annual report
academic year 2016–2017

excel | engage | inform

andlinger center
for energy+the environment

Cover: A group of undergraduate students created a startup, Revolution Outboards/ Flux Marine, to develop electric boat motors. For more on the startup, see page 13. In the photo, from left to right, are company members and their roles: Elisabeth Weiss '17, business development; Coleman Merchant '19, battery engineering; Kirk Robinson '17, systems engineering; Mark Scerbo '18, power transmission engineering; Ben Sorkin '17, team leader; and Aarav Chavda '17, market research. (Photo: David Kelly Crow)

contents

Message from the Director

Photo: David Kelly Crow

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

2016–17 has shown us that past performance is no guarantee of future results. The U.S., after leading the world in promulgating the Paris climate accord, has signaled its intention to withdraw from the accord, while Europe and China have taken the opposite stance in reaffirming it. The U.S. Environmental Protection Agency, after eight years of prioritizing climate action, has geared up for regulatory reform with widened objectives to include national security and economic growth, while 369 mayors across the U.S. have pledged to bolster local efforts to reduce greenhouse gas emissions. Renewables have expanded exponentially with solar and wind producing some of the world's cheapest electricity, yet renewables still only account for less than 5 percent of the world's electricity production. Oil, still the world's leading transportation fuel, grew its market share of global energy consumption for the second year after a 15-year decline, while Tesla and other automakers are signaling the imminent arrival of mainstream electric vehicles with announcements that lithium ion battery costs will drop below $100/kWh in the near future. In short, we are living in interesting times.

As I look back over my first year as director of the Andlinger Center, I find myself reliving our earnest enthusiasm and commitment to do our part in these interesting times. I recall our many conversations and actions as a community of faculty, researchers, staff, students, and supporters. Over the past year, the center welcomed Elke Weber and Minjie Chen to the faculty, and we developed and articulated a strategic plan aimed at strengthening our impact. Our faculty, researchers, and partners made tangible advances in their areas of expertise while also connecting with students in expanding our community to forward our mission. Dan Steingart and his students launched Feasible, a startup already working with manufacturers and integrators on next-generation, non-invasive diagnostic tools for assessing battery health. Elke Weber worked with the Behavioral Science and Policy Association to introduce an energy efficiency toolkit rooted in behavioral science research to guide the crafting and implementation of policy. And from within my own research group, we recently formed Andluca Technologies, a startup poised to bring onboard solar power for smart-window technologies to market. At the Andlinger Center, we are expanding our reach with new strategic initiatives. We are working to identify and hire additional faculty with systems- and process-level expertise at the energy-water nexus, and in long-term energy storage, as well as smart and resilient cities. In an effort to enhance and diversify the community attuned to energy and environmental solutions, we have also launched a Distinguished Postdoctoral Fellows Program and the Gerhard R. Andlinger Visiting Fellows Program (page 21).

At the Andlinger Center, we are making strides and making a difference. However, we can't do this alone. This massive effort for a more sustainable future requires many people of different disciplines, geographies, and vocations to work together. More importantly, this global effort starts with individual responsibility and commitment in the choices we make and actions that we take every day—whether it's selecting more efficient light bulbs for our homes, making more sustainable choices at the supermarket, or making conscious choices to conserve energy in our daily lives. Our collective actions in these everyday decisions have a cumulative and lasting impact on our environment. To that end, I invite you to personally engage with the Andlinger Center community. Join the conversation on social media, attend a lecture or our annual meeting, share our fellowship opportunities with your colleagues and friends, and support the funding of our activities. We are energized and excited about our mission and our plans for the coming year. I hope you will work with us in forging ahead in these interesting times.

mission + goals

Forrest Meggers, assistant professor of architecture and the Andlinger Center for Energy and the Environment, holds the SMART sensor, a specialized radiant temperature monitor developed in his lab. For more on the sensor, go to page 13. (Photo: Frank Wojciechowski)

to develop solutions to ensure our energy and environmental future by

+ fostering a vibrant and interdisciplinary community
+ accelerating innovation through funding, infrastructure, and intellectual discourse
+ training the next generation of leaders in a broad context
+ partnering with industry, not-for-profit, and government
+ being the leading center for information and advice

research areas

built environment, transportation, and infrastructure

Smart infrastructure, resilient cities, building efficiency systems and retrofits involving faculty from the School of Architecture; microgrids and networks, green cements, cleaner burning combustion engines, electric vehicles, and water desalination technologies

electricity production, transmission, and storage

Emerging technologies to harvest wind and solar power, nuclear fusion, power electronics and superconducting materials that enable more power transmission, grid-scale electricity storage, and modeling of grids with high renewables penetration

fuels and chemicals

Advanced fuels and chemicals from engineered microorganisms and artificial photosynthesis, development of catalysts with abundant elements, and techno-economic and lifecycle assessments of advanced biofuel production systems

environmental sensing and remediation

Sensors to detect emissions of carbon and nitrogen cycle gases to the atmosphere from the energy, water and food sectors; carbon capture and storage; and wastewater treatment and soil remediation technologies using nanoparticles and microorganisms

decision and behavioral science, policy, and economics

In partnership with faculty and researchers at the Woodrow Wilson School of Public and International Affairs, individual and collective decision-making and economic analysis related to energy and environmental policy

environmental and climate science

In partnership with faculty and researchers at the Princeton Environmental Institute, environmental monitoring and modeling of Arctic sea ice, carbon dioxide absorption by oceans, extreme weather, and coastal impacts

andlinger center
for energy+the environment

FROM INCEPTION THROUGH JUNE 2017

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40 research projects supported by the Andlinger Center, **$3.8 million** invested

32 external grants totaling **$15.6 million**

151 grad students & postdocs supported

53 publications

9 patent disclosures and applications

3 startups

Over **$4 million** in derivative external funding from seed grants

engage

11 research projects funded, **$1.4 million** invested via Princeton E-ffiliates Partnership research fund

12 E-ffiliates member-directed research projects funded, **$4.4 million** invested

5 corporate E-ffiliates members

115 affiliated faculty across **44** departments, programs, and centers on Princeton campus

inform

38 Energy Studies (ENE) courses

34 undergrad certificate graduates

8 Maeder Fellows

44 undergrad summer interns

selected events timeline 2016-2017

July 2016

Yueh-Lin (Lynn) Loo becomes director of the Andlinger Center.

September 2016

The Andlinger Center Speaks series' debut

Elke Weber joins the center.

November 2016

Princeton E-ffiliates Partnership Annual Meeting

January 2017

Princeton delegation attends World Economic Forum in Davos, Switzerland.

A new strategic plan for the center is developed.

February 2017

Princeton E-ffiliates Partnership Annual Retreat

Minjie Chen joins the center.

April 2017

"Energy for a Carbon-Constrained World" symposium

May 2017

Ching-Yao Lai named 2017–18 Maeder Graduate Fellow.

NRG Energy joins E-ffiliates.

June 2017

Board of Trustees approves Daniel Steingart's promotion to associate professor.

Six undergraduates are awarded summer research internships at the center.

Summer 2017

Siemens joins E-ffiliates.

The Gerhard R. Andlinger Visiting Fellows Program and Distinguished Postdoctoral Fellows Program are launched.

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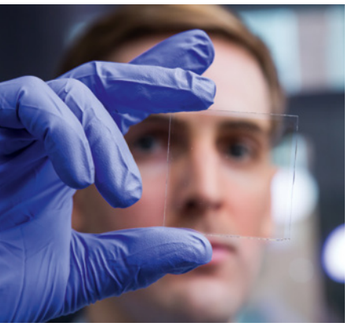


Nicholas Davy, a doctoral student in the chemical and biological engineering department, holds up a transparent solar cell active layer stack. For more on the technology, go to page 10.
(Photo: David Kelly Crow)

Opposite
Claire White, assistant professor of civil and environmental engineering and the Andlinger Center for Energy and the Environment, works in her lab creating sustainable alternatives to Portland cement. (Photo: David Kelly Crow)

From smart environmental policies to the development of superconducting materials, world-class researchers are studying a wide breadth of topics at the Andlinger Center for Energy and the Environment at Princeton University. The center fosters a creative, collaborative atmosphere for research. Andlinger Center faculty members and researchers have been recognized for their work with prestigious awards and grants; they have published their discoveries in top journals; filed national and international patents; and launched startups based on work in their labs. The center furthers energy and environment research by funding innovative, ambitious projects that tackle big problems on multiple fronts.

A constellation of six interacting research areas forms the heart of the center's focus: Built Environment, Transportation, and Infrastructure; Electricity Production, Transmission, and Storage; Fuels and Chemicals; Environmental Sensing and Remediation; Decision and Behavioral Science, Policy, and Economics; and lastly, Environmental and Climate Science (see page 3). Solutions emerging from these areas can be applied to help solve our monumental challenges in energy and the environment.


Daniel Steingart


Elke Weber


Sankaran Sundaresan


Michael Celia

Faculty and Staff News

Daniel Steingart, jointly appointed to Princeton's mechanical and aerospace engineering department and the Andlinger Center, was promoted to associate professor in July 2017. Steingart, an expert on energy storage and battery technologies, joined the University as an assistant professor in 2013, and has been widely recognized for his work, most recently the development of a non-invasive acoustical approach to evaluating battery health.

Elke Weber, the Gerhard R. Andlinger Professor in Energy and the Environment and professor of psychology and public affairs, Woodrow Wilson School, assumed the role of associate director for education at the Andlinger Center in the spring. She replaced **Niraj Jha**, professor of electrical engineering, who held the post since 2013.

Sankaran Sundaresan, the acting associate director for research at the Andlinger Center, the Norman John Sollenberger Professor in Engineering, and professor of chemical and biological engineering, oversaw the creation of the Gerhard R. Andlinger Visiting Fellows and the Distinguished Postdoctoral Fellows programs. He also revamped the center's request for research proposals during the spring semester while **Peter Jaffé**, associate director for research at the Andlinger Center, the William L. Knapp '47 Professor of Civil Engineering, and professor of civil and environmental engineering, was on sabbatical.

Michael Celia, the Theodora Shelton Pitney Professor of Environmental Studies and professor of civil and environmental engineering, was appointed director of the Princeton Environmental Institute in July 2017. Celia, a member of the executive committee for the Andlinger Center, has collaborated with center faculty and was awarded center funding for a project studying abandoned oil and gas wells that leak methane.

In March 2017, **Jeffrey Fitts** joined the Andlinger Center as research and development strategist. Fitts is cultivating and catalyzing cross-disciplinary research relationships to develop and support large, collaborative center grant proposals, and helping grow, refine, and strengthen Princeton E-ffiliates Partnership, the corporate affiliates program administered by the center. Prior to joining the Andlinger Center, Fitts was a research scholar in the Department of Civil and Environmental Engineering at Princeton. He has a doctoral degree in geochemistry from Stanford University.

In August 2017, **Greta Shum '14** joined the center as a digital communications specialist. She is responsible for content on the Andlinger Center website and social media channels, in addition to developing video and multimedia projects featuring center research. Before joining the Andlinger Center, Shum was a research analyst and multimedia journalist at Climate Central, a nonprofit organization devoted to communicating information on climate change. Shum earned a bachelor's degree in comparative literature and a certificate in planets and life from Princeton.


Paul Chirik


Forrest Meggers


Minjie Chen


Claire White


José Avalos

Selected Faculty Award Highlights

Yueh-Lin (Lynn) Loo, director of the Andlinger Center for Energy and the Environment, the Theodora D. '78 and William H. Walton III '74 Professor in Engineering, and professor of chemical and biological engineering, was recognized as a 2017 Scholar through China's Thousand Talents Plan for Distinguished Scientists in the short-term category. The Thousand Talents Plan is an initiative by the government to bring overseas top talent to China.

Elke Weber, the center's associate director for education, the Gerhard R. Andlinger Professor in Energy and the Environment, and professor of psychology and public affairs, Woodrow Wilson School, received the Society for Risk Analysis' Distinguished Achievement Award, the society's highest honor. Weber was honored for her contributions to understanding how people perceive risks and make decisions.

Paul Chirik, the Edwards S. Sanford Professor of Chemistry and member of the Andlinger Center's executive committee, was awarded the 2017 American Chemical Society Catalysis Lectureship for the Advancement of Catalytic Science. This award honors groundbreaking work in the development of impactful new catalytic processes.

Minjie Chen, assistant professor of electrical engineering and the Andlinger Center for Energy and the Environment, received a seed grant to develop a smart energy router for homes and buildings from the Siebel Energy Institute, a global consortium for innovative and collaborative energy research.

Two faculty members jointly appointed to the center, **Claire White**, assistant professor of civil and environmental engineering, and **José Avalos**, assistant professor of chemical and biological engineering, received 2017 Junior Faculty Awards from Princeton's School of Engineering and Applied Science. The award recognizes faculty for early-career accomplishments and clarity of exposition in teaching and research.

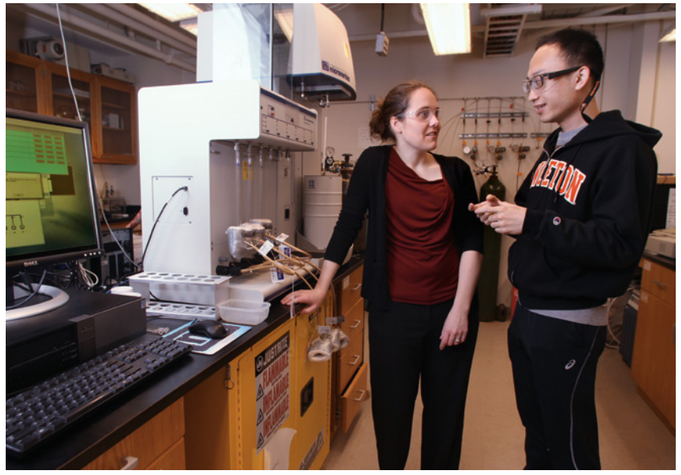
The Eric and Wendy Schmidt Transformative Technology Fund

Two collaborative projects involving Andlinger Center faculty members were awarded funding from the Eric and Wendy Schmidt Transformative Technology Fund, which was started by Eric Schmidt, executive chairman of Google parent company Alphabet Inc., a 1976 alumnus and a former University trustee, and his wife, Wendy.

José Avalos, assistant professor of chemical and biological engineering and the Andlinger Center for Energy and the Environment, is working on a system for boosting the productivity of bioreactors, which could reduce the cost and increase the efficiency of creating biofuels, medicines, and other chemical products. Other team members are **Yannis Kevrekidis**, the Pomeroy and Betty Perry Smith Professor in Engineering, professor of chemical and biological engineering and applied and computational mathematics, emeritus, and senior scholar, and **Jared Toettcher**, assistant professor of molecular biology.

Forrest Meggers, assistant professor of architecture and the Andlinger Center for Energy and the Environment, is helping construct a specialized test facility to develop wind turbine designs without building full-scale prototypes. Other team members are **Marcus Hultmark**, assistant professor of mechanical and aerospace engineering and the project's lead researcher, and **Elie Bou-Zeid**, associate professor of civil and environmental engineering.

Research Highlights



Claire White, assistant professor of civil and environmental engineering and the Andlinger Center for Energy and the Environment, discusses sustainable cement with doctoral student Kengran Yang. (Photo: Frank Wojciechowski)

Taking concrete steps toward lower carbon dioxide emissions

Claire White, assistant professor of civil and environmental engineering and the Andlinger Center for Energy and the Environment, has been working with her research team on testing the long-term durability of greener cement alternatives, called alkali-activated materials, to replace Portland cement, which is responsible for as much as 8 percent of human carbon dioxide emissions and is projected to double in production in the next 30 years. White's research team applied a novel testing approach, dubbed "a beam-bending test," to accurately evaluate the permeability of two types of alkali-activated materials. Permeability is an important indication of a cement's durability and is usually hard to measure on saturated samples in the lab.

"We want to develop new methods to obtain accurate data on how these materials (green cement alternatives) will perform over time. This will help with the implementation of sustainable alternatives in the construction industry."
—Claire White

Analysis shows carbon-slashing promise of new biofuel technology

Developing a sustainable vehicle fuel poses a difficult challenge: it has to be relatively cheap and has to reduce carbon emissions without using up valuable crop land or trees from forests. **Eric Larson**, a senior research engineer, and postdoctoral fellow **Hans Meerman**, both members of the **Energy Systems Analysis Group** at the Andlinger Center, have analyzed and designed one possible solution: catalytic hydropyrolysis, a method that creates fuel from crop or wood residues. The researchers demonstrate how the fuel becomes carbon-negative when carbon capture and sequestration is integrated into the fuel production process.

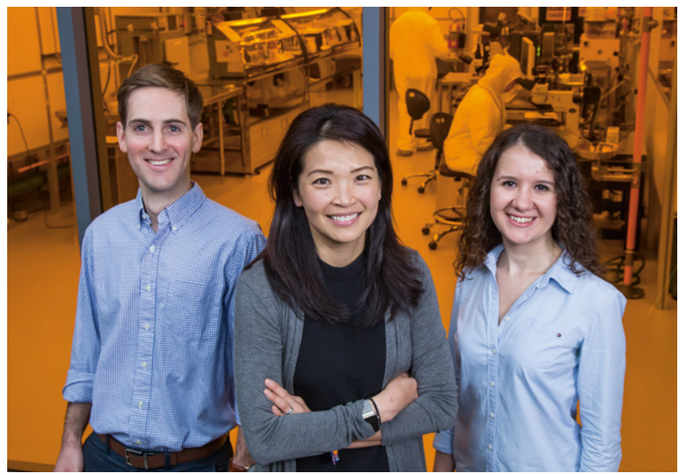
Self-powered system makes smart windows smarter

Smart windows equipped with controllable glazing can augment lighting, cooling, and heating systems by varying their tint, saving up to 40 percent in an average building's energy costs. These smart windows require power for operation, so they are relatively complicated to install in existing buildings. **Yueh-Lin (Lynn) Loo**, director of the Andlinger Center, the Theodora D. '78 and William H. Walton III '74 Professor in Engineering, and professor of chemical and biological engineering, and her lab have developed transparent solar cells that self-power smart windows. The system, whose solar cells selectively absorb near-ultraviolet (near-UV) light, promises to be inexpensive and easy to apply to existing windows.

"By understanding their [emissions'] spatial and temporal variabilities, we can identify methods to take care of our environment, efficiently utilize energy, and improve our food and energy production to minimize the impacts on our climate."
—Mark Zondlo

Vehicles, not farms, are likely source of smog-causing ammonia

Agriculture has long been blamed for smog-causing ammonia in the atmosphere, but vehicle tailpipes actually are a more important source of ammonia's contribution to the haze that hovers over big cities, according to **Mark Zondlo**, associate director of external partnerships at the Andlinger Center and associate professor of civil and environmental engineering. Zondlo's research team found that ammonia emissions from cities are much larger than recognized, and they occur at the very times when unhealthy particulate matter is at its worst and when agricultural emissions are at daily or seasonal lows.



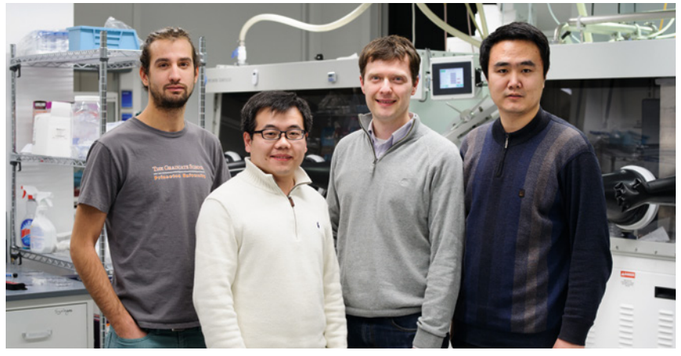
Princeton engineers invented a self-powered window system that could lower heating and cooling costs. The team, led by Professor Yueh-Lin (Lynn) Loo, director of the Andlinger Center for Energy and the Environment, center, includes graduate students Nicholas Davy, left, and Melda Sezen-Edmonds, right. Behind them is a cleanroom at the Andlinger Center. (Photo: David Kelly Crow)

Synthetic natural gas would cut air pollution in China but worsen climate change

A team led by Princeton researchers determined that China would experience a major increase in carbon dioxide emissions if industry and power plants switched from coal to synthetic natural gas (SNG), derived by gasifying coal, but this would have little air quality or health benefit due to the use of pollution controls on existing plants. However, switching from coal to SNG for relatively inefficient residential stoves used for heating and cooking, which lack any end-of-pipe pollution controls, would substantially reduce deaths due to air pollution and cause less of an increase in emissions. The team included **Denise Mauzerall**, professor of civil and environmental engineering and public and international affairs, Woodrow Wilson School, and **Fabian Wagner**, a senior research scholar at the International Institute for Applied Systems Analysis in Austria. Wagner did this work with Mauzerall while he was the Gerhard R. Andlinger Visiting Professor in Energy and the Environment at the Andlinger Center from 2014-16.

Self-assembling particles brighten future of LED lighting

Barry Rand, assistant professor of electrical engineering and the Andlinger Center for Energy and the Environment, developed a technique in which nanoscale perovskite particles self-assemble to produce more efficient, stable, and durable perovskite-based light-emitting diodes (LEDs). Perovskites are crystalline substances that are efficient and potentially a lower-cost alternative to materials used in current LEDs.



Barry Rand, (third from left) an assistant professor of electrical engineering and the Andlinger Center for Energy and the Environment, helped develop a new LED in his lab with lab members (left to right) Ross Kerner, a doctoral student; Zhengguo Xiao, a postdoctoral researcher; and Lianfeng Zhao, a doctoral student.
(Photo: Sameer A. Khan/Fotobuddy)

Andlinger Center 2017 Seed Grant Awards

Collaborative Initiative for Developing Ammonia as a Carbon-Neutral Fuel

The development and implementation of scalable, carbon-neutral, high-energy density liquid fuels are an essential component for a sustained and practical alternative energy economy. Unfortunately, few molecules have the remarkable properties and abundance of hydrocarbons—the principal source of anthropogenic carbon dioxide. Ammonia is promising as an alternative due to its energy density and because it can be made from nitrogen, the most abundant gas in the Earth's atmosphere. It can be used as fuel for transportation and to power homes, but current synthetic methods rely on fossil fuels and hence generate CO_2 waste. For this project, a team of seven faculty, from chemistry and chemical and biological engineering, led by **Paul Chirik**, the Edwards S. Sanford Professor of Chemistry, will explore two experimental methods to generate ammonia that are projected to be more sustainable than current, existing processes.

Electrification of Transportation for Energy Storage and Smart Mobility

In 2015, 67 percent of U.S. electricity was generated from fossil fuels and more than 70 percent of oil was consumed by transportation, making transportation one of the major sources of greenhouse gases and environmental pollution. Wind and solar offer a pathway to clean energy generation, but the intermittency of renewables represents a major engineering challenge, where energy storage seems to offer a potential solution. With the recent development of electric vehicles and autonomous driving technologies, a promising solution to the challenges of renewable energy production and the emissions from fossil fuel-based transportation is the electrification and intelligent management of transportation systems and mobility. For this project led by **Yiguang Ju**, the Robert Porter Patterson Professor of Mechanical and Aerospace Engineering and director of the Program in Sustainable Energy, a team of 12 faculty across six departments will develop technological solutions for electrification of transportation systems for energy storage and smart mobility and address technical questions associated with these systems.

Funding for the Andlinger Center Seed Grant Awards was provided by the following: the Addy/ISN North American Low Carbon Emission Energy Self-Sufficiency Fund, a gift from John E. Cross '72 and Mary Tiffany Cross, a gift from David T. Liu '99 *04, the High Meadows Foundation's Andlinger Center for Energy and the Environment Director's Fund, 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 Energy and the Environment, the David P. Simons Fund for Energy and the Environment, the Sustainability Fund, a gift from William H. Walton, III '74 and Theodora D. Walton '78 P21, a gift from Maura Wong '88 and Kenneth Chen '87 P20, and anonymous gifts for research.

Return on Investment from Andlinger Center Seed Funding
(Since inception in 2011)

Total amount awarded:
$5.2 million
Derivative funding:
Over $4 million

Projects supported:
53 Publications
9 Patent Disclosures and Applications

Moving Research from Lab to Market at the Andlinger Center

"Our innovative solar-powered technology does not generate enough power for a car, but it can provide auxiliary power for smaller devices, for example, a fan to cool the car while it's parked in the hot sun."
—Yueh-Lin (Lynn) Loo

The Andlinger Center actively encourages an entrepreneurial atmosphere, resulting in startups and researchers filing patents for technologies to help solve the world's energy and environmental problems. Below are a few research projects that are being moved from lab to market.

Andluca Technologies

Nicholas Davy, a doctoral student in the chemical and biological engineering department, and **Yueh-Lin (Lynn) Loo**, director of the Andlinger Center, the Theodora D. '78 and William H. Walton III '74 Professor in Engineering, and professor of chemical and biological engineering, founded a company to develop applications for transparent solar cells, such as for powering smart windows (see page 10), internet-of-things sensors, and other low-power consumer products. The transparent solar cells absorb near-ultraviolet light and can be used outdoors and indoors.

Princeton researchers Hans Meerman (left) and Eric Larson (right) are evaluating a method to create alternative vehicle fuel from crop residues, sawdust, and branches. For more on the process, see page 10.
(Photo: Frank Wojciechowski)

The SMART Sensor

Forrest Meggers, assistant professor of architecture and the Andlinger Center for Energy and the Environment, received funding from **Princeton's IP Accelerator Fund** to support his work on developing a novel sensor, the Spherical Motion Average Radiant Temperature (SMART) building sensor, to measure radiant temperature from surfaces instead of air temperature to more accurately determine thermal comfort in a space. Meggers has obtained a provisional patent and developed working prototypes. The end goal is a sleek, compact, marketable product that changes from making rooms comfortable to actually making people comfortable, according to Meggers.

Feasible

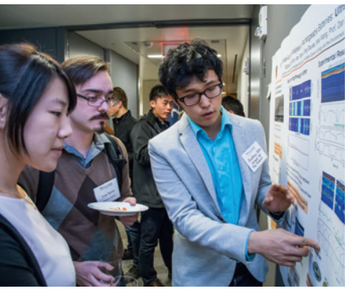
Daniel Steingart, associate professor of mechanical and aerospace engineering and the Andlinger Center for Energy and the Environment, is also using the accelerator funds to support the development of a method to gauge the health of a battery using sound. This technology is the basis for a startup, Feasible, which launched in 2015. Co-founders include **Andrew Hsieh '14**, **Barry Van Tassell**, and **Shaurjo Biswas**. All three were postdoctoral research associates in Steingart's lab.

Revolution Outboards/Flux Marine

A group of Princeton students developed an electric outboard boat motor that can be used in bodies of fresh water and not emit carbon dioxide or leak oil, unlike existing gas-guzzling motors. To implement the technology for the market, the students formed a startup, Revolution Outboards/Flux Marine. The Andlinger Center has provided funding toward this research. Steingart served as adviser to the student team.

In May 2017, the company won the top prize at the 2017 LaunchR competition, a clean technology innovation contest and startup accelerator funded by the U.S. Department of Energy. (See inside front cover for the names of some of the student members.)

engage



Andrew Kim, a graduate student in electrical engineering, presents his research at a poster session at Princeton E-ffiliates Partnership's Fifth Annual Meeting. (Photo: David Kelly Crow)

Opposite
Zahrasadat Lotfian, a postdoctoral researcher in the civil and environmental engineering department, presents her research at the annual meeting of Princeton E-ffiliates Partnership. (Photo: David Kelly Crow)

To catalyze the development of breakthrough technologies that are sustainable and practical, the leadership and staff at the Andlinger Center for Energy and the Environment engage researchers across Princeton University with industry, government, and not-for-profit groups in cross-cutting, multidisciplinary initiatives. The center oversees Princeton E-ffiliates Partnership (E-ffiliates), a corporate membership program that links academic experts and practitioners outside Princeton in big-picture thinking to find innovative solutions to the challenges associated with providing clean energy to a growing population. The diverse community of faculty, researchers, postdocs, and students at the center also interacts with leaders and decision-makers via high-impact events both locally at Princeton and globally, such as at the World Economic Forum in Davos, Switzerland.

"Providing sustainable energy to all is an ambitious task. This requires connections and constant dialogue between industry, government, nongovernmental organizations, and academia. We, at the Andlinger Center, build these links by sponsoring cross-cutting programs and fostering an engaged community that draws people from many backgrounds and disciplines."

—**Mark Zondlo**, associate director for external partnerships at the Andlinger Center for Energy and the Environment and associate professor of civil and environmental engineering

Princeton E-ffiliates Partnership Members

ExxonMobil

Public Service Enterprise Group (PSEG)

Power Survey Company

NRG Energy

Siemens

Top: An audience member asks a question at Princeton E-ffiliates Partnership's Fifth Annual Meeting. (Photo: David Kelly Crow)

Bottom: Peter Jaffé, associate director for research at the Andlinger Center, the William L. Knapp '47 Professor of Civil Engineering, and professor of civil and environmental engineering, speaks at a panel discussion at Princeton E-ffiliates Partnership's annual retreat. (Photo: Frank Wojciechowski)

Princeton E-ffiliates Partnership

Fifth Annual Meeting

In November 2016, energy and environmental experts at E-ffiliates' Fifth Annual Meeting tackled fundamental questions about building and strengthening infrastructure, and proposed solutions for providing and using energy and water more efficiently. **Ralph Izzo**, chairman of the board, president, and CEO of **Public Service Enterprise Group (PSEG)**, a New Jersey energy company and E-ffiliates member, delivered a keynote that touched on the importance of electric grid resiliency, energy efficiency, and renewable energy. The meeting also featured a panel on the energy-water nexus, and another on human behavioral dynamics and climate change. Research talks delved into biofuels, next-generation wind harvesting devices, and decision science. The day-long event was attended by more than 200 guests, including representatives from more than 18 companies and nonprofit organizations, academics from Princeton and other institutions, policy experts, and students and postdocs.

Annual Retreat

Balancing the needs for energy, economic growth, climate change mitigation, and access to clean water and air was the central theme of the animated discussions at E-ffiliates' annual retreat in February 2017. The retreat was attended by more than 75 participants and brought together University faculty, industrial representatives, postdoctoral fellows, and students. The event hosted two interactive panel discussions, a poster session, and a keynote on clean energy by **Matthew Nordan**, managing partner of **MNL Partners**, an international firm that develops energy and environmental projects in global markets, with a focus on China.

E-ffiliates Members Fund Sustainable Energy Research
(Since inception in 2011)

11 total projects funded

$1.4 million
total funds allocated for projects

E-ffiliates Funds Sustainable Energy Research Projects for 2016–17

Forrest Meggers, assistant professor of architecture and the Andlinger Center for Energy and the Environment, is developing new energy-efficient dehumidification technology to cool hot, humid air in buildings.

Diana Tamir, assistant professor of psychology, is deploying Facebook ads that use simple, actionable strategies from psychology research to reduce individuals' energy usage in New Jersey.

Partnership Highlights

Princeton Advances Research & Collaborations with ExxonMobil

Princeton faculty, researchers, and students continue to work side-by-side with **ExxonMobil** researchers on five collaborative research projects across five departments at Princeton. These projects, started in the previous academic year through ExxonMobil's membership in Princeton E-ffiliates Partnership, involve the development of batteries and solar cells, low-temperature plasmas for liquid fuels production, computational modeling of Arctic sea ice, and carbon dioxide absorption in oceans. ExxonMobil has been an E-ffiliates member since 2015, when the company pledged to contribute $5 million over five years to E-ffiliates.

Leveraging their E-ffiliates membership, ExxonMobil sponsored a range of new research projects over the past year. These collaborations involve faculty and researchers in chemistry, chemical and biological engineering, electrical engineering, geosciences, the Princeton Institute for the Science and Technology of Materials (PRISM), and the Program in Atmospheric and Oceanic Sciences.

In 2017, **David Dankworth**, distinguished scientific adviser at ExxonMobil and a 1991 Princeton doctoral graduate in chemical engineering, was named the new company liaison and visitor-in-residence to E-ffiliates, succeeding **Eric Herbolzheimer**, section head of engineering physics and senior scientific adviser at ExxonMobil, upon his retirement.

In April 2017, Dankworth and **John Valenza**, research associate at ExxonMobil and a 2005 Princeton doctoral graduate in civil and environmental engineering, participated in an energy career meet-up with approximately 30 undergraduate students. The event, which featured other alumni speakers, was co-organized by the Andlinger Center and the student organization **Princeton University Energy Association**. Energy professionals talked about their career paths and opportunities in the energy field over lunch. Separately, 43 materials science students (MSE 505), both undergraduates and graduates, visited ExxonMobil's research center in Clinton, New Jersey. They toured imaging labs and specialized facilities, such as 3D printing. In May 2017, approximately 40 ExxonMobil scientists also toured Princeton's Imaging and Analysis Center, located at the Andlinger Center and managed by PRISM.

Closing out the academic year, ExxonMobil hosted their annual Longer-Range Research Meeting in Princeton in May 2017. Princeton researchers presented highlights of their work on innovative technologies and potential solutions for ensuring the world's energy and environmental future to over 200 ExxonMobil researchers. The event also featured laboratory tours at the Andlinger Center and a student-postdoc-faculty poster session.

PSEG Engagement at Princeton

PSEG networked with undergraduates at an info session at the E-ffiliates Fifth Annual Meeting in November 2016. (See page 16 for more.) PSEG has also played a vital role in psychology professor **Diana Tamir's** E-ffiliates research project by providing monthly electricity usage data broken down by municipality. (See page 16.)

Power Survey Company Sparks Research

In November 2016, E-ffiliates and **Power Survey Company** facilitated collaborative research by bringing in **UK Power Networks** (the utility owns, operates, and manages regulated electricity distribution networks for 18 million residents in Great Britain) to campus to meet with Andlinger faculty.

NRG Energy and Siemens Join E-ffiliates

In the second half of the academic year, **NRG Energy** and **Siemens** joined E-ffiliates as corporate members.

NRG Energy, the leading integrated power company in the U.S., serves almost 3 million residential and commercial customers throughout the country via its retail electricity providers, and is headquartered in Princeton and Houston.

Siemens, one of the world's largest producers of energy-efficient, resource-saving technologies, is a leading supplier of systems for power generation and transmission.

Energy Systems Analysis Group Collaborations

The **Energy Systems Analysis Group (ESAG)** at the Andlinger Center was one of nine research groups selected to receive funding from **Princeton's Innovation Fund**. ESAG's research project involves modeling the U.S. electric grid in collaboration with **NRG Energy**. The project's goal is to assess the ongoing penetration of renewables on the U.S. electric grid and prospects for decarbonization in order to meet the goals of the Paris Agreement on climate.

ESAG collaborated with researchers at the **University of Queensland, the Politecnico di Milano**, and **Southern Company** to complete a two-and-a-half-year study of the techno-economic and carbon-mitigation potential of jet fuel production from coal and biomass with carbon capture and storage. The **U.S. Department of Energy** provided primary funding. The study focused on systems using lignite and woody biomass, both of which are abundant in the southeastern U.S. The study found that with a sufficiently high biomass-to-lignite ratio, the resulting jet fuel would have zero net lifecycle carbon emissions, but would not be economically competitive even in the presence of a high future carbon tax. In contrast, a plant processing only biomass might be competitive without subsidy with a sufficiently strong carbon mitigation policy. Future R&D-driven technological innovations might further improve the economics.

External Collaborations and Engagements

World Economic Forum in Davos

A cohort of Princeton faculty, including Dean of Engineering **Emily A. Carter** and **Yueh-Lin (Lynn) Loo**, director of the Andlinger Center, the Theodora D. '78 and William H. Walton III '74 Professor in Engineering, and professor of chemical and biological engineering, participated in the annual World Economic Forum in Davos, Switzerland, in January 2017. Princeton University President **Christopher L. Eisgruber** led the delegation that took part in important discussions on topics, such as climate change, income inequality and public health, and technological innovation. Other Andlinger Center-affiliated faculty members in the delegation included **Denise Mauzerall**, professor of civil and environmental engineering and public and international affairs at the Woodrow Wilson School; **Guy Nordenson**, professor of architecture; and **Michael Oppenheimer**, the Albert G. Milbank Professor of Geosciences and International Affairs and the Princeton Environmental Institute.

Loo, a World Economic Forum Young Global Leader, took part in a discussion, "Beyond the Possible," with scientists, technologists, and artists on envisioning reality beyond the near term with emerging technologies. Loo also participated in a panel on energy technology and women in technology.

Top
Princeton professors Michael Oppenheimer (left to right) and Guy Nordenson confer as Professor Denise Mauzerall, Dean Emily Carter, and panel moderator Philip Campbell, editor-in-chief of the journal Nature, get ready for discussion at an "Ideas Lab" panel and workshop on climate change at the World Economic Forum in Davos, Switzerland.
(Photo: Pierre Abensur/World Economic Forum)

Middle Left
President Christopher L. Eisgruber makes a point during an "Ideas Lab" program at the World Economic Forum.
(Photo: Pierre Abensur/World Economic Forum)

Middle Right
From left to right at a panel discussion are Bill Gates, co-founder of Microsoft Corporation; President Christopher L. Eisgruber; Navdeep Bains, minister of Innovation, Science, and Economic Development of Canada; and Dean Emily Carter.
(Photo: Princeton University)

Bottom
From left to right: Lynn Loo, director of the Andlinger Center; former Vice President Al Gore; and Professor Denise Mauzerall.
(Photo: Princeton University)

Robert Williams, senior research scientist emeritus, at the symposium held in his honor. (Photo: Frank Wojciechowski)

Panelists discussed the future of climate-change mitigation policies at a symposium honoring Robert Williams. From left to right: Brad Crabtree, vice president at the Great Plains Institute; Henry Kelly, senior scientist at the Michigan Institute for Data Science, University of Michigan; David Hawkins, director of the Climate Program, Natural Resources Defense Council, Washington, D.C.; and John Holdren, former science adviser to President Barack Obama. (Photo: Frank Wojciechowski)

Energy for a Carbon-Constrained World, A Symposium Honoring Robert Williams

John Holdren, former science adviser to **President Barack Obama**, and several influential leaders in energy and the environment, were featured panelists at a symposium, "Energy for a Carbon-Constrained World," held in April 2017 at the Andlinger Center. The all-day event honoring the influential career of **Robert Williams**, senior research scientist emeritus who headed the **Energy Systems Analysis Group** at the Andlinger Center, featured 18 speakers from academia, government, and industry. Presentations covered the important impact of energy efficiency, the explosive growth of wind and solar energy, new technology for carbon capture and sequestration, and the challenges of deep penetration of renewable energy on the electric grid. Panel discussions touched on the future of climate-change mitigation policies. The event attracted over 150 people, many of them from different sectors of the energy field, and some of whom were former colleagues of Williams.

The energy parklet in downtown Princeton that Andlinger Center faculty helped design and build. (Photo: Sharon Adarlo)

Other Engagements

Representatives from **Singapore Power Ltd.**, which distributes power throughout the city-state, visited the Andlinger Center in December 2016 and gave a talk on the challenges of providing energy in a place with few natural resources.

Princeton faculty and students got a first-hand look at the growing wind industry when they toured **BP's Sherbino Mesa II Wind Farm** in Fort Stockton, Texas, in May 2017.

In the summer of 2017 in downtown Princeton, **Daniel Steingart**, associate professor of mechanical and aerospace engineering, and **Forrest Meggers**, assistant professor of architecture, both jointly appointed to the Andlinger Center, took part in the design and construction of a parklet, a public art installation that turned curbside parking into a community space and featured a variety of green-energy technologies. **The Arts Council of Princeton** organized the construction of the parklet.

The Gerhard R. Andlinger Visiting Fellows Program

The Andlinger Center launched the Gerhard R. Andlinger Visiting Fellows Program over the summer of 2017. The initiative is designed to attract distinguished visitors, who will collaborate with center faculty, researchers, and students, to enrich the research and teaching at the center. Applications from prospective visitors from a variety of backgrounds, including from academia, industry, government, and nongovernmental organizations, are encouraged.

Distinguished Postdoctoral Fellows Program

The Andlinger Center also began accepting applications for its inaugural cohort of Distinguished Postdoctoral Fellows. The program is designed to support outstanding scholars studying in a field related to energy and the environment. Postdoctoral fellows must identify and work with a Princeton mentor.

For more information, go to acee.princeton.edu/opportunities/

Top
Audience members gather in the courtyard at the Andlinger Center during the symposium honoring Robert Williams.
(Photo: Frank Wojciechowski)

Bottom
Joan Ogden, professor of environmental science and policy and director of the Sustainable Transportation Energy Pathway Program, Institute of Transportation Studies at the University of California, Davis, at the symposium on the future of transportation.
(Photo: Frank Wojciechowski)

inform

Andrew Ma '19 examines a thin-film device as part of his summer internship project to improve organic light-emitting diodes at the Andlinger Center for Energy and the Environment. For more on Ma and the internship program, go to page 26.
(Photo: Frank Wojciechowski)

Opposite
Clark Chen, Maeder fellow of 2016–17, works on a surface science instrument, which allows him to investigate the chemistry of molecules for the creation of sustainable fuels.
(Photo: David Kelly Crow)

To achieve the ambitious climate goals of the Paris Agreement, the next generation of leaders will require tools for developing innovative technologies and policy solutions that will ensure a more sustainable future for all. The Andlinger Center for Energy and the Environment at Princeton University facilitates this task through our educational certificate programs, fellowships, internships, and other activities for undergraduates, graduates, and postdocs. Education at Princeton, and at the Andlinger Center more specifically, encourages creative, lateral thinking and prepares our students and postdocs to be fluent in engineering disciplines, social sciences, humanities, and public policy.

The Andlinger Center also aims to inform the population beyond the University. To help shape policy that balances the world's need for energy while healing our environment, active and engaged citizens need more than information—they need smart analysis. The center provides information on existing or emerging energy alternatives and solutions via variety of communication initiatives and public events. These programs are part of the fabric of the center and are an essential part of our mission.

Certificate Programs

The Energy track of the **Program in Technology and Society (ETS)**, offered jointly by the Andlinger Center and Princeton's Keller Center, has graduated students majoring in English, economics, Near Eastern studies, history, and in a variety of engineering disciplines since its inception in 2013.

In June 2017, the ETS program graduated **Joshua Burd**, a senior in chemical and biological engineering. His senior project research, titled "Improvement of Electrochromic Windows through Materials Optimization," focused on investigating a new set of materials to increase the efficiency with which smart windows modulate light and heat entering buildings. **Rachel Zuckerman**, a major in English, also graduated from the ETS program. Her thesis, "Overcoming the Price Barrier: Examining the Value of Applying Group Discounts to Green Energy," concluded that group discounts, through mechanisms, such as those employed by Groupon and Living Social, can effectively overcome price barriers and motivate consumers to purchase green-energy technology without creating risks for vendors.

Burd and Zuckerman presented their work at the Program in Technology and Society symposium in May 2017. This fall, Burd started a master's degree in technology and public policy at the Massachusetts Institute of Technology. After graduation, Zuckerman began consulting for the healthcare industry at a Washington, D.C. firm.

The **Program in Sustainable Energy** graduated 14 engineering students this year from five areas of concentration: chemical and biological, civil and environmental, mechanical and aerospace, operations research and financial engineering, as well as computer science. Many of the graduates have moved on to careers in the energy sector, including positions at Applied Predictive Technologies, PGIM, juwi Inc., ICF International, and Charles River Associates. Others are pursuing further study in energy and environmental disciplines, including environmental change and management at the University of Oxford,

Left
Rachel Zuckerman '17 presents her thesis at the Program in Technology and Society symposium.
(Photo: Frank Wojciechowski)

Right
Joshua Burd '17 at the same symposium.
(Photo: Frank Wojciechowski)

Minjie Chen, assistant professor of electrical engineering and the Andlinger Center for Energy and the Environment.
(Photo: David Kelly Crow)

energy technologies at the University of Cambridge, and software-based techniques to boost the deployment of solar electricity at the KTH Royal Institute of Technology in Stockholm, Sweden.

Course Updates

With the introduction of two new undergraduate courses in the past year, the total number of ENE (Energy Studies) courses the Andlinger Center offers is 38, with 30 at the undergraduate level and eight at the graduate level.

Minjie Chen, assistant professor of electrical engineering and the Andlinger Center for Energy and the Environment, taught a new graduate course in the spring of 2017. ELE 581/ENE 581: Principles of Power Electronics covered the principles and design techniques of electronics, such as circuit topologies, system modeling, and control. Chen is teaching an undergraduate elective in the fall of 2017. ENE 273/ELE 273: Renewable Energy and Smart Grids explores the technical and operational principles of modern electric grids, and provides an overview of various energy sources from fossil-fuel power generators to photovoltaic and wind energy systems.

In the fall of 2017, **Elke Weber**, the Gerhard R. Andlinger Professor in Energy and the Environment and professor of psychology and public affairs, Woodrow Wilson School; and associate director for education at the Andlinger Center, is teaching a new course, ENE 475/PSY 475: Human Factors 2.0–Psychology for Engineering, Energy, and Environmental Decisions. This course covers recent theoretical advances and empirical insights in cognitive and social psychology, especially in human judgment, decision making, and choice architecture, that are relevant for engineers as they address technical and societal challenges related to sustainability. Cross-listed in psychology, this course exposes humanities and social science students to engineering and sustainability solutions as important applications of psychological science.

"Working in a lab is really cool. Having the opportunity to actually work in a lab day in and day out, see what it is like, and see the issues that researchers face is something I really appreciate."
—Abdulghafar Al Tair '19

Dominic Saunders '20 (right) poses with Michael Mueller, assistant professor of mechanical and aerospace engineering and Saunders' summer internship faculty mentor.
(Photo: David Kelly Crow)

Summer Internships at the Andlinger Center

In the summer of 2017, six student interns (listed below), funded by 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**, received more than $36,000 in stipends and support for research materials and supplies to conduct research on campus. Since inception, 44 students have participated in the program. Students have cumulatively received $253,435 in support.

Lindsey Conlan '18

Department of Civil and Environmental Engineering
Mentored by **Claire White**, assistant professor of civil and environmental engineering and the Andlinger Center for Energy and the Environment. Conlan identified the molecular structure, mechanical properties, and ability to sequester carbon in recycled and treated concrete.

Andrew Ma '19

Department of Physics
Mentored by Barry Rand, assistant professor of electrical engineering and the Andlinger Center for Energy and the Environment. Ma improved the efficiency of organic light-emitting diodes using a nanostructured top metal electrode. Ma, a previous summer intern of this program, built on work performed the previous year.

Abdulghafar Al Tair '19 and Fida Newaj '18

Department of Electrical Engineering
Mentored by Minjie Chen, assistant professor of electrical engineering and the Andlinger Center for Energy and the Environment. The students developed a merged photovoltaic cell balancer and power transmitter to wirelessly charge cellphones and drones, with solar energy.

Dominic Saunders '20

Department of Mechanical and Aerospace Engineering
Mentored by Michael Mueller, assistant professor of mechanical and aerospace engineering. Saunders developed a computational metric for measuring and determining the performance and viability of biofuels for use in aircraft engine systems.

Jaehwan Kim '18

Department of Chemistry
Mentored by José Avalos, assistant professor of chemical and biological engineering and the Andlinger Center for Energy and the Environment. Kim modified different yeast species by using cutting-edge metabolic engineering techniques for the sustainable production of biofuels, bioplastics, chemicals, and drugs.

"This fellowship allows me to broaden my interests and try something new in my research."—Ching-Yao Lai

Egemen Koleman

Maeder Graduate Fellowships in Energy and the Environment

As the latest recipient of the Maeder graduate fellowship, **Ching-Yao Lai**, a doctoral student in the Department of Mechanical and Aerospace Engineering, is exploring the use of foams to decrease water use in hydraulic fracturing. Her adviser is **Howard Stone**, chair of mechanical and aerospace engineering and the Donald R. Dixon '69 and Elizabeth W. Dixon Professor of Mechanical and Aerospace Engineering.

Lai joined Princeton in 2013 after receiving her bachelor's degree in physics from National Taiwan University in Taipei. Beyond the Maeder fellowship, Lai's prolific research accomplishments include three first-author papers on hydraulic fracturing, including one in the journal Physical Review Letters.

The **Paul A. Maeder '75 Fund for Innovation in Energy and the Environment** supports the Maeder fellowship.

Previous Maeder Winners

2016–17
Clark Chen (chemical and biological engineering) and **Ryan Edwards** (civil and environmental engineering)
2015–16
Wenkai Liang (mechanical and aerospace engineering)
2014–15
Janam Jhaveri (electrical engineering) and **Jennifer Obligacion** (chemistry)
2013–14
Warren Rieutort-Louis (electrical engineering)
2012–13
Josephine Elia (chemical and biological engineering)

More Student Activities

More than 50 graduate students and postdocs are members of a monthly gathering called the **Energy Group**, a forum for graduate students and postdocs to share their energy-related research with one another over lunch. **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 **Michael Mueller**, assistant professor of mechanical and aerospace engineering, run the group. Any student or postdoc who is interested in energy research is welcome to join or attend.

March 2017: The Andlinger Center sponsored 21 undergraduates, members of the **Princeton University Energy Association (PUEA)**, to attend the Massachusetts Institute of Technology Energy Conference, which had panel discussions on electrical grid resiliency, fossil fuel development, energy storage, and nuclear power. The students networked with their peers, industry professionals, and academic researchers in the energy field.

April 2017: The center and PUEA co-hosted an Energy Career Meet-up with alumni from **ExxonMobil, Picatinny Arsenal**, and other organizations. More on this event can be found on page 17.

May 2017: **Princeton Racing Electric**, a student organization dedicated to advancing and developing sustainable energy drive systems and supported by the center, competed and placed second in the electric vehicle division in the Formula Hybrid Competition, an interdisciplinary design and engineering challenge for undergraduate and graduate students.

2016–17 Highlight Seminar Series

Alexander Mitsos (September 12, 2016)
Professor and Director of the Laboratory for Process Systems Engineering
RWTH Aachen University
"(Chemical) Process Industry: An Enabler for Renewable Energy?"

Lee Rybeck Lynd (October 24, 2016)
Paul E. and Joan H. Queneau Distinguished Professor in Environmental Engineering Design and Adjunct Professor of Biology
Darthmouth College
"Low Cost Cellulosic Biofuels: New Questions and New Answers"

Steven Cowley (November 9, 2016)
President
Corpus Christi College, University of Oxford
"Driving Down the Cost and Scale of Fusion Energy"

Edward Arens (February 6, 2017)
Professor Emeritus of Architecture, Director of the Center for Environmental Design Research, and Director of the Center for the Built Environment
University of California, Berkeley
"Personal Comfort System Research at the Center for the Built Environment, University of California, Berkeley"

Jessika Trancik (March 6, 2017)
Atlantic Richfield Career Development Associate Professor in Energy Studies
Massachusetts Institute of Technology
"Value of Storage Technologies for Wind and Solar Energy"

Jenny Nelson (March 27, 2017)
Professor of Physics
Imperial College London
"Structure-Property-Function Relationships in Molecular Electronic Materials and Devices"

Jean-Luc Brédas (May 1, 2017)
Regents' Professor of Chemistry and Biochemistry
Georgia Institute of Technology
"Organic Electronics and Energy"
Inaugural Sigma-Aldrich Lecture, sponsored by Sigma-Aldrich, a leading life science and high technology company.

Yueh-Lin (Lynn) Loo, director of the Andlinger Center, presents a special gift of a lecture poster to Jean-Luc Brédas, Regents' Professor of Chemistry and Biochemistry at the Georgia Institute of Technology. Brédas gave the inaugural Sigma-Aldrich Lecture. (Photo: Sharon Adarlo)

Energy Technology Distillates

The deployment of solar power has dramatically increased in the last several years. Looking ahead, solar power may become a significant contributor to the world's electric power system by mid-century and help slash our reliance on fossil fuels. For the center's fourth **Energy Technology Distillate, "Sunlight to Electricity: Navigating the Field,"** the authors examined key issues that will shape the future of solar power, such as intermittency, and whether and how it will limit further penetration into the grid, and the possible future deployment of solar power, whether in large-scale solar farms or distributed in smaller systems like the roofs of homes, schools, warehouses, and public and private land.

Robert Socolow, professor emeritus and senior research scholar in the Department of Mechanical and Aerospace Engineering, led the project. Other research authors include **Barry Rand**, assistant professor of electrical engineering, and **Forrest Meggers**, assistant professor of architecture, both jointly appointed to the Andlinger Center; **William C. Witt**, doctoral student in mechanical and aerospace engineering; and **Manali Gokhale '16** and **Samantha Walter '17**, who both concentrated in chemical and biological engineering.

To read the latest Distillate and others, go to acee.princeton.edu/distillates/

In the News

In 2016–17, 27 affiliated faculty and researchers listed in the Andlinger Center research directory were referenced more than 155 times in various news sources, such as The New York Times, The Guardian, The Washington Post, and other publications. A small sampling that represents the range of sources and topics follows:

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
The Wall Street Journal, "The Smart Windows That Could Be Sunglasses for Your House"

Michael Oppenheimer
Albert G. Milbank Professor of Geosciences and International Affairs and the Princeton Environmental Institute, and Director of the Center for Science Technology and Environmental Policy
Politico, "Trump's already making his mark on climate"

Daniel Steingart
Associate Professor of Mechanical and Aerospace Engineering and the Andlinger Center for Energy and the Environment
CBS, "Safety of lithium-ion batteries questioned after phone recall"

Elke Weber
Gerhard R. Andlinger Professor in Energy and the Environment; Professor of Psychology and Public Affairs, Woodrow Wilson School; and Associate Director for Education at the Andlinger Center for Energy and the Environment
Quartz, "Two business-school professors discovered how to make both red and blue Americans care about Trump's drastic budget cuts"

“We are demanding more and more from batteries: to store more energy, take up less space, charge more quickly, and to be cheaper. Pushing those demands to their limits has the unfortunate physical consequence of increased fires or explosion risk.”
—Daniel Steingart

The Andlinger Center Speaks

When Samsung smartphone batteries started bursting into flames in 2016, Daniel Steingart, associate professor of mechanical and aerospace engineering and the Andlinger Center for Energy and the Environment, was on the case. For the center’s inaugural Q/A series, “The Andlinger Center Speaks,” he provided analysis on the possible defect in the batteries and how to make them safer.

Pieces that appeared in the series this year

Why are Samsung batteries exploding and how can we make them safer?
September 14, 2016
Daniel Steingart
Associate Professor of Mechanical and Aerospace Engineering and the Andlinger Center for Energy and the Environment

On the Paris climate deal and clean energy
October 18, 2016
The Energy Systems Analysis Group:
Robert H. Williams
Senior Research Scientist Emeritus
Eric Larson
Senior Research Engineer
Thomas G. Kreutz
Energy Systems Modeler

Trump and climate change
November 23, 2016
Robert Socolow
Professor Emeritus and Senior Research Scholar at the Department of Mechanical and Aerospace Engineering

Trump and emerging energy technologies
January 9, 2017
Michael Oppenheimer
The Albert G. Milbank Professor of Geosciences and International Affairs and the Princeton Environmental Institute, and Director of the Center for Science Technology and Environmental Policy

Growth and challenges of wind and solar power
April 18, 2017
Warren Powell
Professor of Operations Research and Financial Engineering, and Director of the Program in Engineering and Management Systems

Is the driverless car good for the environment?
May 25, 2017
Alain Kornhauser
Professor of Operations Research and Financial Engineering and Director of the Program in Transportation

Opposite from left to right:
Fida Newaj ’18, Alex Ju ’20, and Abdulghafar Al Tair ’19. They are working on a drone for their summer internship project. For more on the project, see page 26. (Photo: Frank Wojciechowski)

Andlinger Center for Energy and the Environment

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Professor of Chemical and Biological Engineering

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Faculty and Researchers

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

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

Thomas Kreutz
Energy Systems Modeler
Energy Systems Analysis Group

Eric Larson
Senior Research Engineer
Energy Systems Analysis Group

Forrest Meggers
Assistant Professor of Architecture and the Andlinger Center for Energy and the Environment

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

Daniel Steingart
Associate Professor of Mechanical and Aerospace Engineering and the Andlinger Center for Energy and the Environment

Claire White
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Robert Williams
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Energy Systems Analysis Group

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Professor of Electrical Engineering

Yueh-Lin (Lynn) Loo
Director, 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

Francois Morel
Director, Princeton Environmental Institute
Albert G. Blanke, Jr. Professor of Geosciences

Michael Oppenheimer
Director, Center for Science Technology and Environmental Policy
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Susan Dod Brown Professor of Chemical and Biological Engineering

Stewart C. Prager
Professor of Astrophysical Sciences

Daniel Steingart
(Effective July 2017)
Associate Professor of Mechanical and Aerospace Engineering and the Andlinger Center for Energy and the Environment

Sankaran Sundaresan
Associate Director for Research, Andlinger Center for Energy and the Environment (Spring 2017)
Norman John Sollenberger Professor in Engineering
Professor of Chemical and Biological Engineering

David Wilcove
Professor of Ecology and Evolutionary Biology and Public Affairs and the Princeton Environmental Institute

Elke Weber
Associate Director for Education
Gerhard R. Andlinger Professor in Energy and the Environment
Professor in Psychology and Public Affairs, Woodrow Wilson School

Mark Zondlo
Associate Director for External Partnerships
Associate Professor of Civil and Environmental Engineering

Supporters

The Andlinger Center for Energy and the Environment at Princeton University is grateful to the following supporters whose gifts help to realize the vision of the center. 2016–17 donors are denoted with asterisks.

Gerhard R. Andlinger '52 P80 P91 Founding Gift

James W. and Dede T. Bartlett to the *Dede T. Bartlett P03 Fund for Student Research in Energy and the Environment**

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

David T. Liu '99 *04 to further the center's mission*

William N. Neidig '70 and Christy E. Neidig P08 to further the center's mission*

Nicholas G. Nomicos '84 and Kathleen Connor Nomicos '84 to 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*

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

Tapesh Sinha and Sandra Jin P19 to establish the *Sandra and Tapesh Sinha P19 Fund* to further the center's mission*

William H. Walton, III '74 and Theodora D. Walton '78 P21 to further the center's mission*

Maura Wong '88 and Kenneth Chen '87 P20 to further the center's mission*

Lydia and William M. Addy '82 P14 P19 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*

Tia Barancik '83 P19 to establish the *Class of 1983 Fund for Energy and the Environment*

Solomon D. Barnett '05 to further the center's mission

Peter Bartlett '77 and Erin T. Bartlett P09 P10 P14 to further the center's mission

Charles A. Bernheim '57 to further the center's mission

Erik C. Blachford '89 to further the center's mission

Patricia and Dante Bonardi F57 to the *David P. Simons Fund for Energy and the Environment*

John E. Cross '72 and Mary Tiffany Cross to further the center's mission

Nancy A. Curtin '79 and John Stafford P18 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* for 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 for equipment

Thomas W. Horton Family P15 for equipment

Fred W. Kittler, Jr. '70 P08 P19 to further the center's mission

Peter C. Klosowicz '76 P19 to establish the *Peter C. Klosowicz '76 Fund for Energy and the Environment* for research and teaching

Sally Liu '87 and Bay-Wei W. Chang '87 P21 to establish the *Sally Liu '87 and Bay Chang '87 Fund* for Energy and the Environment

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* for graduate fellowships

Jay P. Mandelbaum '84 P17 P20 to establish the *Laurie and Jay P. Mandelbaum '84 Fund for Energy and the Environment*

Lisa Lee Morgan '76 *79 for 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

Sarah Finnie Robinson '78 and Jackson W. Robinson to further the center's mission

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

Ernest H. Ruehl, Jr. '85 P19 to establish the *Ruehl Family Fund for the Environment* for faculty and student research

Elchin A. Safarov and Dilyara Allakhverdova P15 to further the center's mission

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

Richard and Enika Schulze Foundation for research

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

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

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

Anonymous gift for research in carbon sequestration, solar energy, and fusion energy

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

Where to Find Us

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Back Cover

Top left: Lindsey Conlan '18 loads a sample of cement for analysis in the lab of Claire White, assistant professor of civil and environmental engineering and the Andlinger Center for Energy and the Environment. See page 26 for more on Conlan's project. (Photo: David Kelly Crow)

Bottom left: An indoor air quality sensor being developed in the lab of Forrest Meggers, assistant professor of architecture and the Andlinger Center for Energy and the Environment. (Photo: Frank Wojciechowski)

Top right: The ThermoHelioDome is a pavilion that combines a cooling tower and spherical and conical geometries to focus the effects of evaporative cooling on the interior of the structure. The structure was built in the lab of Meggers. (Photo: CHAOS Lab)

Bottom right: Jaehwan Kim '18 works on a biofuels experiment. For more on his project, See page 26. (Photo: Frank Wojciechowski)

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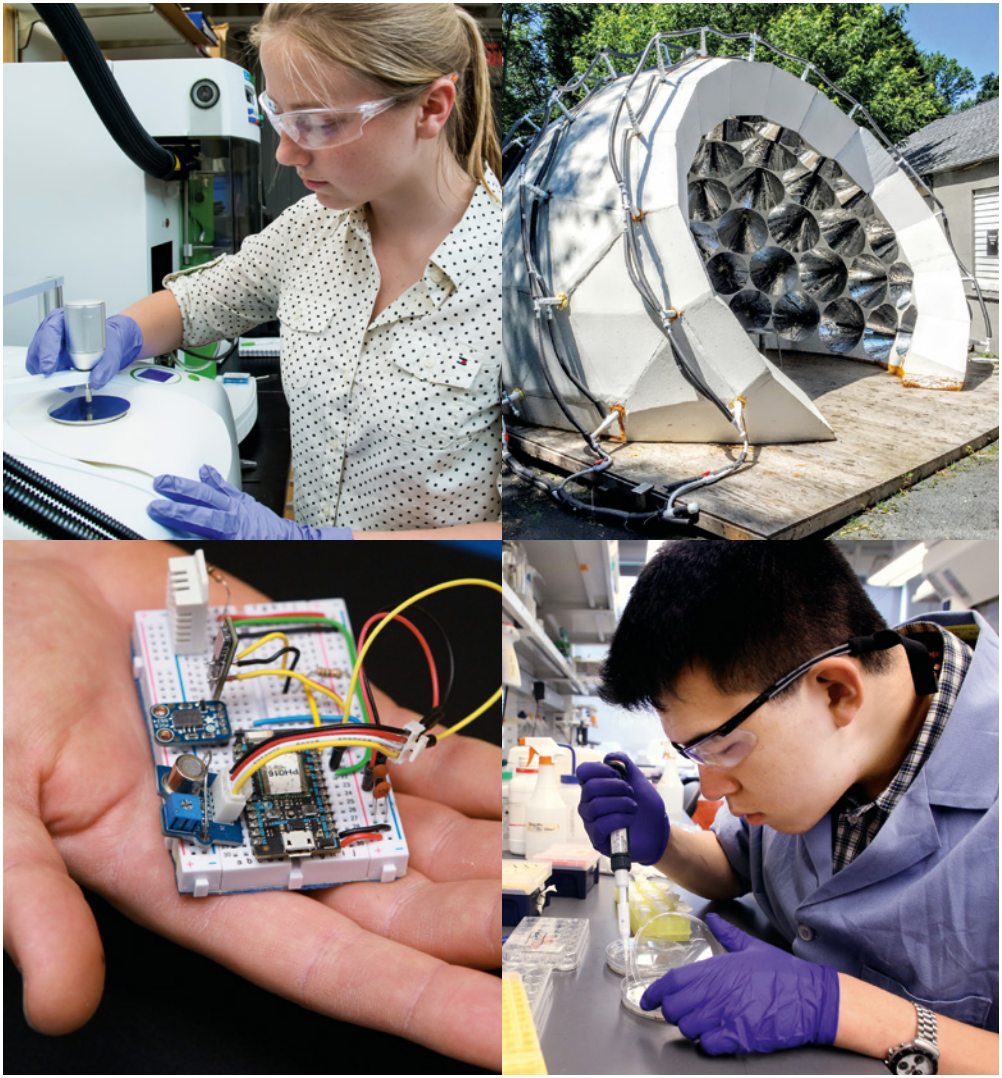

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