

ANNUAL IMPACT REPORT FY 2017

The Energy Initiative (EI) is a university-wide, interdisciplinary hub that advances an accessible, affordable, reliable, and clean energy system. The Initiative reaches across Duke to educate tomorrow's energy innovators, to develop new solutions through research, and to improve energy decisions by engaging business and government leaders. Three keywords illuminate the role that EI plays as part of a diverse field of collaborators driving energy at Duke: **connect**, **support**, and **create**.

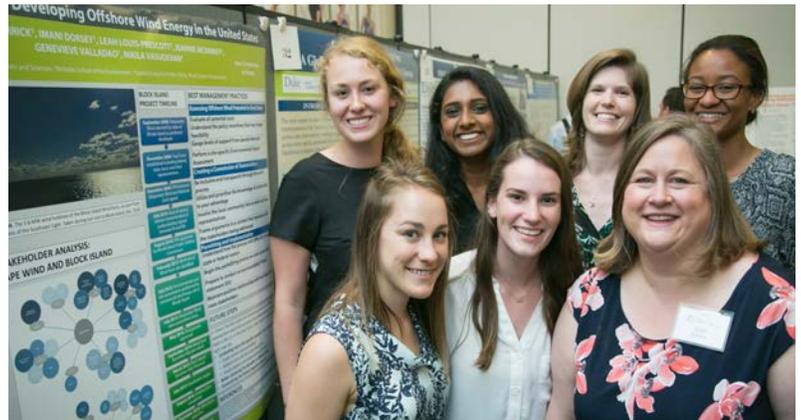
The EI **connects** individuals and programs at Duke so that all can benefit from and maximize the impact of efforts underway within and beyond the University. EI serves as a clearinghouse for energy news, events, courses, activities, and funding opportunities. EI plans and promotes events that convene (and offer value to) the campus energy community as well as energy professionals.

Through administrative and promotional activities, EI **supports** targeted energy offerings across Duke: the *Bass Connections in Energy* theme, undergraduate certificate program (*Pratt/Trinity*), energy engineering minor (*Pratt*), and MEM energy and environment concentration (*NSOE*). EI also supports individual energy students—both informally and through a formal arrangement with *NSOE*—and supports them to plan and take part in out-of-class learning opportunities (e.g., case competitions, national programs like Solar Spring Break, student-led “energy treks” to other cities or panel discussions at Duke). In addition, EI convenes and encourages interdisciplinary collaboration among seven student energy organizations; for example, EI guided the student leaders of the first-ever Energy Week at Duke.

“The EI is a very active and supportive entity that creates cohesion around a central societal challenge and research topic—cohesion across very different disciplines.

I came to Duke as new faculty in September 2013. Among the many different good initiatives that Duke offers, I found that the Energy Initiative truly embraces and promotes the open, collaborative and supportive spirit of which Duke prides itself. The EI accomplishes something remarkable in this respect.”

– Respondent to EI's fall 2016 energy faculty survey



Students share research they conducted as part of a Bass Connections project on the History and Future of Wind Energy. Dr. Lori Benneer (lower right), EI's Associate Director for Educational Programs, was one of the project's faculty leads.

The EI **creates** and refines in-house programs that strategically strengthen Duke's profile as a top-tier institution in energy. Key examples this year include the Energy Data Analytics Lab, Energy Research Seed Fund, Research Collaboration Workshop, introducing Energy as a topic on SciPol, developing new communities and programming for graduate students interested in energy, and (with *Nicholas Institute*, *Sanford*, and *NSOE*) shaping the emergence of a university-wide energy access project.

In short, EI serves as a linchpin. It positions Duke University to strategically develop and maximize its strengths as a leading institution for energy education, research, and engagement.

EDUCATION ACCOMPLISHMENTS

- * **1,347 students** were enrolled in **57 energy-related courses** across **six schools**, including **six new courses** offered this year.
- * **50 students** were enrolled in the **undergraduate Certificate in Energy and the Environment** or the **undergraduate minor in Energy Engineering** (EI supports with *Trinity & Pratt*)
- * **109 graduate students (73 of whom graduated this year)** enrolled in **energy concentrations at the three degree programs that track this information:** MBA (*Fuqua*), MEM (*NSOE*), and UPEP doctoral program (*NSOE/Sanford*). EI supports these programs through co-curricular activities, funding for student groups, and career services but does not control number of students admitted. Many other Duke graduate students focus on energy but are not formally tracked by degree programs (e.g., *Law, Pratt, and Sanford*).
- * Administered **nine Bass Connections in Energy team projects and courses** involving **105 students (68 undergraduates and 37 graduate students)** and **45 faculty or staff** (including **30 team leaders and 15 contributors**). Project topics ranged from ocean energy to carbon pricing to animal waste management.
- * Provided **career advising to MEM students** via a formal agreement with *NSOE* and informally advised other undergraduate and graduate students.
- * Taught or led **several energy courses/teams** on topics including ocean energy, energy economics, energy data analytics, and the history of energy.

ENERGY EDUCATION: A SUCCESS STORY



L to R: Bass Connections team members Mengyi (Mavis) Zhou (MEM'17) and Kristen Collar (PhD'17) at a meeting with Corning executives in fall 2016.

Corning—the world's largest fiberoptic manufacturer—risks painful financial hits from power outages at its Concord, NC plant, even when the interruptions are brief.

Enter a Bass Connections in Energy team.

Led by Gale Boyd (SSRI) and Josiah Knight (Pratt), nine Duke undergraduate and graduate students worked with Corning employees to evaluate the company's current approach to asset protection, research the alternatives, and recommend a solution.

Ultimately, the team proposed that Corning could reap greater energy savings, increase reliability, and reduce carbon emissions via a combined heat and power system and installation of absorption chillers.

Gene Gano, the team's key contact at Corning, told students he is certain their research will be impactful for the company. "I applaud the Bass Connections program, Duke University faculty, and especially the students for delivering data Corning can use to implement a solution that is not only financially but also environmentally beneficial," he wrote in a memo to the team.

Doctoral student in physics Kristen Collar noted that it was clear Corning representatives "were actively interested in the outcome of our work, and were invested in us proposing a useful solution." She said, "I learned the value of a diverse team, which enabled us to think more broadly about the question at hand."

Collar graduated this spring. She recently interviewed for a position at the Johns Hopkins University Applied Physics Laboratory and told Boyd and Knight that being able to reflect on the Bass Connections project had strengthened her interview.

The job? She landed it.

* Offered a **diverse portfolio of co-curricular learning opportunities** for graduate and undergraduate students, often **in collaboration with other Duke units**:

- **Power Trips** to Duke Energy, CLT JOULES, EPIC Center at UNC Charlotte, Electric Power Research Institute, EPA, and NCSU's PULSTAR nuclear reactor.
- **Solar Spring Break** (*with Grid Alternatives*) – Organized and supported a team of 8 undergraduates who installed solar panels in Fresno and learned about the food-energy-water nexus.
- **California Clean Energy Trip** – Helped coordinate four-day trip to energy companies, offered as part of a *NSOE* course.
- Advised, facilitated collaboration among, and provided financial support to **seven student energy organizations**, achieving unprecedented interdisciplinary exchange among student groups via **dozens of student-planned events and activities**.

A SAMPLING OF FY17 EDUCATION EVENTS

Introductory events regarding energy at Duke

Introduced 100+ undergraduates and graduate students to key energy challenges, faculty working on those topics, and student opportunities.

Power Trends (with *Duke Alumni Association* and *GPSC*)

Career event featuring Duke alumni in cleantech.

Winter Forum 2017 (with *Office of Undergraduate Education*, *Nicholas Institute*, and *Samuel Dubois Cook Center on Social Equity*)

Organized immersive undergraduate learning experience addressing energy access and inequality.

The (Uncertain) Future of Energy

Responded to students' post-election concerns by organizing a panel of energy faculty to share insights and predictions.

Women in Energy (with *EDGE Center at Fuqua* & *the Penny Pilgram Women's Leadership Initiative*)

Organized panels and small-group lunches so students could learn from women (including 3 alumnae) in the energy sector.

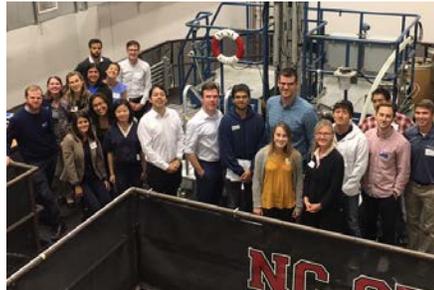
Is Nuclear Energy a Safe Option for a Sustainable Energy Future?

Featured experts from USDOE, GE Hitachi Nuclear Energy, NCSU, & Duke.

5 Power Lunches

Connected students with professionals in solar energy, biofuels, oil and gas, energy management, and more.

Clockwise from far left:



- Alumnus Steve Slawson (BSE'78) (Slawson Exploration) discusses the oil and gas industry at a Power Lunch;
- Alumni panelists discuss their careers in the cleantech sector;
- Cheryl LaFleur [Federal Energy Regulatory Commission (FERC) Acting Chair] answers Duke students' questions after her talk;
- Students learn about the PULSTAR Reactor at NC State during a Power Trip; and
- Grad students from 3 Duke schools visit Gravity Renewables during the Denver Career Trek.

RESEARCH ACCOMPLISHMENTS

* The Energy Research Seed Fund, in its fourth year, awarded \$238,941 to seven cross-disciplinary teams.

- Teams include 14 different faculty investigators across four schools, eight Ph.D. students, and several other graduate students.
- This round's co-funders were Trinity, Pratt, iD, and the Provost's Office and topics ranged from machine learning methods to estimate energy reliability to new nanowire mesh electrodes that will improve the efficiency, power, and affordability of fuel cells. Recipients have primary appointments in engineering (30%); natural sciences (30%); and social sciences, policy, and environmental management (40%).
- In the program's first three rounds, the EI awarded approximately \$667,000 in seed grants, which has generated more than \$3.6 million in external funding. That's more than five times the original investment. Cumulatively, 52% of recipients in the first four rounds have had primary appointments in engineering, 19% in natural sciences, and 29% in social sciences, policy, and environmental management.

* Partnered with Bass Connections, Nicholas Institute, NSOE, and Sanford to launch the Energy Access Project at Duke. The university-wide project aims to develop a long-term, sustainable focus at Duke on the challenge of access and transitions to sustainable energy for low- and middle-income countries around the world. The project will build on energy access work already underway at Duke.

ENERGY RESEARCH: A SUCCESS STORY



From left: Duke researchers Josiah Knight, Angel Peterchev, and Stefan Goetz

This work was kickstarted by a \$40,000 Energy Research Seed Fund grant from the Duke University Energy Initiative, which was followed by a \$500,000 National Science Foundation grant supporting Duke researchers' collaboration with colleagues at the FREEDM Systems Center in Raleigh.

Goetz has also teamed up with graduate student Chris Dougher (MEM/MBA'18) (left, in photo below) to pursue a business plan for the Perle Converter, which emerged from this research. Their plan was awarded the EI/Duke Startup Challenge's \$10K Clean Energy Prize for 2017. Dougher and Goetz are targeting electric vehicle, solar energy, and battery storage markets.

Goetz says that the widespread interest in energy across the university—and a culture that encourages interdisciplinary collaboration via units like the Energy Initiative—makes Duke a great place to innovate.

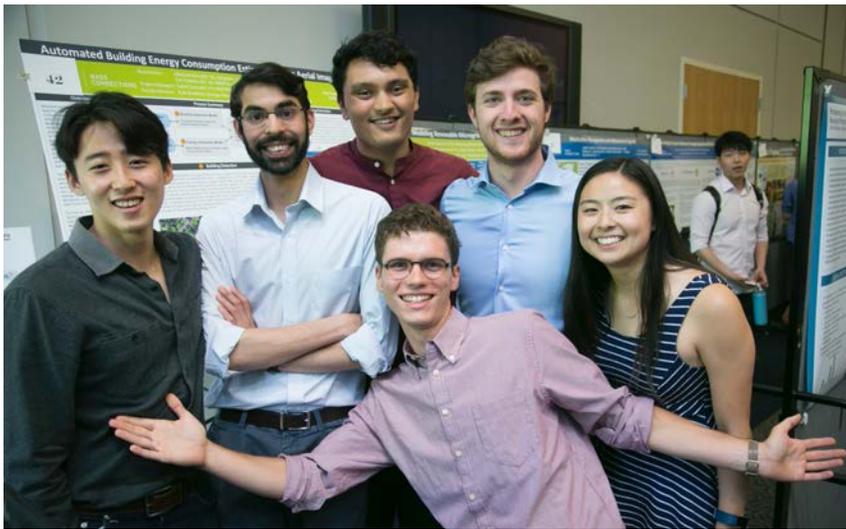
"My research has taken so many unexpected turns through collaboration at Duke—and I love that," he notes. "It's very intentional, how this university brings people together across disciplines to work on important problems like energy. It's a strategy that helps make Duke researchers' work stronger and more actionable."

Duke researcher Stefan Goetz (an assistant professor of psychiatry and behavioral science, electrical engineering, and neurosurgery) has developed high-performance electronics that control electrical pulses in noninvasive magnetic brain stimulation.

Now—working with Josiah Knight, Angel Peterchev, and other Duke researchers—Goetz is investigating how this technology could improve electric vehicles and solar energy systems.



Chris Dougher (MEM/MBA'18) & Stefan Goetz



The Energy Data Analytics Lab team was among four teams invited to speak about their work at the 2017 Bass Connections Showcase.

* Continued to strengthen the **Energy Data Analytics Lab** as a hub of research, education, and engagement activity with involvement from **16 faculty, 3 postdoctoral associates, 2 staff**, and a total of **33 students** (15 undergraduates, 11 master's students, and 6 PhD students).

In FY17, the Lab investigated **energy access in developing countries** using satellite data (involving collaboration among *Pratt* and *Sanford* researchers).

More student applicants than ever sought selection to the Lab's *Bass Connections* and *Data+* teams. **Significant accolades** for team members include top honors at the State Energy Conference poster competition,

Audience Choice award at the Bass Connections Showcase poster presentation, and selection by the *Graduate School* as one of two student projects to display at a spring event for state policymakers.

* **New EI faculty affiliate Dr. Robyn Meeks** is a joint hire with *Sanford*, where she is appointed as an Assistant Professor. Meeks's research is at the intersection of environmental and development economics, with an emphasis on understanding individual and household responses to the introduction of various water and energy technologies, policies, and types of infrastructure in developing countries. She will contribute to the new Energy Access Project at Duke.

* Although EI is not solely responsible for external funding, it does track the following: In FY17, the yearly budgets of all active external energy grants totaled more than **\$15.2 million**. This represents a **\$5 million increase** over FY16, and is more than **four times the total** in FY11, EI's first year.



EI is helping develop the new Energy Access Project at Duke. One aspect of the Project is an international research network housed at Duke: the Sustainable Energy Transitions Initiative (SETI). Above is a photo documenting the 2017 SETI Annual Meeting at Duke, which drew researchers from 20+ countries.

GRADUATE STUDENTS & RESEARCH

EI launched three **new interdisciplinary communities of graduate students** focused on key energy research areas at Duke.

Energy Access - GLEAN, a new interdisciplinary network of **more than 50 graduate students**, published an ebook of energy access case studies (in addition to other activities). Funded by a *D-SIGN* grant.

Energy Economics & Policy - Advised by Steve Sexton (*Sanford* and EI joint appointment), a community of six EI Doctoral Student Fellows worked in EI offices (facilitating ongoing exchange with one another, EI staff, and visiting faculty) and met biweekly to discuss work-in-progress with faculty, staff and other students, usually with 10-12 attending.

Energy Materials - In the spring semester, EI partnered with David Mitzi (*Pratt*) to organize monthly lunch meetings on energy materials research, usually with about 30 faculty and graduate students from multiple schools in attendance.

ENGAGEMENT ACCOMPLISHMENTS

COMMUNITY & INDUSTRY ENGAGEMENT

- * Partnered with *Nicholas Institute* to host a **conference on the future of the electricity sector** in the Southeast, which connected energy professionals (representing utilities, government agencies, and nonprofits) with Duke faculty conducting relevant research. This event is part of ongoing work to engage regulators in more than 20 states as they wrestle with how to implement environmental policy objectives in the context of an ever-changing electric grid.
- * Connected local energy professionals to students and faculty via **Energy Mixes**, which often also included professionals from other states and countries who were visiting Duke for closed events.
- * Deepened collaboration with the **Research Triangle Cleantech Cluster (RTCC)**, with three EI staff serving on the Advisory Board, Talent Action Committee and Marketing Programs Committee.
- * Ramped up efforts to use social media to inform and engage Duke alumni, energy professionals across the globe, and energy researchers and students at other institutions.
- * Collaborated with *Nicholas Institute*, *Duke Facilities*, and *Sustainable Duke* to organize events and share information about **the proposed CHP natural gas plant**.

ENGAGEMENT: A SUCCESS STORY



Energy Week

AT DUKE UNIVERSITY

In spring 2016, Andrew Seelaus (MEM/MBA'17) approached EI staff with an idea. For years, the MBA Energy Club had organized an annual energy conference—eventually adding a case competition (both of which EI has cosponsored with the EDGE Center).

But what if Duke's student energy clubs teamed up to extend that success? EI staff were intrigued. And so were Andrew's peers. The result: the first-ever Energy Week at Duke.

Energy Week 2016 was a smash hit, attracting total attendance of 1,200. The students planned 41 hours of programming to engage the Duke community, students from other schools, and professionals in a weeklong exploration of energy challenges and innovations.

EI cosponsored the week's events and supported student leaders to design agendas, invite speakers, recruit sponsors, organize logistics, navigate budgets, and promote events.



ENERGY WEEK HIGHLIGHTS

- * **More than 40 companies and agencies** sponsored events and/or sent speakers or judges to take part, and **an additional 50+ companies** were represented by attendees.
- * The Duke University Energy Conference attracted its **largest crowd ever**, with **more than 30% of attendees** coming from beyond Duke.
- * **Energy in Emerging Markets Case Competition** drew a **stronger applicant pool than ever**, including top-tier US universities and even a team based in Hong Kong.
- * **Energy Startup Demo Day** (organized in partnership with *I&E*) drew a packed house at The Bullpen, yielding **student internships** and **new collaborations between businesses**.
- * **Spark Career Event** earned rave reviews from students and the **10 participating employers** (who appreciated being able to connect with talent from diverse degree programs).
- * This spring, ExitEvent (a key information source for the North Carolina startup community) named Energy Week at Duke among **the emerging forces helping to propel the growth of NC's cleantech sector**.



POLICY WORK

- * Cohosted a **webinar (240 participants) on the future of California's innovative cap and trade program**, including analysis of implications for Canadian provinces that link to it. Partners were two Canadian institutions, *Nicholas Institute*, and Resources for the Future. EI's Brian Murray moderated.
- * Partnered with leaders at the *Nicholas Institute*, *NSOE*, and *Sanford* to release a **public statement** on President Trump's announcement that the U.S. would withdraw from the Paris Accord.
- * Invited by Mexico's Ministry of Energy and the National Autonomous University of Mexico, Brian Murray delivered a **talk on trilateral coordination of energy policy** to an audience of 500+ in Mexico City.



- * Advised cultural anthropologist Christine Folch on a **project to inform Paraguay's upcoming policy negotiations regarding Itaipu Dam**, the world's largest hydroelectric dam. EI connected Folch with several Duke researchers and graduate students outside her discipline to strengthen the project's impact. At left, Folch (middle) poses with Paraguayan researchers who traveled to Durham to meet with the Duke research team in late spring 2017.

SCIPOL ENERGY COVERAGE

EI partnered with *Science & Society* to **introduce energy as a topic on the SciPol website**, tracking and translating developments in policy, industry, and science that have direct and intentional impacts on the U.S. energy sector.

This collaboration will provide an **unbiased resource to the energy sector and policy community**, spotlight Duke expertise in energy (as appropriate), and offer energy policy writing experience to Duke students via a new *Bass Connections* course and other opportunities.

SELECTED HIGH-IMPACT PUBLICATIONS

- * EI Director Brian Murray published (with Billy Pizer of *Sanford* and Christina Reichert of *Nicholas Institute*) a *Harvard Environmental Law Review* piece on **increasing emissions certainty under a carbon tax**.
- * Murray published (with Jonas Monast of *Nicholas Institute* and Jonathan Wiener of *Law*) a journal article in *Law and Contemporary Problems* exploring the **movement toward environmental markets** in light of Pope Francis's commentary in the 2015 encyclical *Laudato Si*.
- * Energy Data Analytics Lab managing director Kyle Bradbury was lead author of a paper in *Scientific Data* (coauthored by *NSOE* and *Pratt* faculty) that highlighted the publication of a new **aerial imagery object identification dataset** by *Bass Connections/Data+* teams.
- * Energy Data Analytics Lab members presented three papers at the 2017 IEEE International Geoscience and Remote Sensing Symposium and two at the 2016 International Conference on Renewable Energy Research and Applications. Bradbury delivered three invited talks this year.
- * With a UC Davis colleague, Steve Sexton (Energy Faculty Fellow, joint appointment with *Sanford*) reviewed the California Air Resources Board (CARB)'s plan to **limit emissions leakage from the California cap and trade program**. The review was presented to CARB, which has since taken actions consistent with the review and recommendations.
- * An article Sexton coauthored with Billy Pizer on **distributional impacts of energy taxes** is forthcoming in *Review of Environmental Economics and Policy*. Sexton also coauthored a journal article on **dynamic prices and electricity demand response** (forthcoming in *Annual Review of Resource Economics*)—work that was supported by an Energy Research Seed Fund grant.