMobil Research and Engineering Company, gave the keynote. More than 30 students and postdoctoral researchers presented their projects at a poster session.

In response to the 2015 annual request for research proposals, E-affiliates awarded funding to two projects. One project, led by **José Avalos**, assistant professor of chemical and biological engineering and the Andlinger Center for Energy and the Environment, proposed to develop yeast strains for advanced biofuels production. In the other project, **Alexander Smits**, the Eugene Higgins Professor of Mechanical and Aerospace Engineering, is collaborating with Southern Company to develop a new wind-energy-collecting device.

### U.S. Army Collaboration

The Andlinger Center signed an agreement for future collaborations on energy and environmental research and information exchange with the Picatinny Arsenal Garrison and the U.S. Army's Armament Research, Development and Engineering Center on June 6, 2016.

Through the new partnership, all three parties agreed to share ideas and institutional knowledge related to energy and environmental issues, help accelerate research, catalyze technology transfer, assist in meeting the Army's sustainability goals, make available facilities and infrastructure at Picatinny for demonstration and research, and hold periodic site meetings to further grow dialogue and collaboration. Picatinny Arsenal is recognized as the Army's home in northern New Jersey. The Armament Research, Development and Engineering Center, the largest tenant in Picatinny, researches, develops, and manages weapon systems and munitions.

On specific projects, discussions are ongoing between researchers at Princeton and at Picatinny to take unused ammunition and convert it into biofuels instead of simply burning it as a means of disposal.



Vijay Swarup, vice president of research and development for ExxonMobil Research and Engineering Company, presented the keynote address at the E-affiliates Annual Retreat.

Photo by Frank Wojciechowski



From left to right: Brigadier General Patrick W. Burden, senior commander at Picatinny Arsenal Garrison; Pablo Debenedetti, Princeton's dean for research, Class of 1950 Professor in Engineering and Applied Science, and professor of chemical and biological engineering; and John Hedderich III, director of the U.S. Army's Armament Research, Development and Engineering Center.

Photo by Frank Wojciechowski

### Equipment and Facilities

Brand new cleanrooms and an imaging and analysis center, both of which feature state-of-the-art equipment, are now operational at the Andlinger Center for Energy and the Environment at Princeton University. These facilities and tools, administered by the Princeton Institute for the Science and Technology of Materials, will push forward the development of sustainable energy technologies and solutions.

There are close to 27,000 square feet of cleanrooms on two floors, of which 10,000 square feet houses the Micro/NanoFabrication Lab. These spaces have infrastructure that filters and reduces airborne dust. This dust-free space enables the research and fabrication of delicate materials and devices. The new cleanrooms, which more than double the former cleanroom capacity on campus, are home to new equipment, such as energy-efficient clean hoods for fabrication, a direct-write laser-based lithography system that exposes light-sensitive materials in order to produce patterns on wafers, and new capability atomic-layer and chemical-vapor materials deposition tools.

The imaging and analysis center features new tools, such as high-end, state-of-the-art electron- and focused ion-beam instruments, an X-ray photoelectron spectrometer, and in-situ analysis and sample preparation tools to conduct fundamental investigations of complex materials for applications in nanotechnology, energy, and the environment.

One notable piece of equipment in the imaging and analysis center is the Titan Themis, a 12-and-a-half-foot tall scanning/transmission electron microscope that can examine substances at the level of a single atom. The Titan Themis is considered one of the most powerful microscopes in the world with a resolution of 0.7 Ångstrom. A hydrogen atom is about one Ångstrom in diameter. One of four such microscopes in the world, the Titan Themis will catapult energy research at the Andlinger Center to a new frontier.

### Sculpture

In front of the Andlinger Center is a stunning 19-foot sculpture of hand-beaten copper. The piece was created by famed artist Ursula von Rydingsvard and was first modeled in her signature material of choice, rough-hewn cedar block. Metal artist Richard Webber and a team of artisans fabricated the final piece.



Photo by Frank Wojciechowski

Marcos Reyes-Martinez, a postdoc in chemical and biological engineering, uses an optical microscope at the new imaging and analysis center.



Photo by David Kelly Crow

Ursula von Rydingsvard designed the iconic sculpture in front of the Andlinger Center.

### Building Facts

- Designed by Tod Williams Billie Tsien Architects
- Totals 129,000 square feet
- Construction began in 2012 and continued for four years
- Layout features Maeder Hall (208-seat lecture hall and meeting spaces); central structure contains offices, graduate student and postdoc spaces, a classroom, and teaching and research labs; rear area holds cleanrooms and an imaging and analysis center
- Interior art crafted using felt murals that display enlarged laboratory notebook images from famous scientists and engineers, such as Rosalind Franklin and Nikola Tesla
- Exterior enhanced by three sunken courtyards with gardens; plants include weeping beech trees, boxwood, ferns, witch hazel, day lilies, and rhododendrons

### Sustainability Features

- 60 percent of the building is below grade to leverage the Earth's natural thermal insulation.
- Recycled rainwater is captured and reused for irrigation and other non-potable uses.
- Green roofs and gardens provide temporary rainwater storage to and provide filtration of water; reduce CO<sub>2</sub> and the heat-island effect; and increase the urban habitat.
- Radiant ceiling panels
- Exterior windows are strategically placed to maximize daylight while minimizing heating and cooling loads. Operable windows provide ventilation in offices, and to conserve energy, will shut down the air conditioning when opened.
- Operable shades and louvers at windows and skylights reduce heating and cooling loads.
- Exhaust fans are strategically located to reduce power consumption and noise.
- Daylight sensors and dimmers reduce the consumption of electricity.
- Showers/changing rooms accommodate cyclists and walkers to encourage low-carbon commuting.
- Heat recovery at exhaust fans pre-tempers water used for heating and cooling.
- Vacancy sensors turn lights off when offices and labs are unoccupied.
- Bottle filling stations provide fresh and filtered water.



A view of the green roof at the Andlinger Center.

Photo by David Kelly Crow

## Andlinger Center for Energy and the Environment

### Emily A. Carter

Founding Director, Andlinger Center for Energy and the Environment  
Dean, School of Engineering and Applied Science (effective July 1, 2016)  
Gerhard R. Andlinger Professor in Energy and the Environment  
Professor of Mechanical and Aerospace Engineering and Applied and Computational Mathematics

### Yueh-Lin (Lynn) Loo

Director, Andlinger Center for Energy and the Environment (effective July 1, 2016)  
Theodora D. '78 and William H. Walton III '74  
Professor in Engineering  
Professor of Chemical and Biological Engineering

### Paul Chirik

Associate Director for External Partnerships  
Edwards S. Sanford Professor of Chemistry

### Peter Jaffé

Associate Director for Research  
Professor of Civil and Environmental Engineering

### Niraj Jha

Associate Director for Education  
Professor of Electrical Engineering

### Jennifer L. Poacelli

Associate Director for Administration

### Sharon Adarlo

Communications Specialist

### Robert Eich

Program and Financial Assistant

### Robin Hauer

Assistant Director, Princeton E-filiates Partnership

### Sarah Jackson

Administrative Assistant

### Brenda Mikeo

Business Manager

### Moira Selinka

Education and Outreach Coordinator

### Charmaine Smiklo

Program Assistant, Princeton E-filiates Partnership

## External Advisory Council

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Hines Professor of Sustainable Architectural Design  
Yale University

### A. Paul Alivisatos

Vice Chancellor for Research  
University of California, Berkeley

### Gerhard R. Andlinger '52 P80 P91

Chairman of the Board  
Andlinger & Company, Inc.

### Merrick G. Andlinger '80

President  
Andlinger & Company, Inc.

### Sally Benson

Director, Global Climate and Energy Project  
Stanford University

### Yet-Ming Chiang

Kyocera Professor of Ceramics  
Massachusetts Institute of Technology

### David Eaglesham

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### Ralph Izzo

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### Lisa Lee Morgan '76 \*79

Co-Founder and Chief Executive Officer  
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### Gregory H. Olsen

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GHO Ventures, LLC

### Mark F. Rockefeller '89

Chief Executive Officer and Founder  
Rockefeller Consulting/Insight Capitalists

### Timothy Sands

President  
Virginia Polytechnic Institute and State University

## **Executive Committee**

### **José L. Avalos**

*Assistant Professor of Chemical and Biological Engineering and the Andlinger Center for Energy and the Environment*

### **Emily A. Carter**

*Founding Director, Andlinger Center for Energy and the Environment  
Dean, School of Engineering and Applied Science (effective July 1, 2016)  
Gerhard R. Andlinger Professor in Energy and the Environment  
Professor of Mechanical and Aerospace Engineering and Applied and Computational Mathematics*

### **Paul Chirik**

*Associate Director for External Partnerships, the Andlinger Center for Energy and the Environment  
Edwards S. Sanford Professor of Chemistry*

### **Peter Jaffé**

*Associate Director for Research, the Andlinger Center for Energy and the Environment  
Professor of Civil and Environmental Engineering*

### **Niraj Jha**

*Associate Director for Education, the Andlinger Center for Energy and the Environment  
Professor of Electrical Engineering*

### **Egemen Kolenen**

*Assistant Professor of Mechanical and Aerospace Engineering and the Andlinger Center for Energy and the Environment and the Princeton Plasma Physics Laboratory*

### **Forrest Meggers**

*Assistant Professor of Architecture and the Andlinger Center for Energy and the Environment*

### **François Morel**

*Albert G. Blanke, Jr., Professor of Geosciences  
Professor of Geosciences and the Princeton Environmental Institute (PEI)  
Director, PEI*

### **Michael Oppenheimer**

*Albert G. Milbank Professor of Geosciences and International Affairs and PEI  
Director, Center for Science, Technology and Environmental Policy*

### **Athanassios Z. Panagiotopoulos**

*Susan Dod Brown Professor of Chemical and Biological Engineering*

### **Stewart C. Prager**

*Professor of Astrophysical Sciences  
Director, Princeton Plasma Physics Laboratory*

### **Barry Rand**

*Assistant Professor of Electrical Engineering and the Andlinger Center for Energy and the Environment*

### **James A. Smith**

*William and Edna Macaleer Professor of Engineering and Applied Science  
Professor of Civil and Environmental Engineering  
Chair, Department of Civil and Environmental Engineering*

### **Daniel Steingart**

*Assistant Professor of Mechanical and Aerospace Engineering and the Andlinger Center for Energy and the Environment*

### **Claire White**

*Assistant Professor of Civil and Environmental Engineering and the Andlinger Center for the 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 for Energy and the Environment at Princeton University. The faculty leadership team and all members of the Executive Committee are named Associated Faculty.

### **Craig B. Arnold**

*Professor of Mechanical and Aerospace Engineering  
Director, Princeton Institute for the Science and  
Technology of Materials*

### **Jay Benziger**

*Professor of Chemical and Biological Engineering*

### **Rene Carmona**

*Paul M. Wythes '55 Professor of Engineering and  
Finance  
Professor of Operations Research and Financial  
Engineering  
Chair, Department of Operations Research and  
Financial Engineering*

### **Michael A. Cella**

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

### **Christopher F. Chyba**

*Professor of Astrophysical Sciences and International  
Affairs  
Director, Program on Science and Global Security*

### **Pablo G. Debenedetti**

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

### **Alexander Glaser**

*Associate Professor of Mechanical and Aerospace  
Engineering and International Affairs  
Co-Director, Program in Science and Global Security*

### **Claire Gmachl**

*Eugene Higgins Professor of Electrical Engineering  
Director, Program in Materials Science and Engineering  
Director, Mid-InfraRed Technologies for Health and  
the Environment — a National Science Foundation  
Engineering Research Center*

### **Mikko Haataja**

*Professor of Mechanical and Aerospace Engineering*

### **Yiguang Ju**

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

### **Bruce E. Koel**

*Professor of Chemical and Biological Engineering*

### **Chung (Ed) Law**

*Robert H. Goddard Professor of Mechanical and  
Aerospace Engineering*

### **A. James Link**

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Our online directory of Princeton University faculty and senior researchers, whose research portfolios include energy or energy-related environmental issues, continues to grow with 111 entries at the end of June 2016. The Andlinger Center for Energy and the Environment 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](http://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	
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Faculty and researchers associated with the Andlinger Center for Energy and the Environment at Princeton University are often cited in local, national, and international news publications, or have had their research highlighted in journals and scientific publications.

In 2015–2016, 35 faculty and researchers listed in the Andlinger Center research directory were referenced more than 240 times in various news sources, such as The New York Times, The Guardian, The Washington Post, BuzzFeed, and other publications. They were quoted, their research featured, or faculty and researchers wrote pieces for the media.

A few that represent the range of sources and topics are:

**Andrew Bocarsly**

*Professor of Chemistry*

The Guardian, “Making money from CO<sub>2</sub>”

<https://www.theguardian.com/environment/2015/sep/27/making-money-co2>

**Emily A. Carter**

*Founding Director, Andlinger Center for Energy and the Environment*

*Dean, School of Engineering and Applied Science (effective July 1, 2016)*

*Gerhard R. Andlinger Professor in Energy and the Environment*

*Professor of Mechanical and Aerospace Engineering and Applied and Computational Mathematics*

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**Peter Jaffé**

*Associate Director for Research, Andlinger Center for Energy and the Environment*

*Professor of Civil and Environmental Engineering*

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**Egemen Kolenen**

*Assistant Professor of Mechanical and Aerospace Engineering and the Andlinger Center for Energy and the Environment and the Princeton Plasma Physics Laboratory*

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**Ning Lin**

*Assistant Professor of Civil and Environmental Engineering*

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**Sander van der Linden**

*Postdoctoral Research Associate and Lecturer at the Andlinger Center for Energy and the Environment, the Woodrow Wilson School of Public and International Affairs, and the Department of Psychology*

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**Michael Oppenheimer**

*Albert G. Milbank Professor of Geosciences and International Affairs and the Princeton Environmental Institute Director, Center for Science Technology and Environmental Policy*

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**Robert Socolow**

*Professor of Mechanical and Aerospace Engineering, Emeritus*

*Senior Research Scholar, Mechanical and Aerospace Engineering*

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**Daniel Steingart**

*Assistant Professor of Mechanical and Aerospace Engineering and the Andlinger Center for Energy and the Environment*

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**Gerard Wysocki**

*Associate Professor of Electrical Engineering*

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